

# NANOSEA 2018

## International Conference

NanoSEA.2018

**July 2-6th 2018**

**7th International Conference NANOSEA NANO-structures  
and nanomaterials SELF-Assembly**

Chairpersons : I. Berbezier (Im2np, CNRS, Marseille, France), M. De Crescenzi, (University di Roma II Tor Vergata, Italy), S. Boninelli (IMM-CNR, Catania, Italy), D. Grosso (Aix Marseille University, CNRS, IM2NP, Marseille, France)

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We would like to thank for their support :



Région Provence-Alpes-Côte d'Azur



# MONDAY

	<b>INTRODUCTION</b>		
10H40 - 11H00	<b>Opening speeches + C. FONTAINE (GDR PULSE)</b>		
11H00 - 11H20	<b>E. VERZEROLI (Orsay Physics)</b>		
<b>ROOM GIENS</b>	<b>PLENARY SESSION: 2D MATERIALS (Chairman: Simona BONINELLI)</b>		
11H20 - 12H00	<b>Dietrich ZAHN</b>	Raman and other spectroscopies on nanostructures, including silicene	Semiconductor Physics Technische Universität Chemnitz, Germany
12H00 - 12H30	<b>Mona ZEBARJADI</b>	Semimetals as potential thermoelectric materials	ECE and MSE departments, Uni of Virginia, USA
12H30 - 13H00	<b>Francesco BUATIER DE MONGEOT</b>	Designer Shape Anisotropy on Transition-Metal-Dichalcogenide Nanosheets	Dipartimento di Fisica, Università di Genova, Genova, Italy
13H00 - 15H00	<b>LUNCH AND BREAK</b>		
<b>ROOM GIENS</b>	<b>PLENARY SESSION: (Chairman: David GROSSO)</b>		
15H00 - 15H40	<b>Andreas STEIN</b>	Designing functional porous and nanostructured materials at multiple length scales	University of Minnesota, Department of Chemistry, USA
15H40 - 16H10	<b>Petra GRANITZER</b>	Photoluminescence of porous silicon influenced by magnetic metal filling	Institute of Physics, Uni. Graz, Austria
16H10 - 16H40	<b>Olivier SOPPERA</b>	Laser Direct write of semiconducting metal oxide micro and nanopatterns	CNRS IS2M, Mulhouse, France
16H40 - 17H10	<b>COFFEE BREAK</b>		

ROOM GIENS 17H10 - 18H10	FLASH PRESENTATION POSTERS (Chairman: Isabelle BERBEZIER)		
<b>Mama BOUCHAOUR</b>	URMER, Université de Tlemcen, Algeria	Physical properties of ZnO on GaN by thermal evaporation	M.Bouchaour, R. Bensaha, F.Lekoui, N-E. Chabane Sari, N. Maloufi
<b>Štěpan POTOCKY</b>	Institute of Physics of the Czech Academy of Sciences, Czech Republic	Diamond film grown from carbon nanosheets and polymer composites for sensoric applications	Stepan Potocky, Tibor Izak, Marian Varga, Zdenek Remes, Sukang Bae, Sungho Lee, Han-Ik Joh, Dong Su Lee, Alexander Kromka
<b>Ilya MILEKHIN</b>	INovosibirsk State University, Pirogov 2, 630090 Novosibirsk, Russia	Au antenna arrays with different morphology for detection of CdSe nanocrystals	I. A. Milekhin 1,2, S. A. Kuznetsov 1,3, L. L. Sveshnikova 1, T. A. Duda 2, A. G. Milekhin 1,2, E. E. Rodyakina 1,2, A. V. Latyshev 1,2, V. M. Dzhagan 4, and D. R. T. Zahn 5
<b>Luminita POPA</b>	Faculty of Physics, Alexandru Ioan Cuza University, Iasi, Romania	Effects of non-uniform dopant distribution near Si surfaces for advanced applications	D. Moraru, L. Popa, F. Iacomì
<b>Felicia IACOMI</b>	Faculty of Physics, Alexandru Ioan Cuza University, Romania	EPR studies on perovskite and ferrite nanoparticles and thin films	A. Popa, D. Toloman, C. Doroftei, A. Carlescu, M. Toma, M. Irimia, G. Nedelcu, G. Bulai, E. Ware, F. Iacomì
<b>Thomas BOTTEIN</b>	NOVA - IM2NP – AMU, France	Nanofabrication of large scale photonic structures using Soft-Nano Imprint Lithography applied to sol-gel coatings	Thomas Bottein, Olivier Dalstein, Magali Putero, Marco Faustini, Andrea Cattoni, Marco Abbarchi, David Grosso
<b>Lionel PATRONE</b>	AMU, Uni. Toulon, CNRS, IM2NP, France	Combining SERS and DFT for studying surface orientation of push-pull chromophore within self-assembled monolayers	V. Gadenne (1), C. Praveen (2), B. Grenier (2), P. Marsal (2), J. C. Valmalette (3), J. M. Raimundo (2), and L. Patrone (1)
<b>Mohamed-Amine GUERBOUKHA</b>	AMU, Uni. Toulon, CNRS, IM2NP, France	Self-assembled organic monolayers on Ge and GaAs : application to nanodielectrics	Mohamed-Amine Guerboukha (1), Virginie Gadenne (1), Bruno Jousset (2), Jean-Manuel Raimundo (3), and Lionel Patrone (1)
<b>Vincent SALLET</b>	GEMAC, CNRS-UVSQ, France	Morphology Studies of Gallium doped ZnO Nanowires for Plasmonics	Vincent Sallet*, Corinne Sartel, Said Hassani, Christèle Vilar, Gaelle Amiri, Alain Lussan, François Jomard, Pierre Galtier, Isabelle Lefebvre, Christophe Delerue, Mohamed K. Hamza, Bruno Canut, Bruno Masenelli
<b>Oumaima ABOUZAIID</b>	CNRS/LTM, France	MOCVD grown InAs/GaAs quantum dots on Si substrate	O. Abouzaid1, 3, M.Martin1, J. Moeyaert1, B. Salem1, S. David1, F. Bassani1, A. Souifi 2, N. Chauvin 2, A. Ahaitouf 3, Az. Ahaitouf 4, T.Baron1

<b>Hussein MEHDI</b>	Institut Pascal (UCA CNRS), France	Toward optimum N2 plasma nitriding process for GaAs(100) surface passivation	H. Mehdi, G. Monier, C. Robert-Goumet, P. E. Hoggan, V. G. Dubrovskii
<b>Clément LAUSECKER</b>	Uni. Grenoble Alpes, CNRS, Grenoble INP, LMGP, France	Nucleation and growth mechanisms of ZnO nanowires on Au thin films by chemical bath deposition for piezoelectric nanogenerators	Clément Lausecker 1,2,3 ; Bassem Salem 2 ; Xavier Baillin 3 ; Hervé Roussel 1 ; Eirini Sarigiannidou 1 ; Franck Bassani 2 ; Estelle Appert 1 ; Sebastien Labau 2 ; and Vincent Consonni 1
<b>Roy DAGHER</b>	Uni. Grenoble Alpes, CEA-LETI, France	Defect engineering in GaN epilayers on nanopatterned SOI	Roy Dagher, Blandine Alloing, Virginie Brändli, Maud Nemoz, Jesus Zuniga Perez and Guy Feuillet
<b>Ali EL BARRAJ</b>	CINaM – AMU, France	A low Energy Electron Microscopy study of the growth and surface electromigration of Au on Ge(111)	Ali El Barraj, Stefano Curiotto, Fabien Cheynis, Pierre Müller, Frédéric Leroy
<b>Abdessalam BOUDDOUCH</b>	LME, Faculté des Sciences, Uni. Ibn Zohr, Agadir, Morocco	Photodegradation of rhodamine B under UV-visible light irradiation in aqueous medium by monoclinic CePO4 nano-crystalline prepared by co-precipitation method	A. Bouddouch(1,2,*), F.Guinneton (2), A. Benlhachemi (1), B. Bakiz (1), S. Villain (2), J. C. Valmalette(2), A. Taoufyq(1)
<b>Amina MERABET</b>	AMU, Uni. Toulon, CNRS, IM2NP, France	Plasticity of silicon in low dimensions: extended defects and deformation mechanisms	Amina MERABET, Michaël TEXIER, Christophe TROMAS, Anne TALNEAU, Olivier THOMAS, Julien GODET
<b>Nicolas CAVASSILAS</b>	AMU, Uni. Toulon, CNRS, IM2NP, France	Double-junction solar-cell based on two monolayers	Nicolas Cavassilas, Demetrio Logodeta, Fabienne Michelini, Marc bescond, Mathieu Luisier
<b>Manuella SCARSELLI</b>	Dipartimento di Fisica, Università di Roma “Tor Vergata”, Roma, Italy	Structural properties of carbon spheres: how the iron catalyst marks the difference in their Energy and Electrochemical response	M. Scarselli, F. Limosani, F. Possanza, M. Passacantando, F. D’Orazio, F. Arduini, M. De Crescenzi
<b>Antoine RONDA</b>	AMU, Uni. Toulon, CNRS, IM2NP, France	Quantitative explanation of 1D instabilities self-organisation on vicinal substrate	Kailang Liu, Antoine Ronda, Luc Favre, Thomas David, Marco Abbarchi, Isabelle Berbezier, Philippe Gaillard and Thomas Frisch, Bernard Croset, Jean-Noël Aqua
<b>Khawla AZAIEZ</b>	Univ Tunis, Laboratoire Photovoltaic, CRTen, Ecole Nationale Supérieure Ingénieur de Tunis, Tunis, Tunisia	Enhancement of physical properties of porous silicon treated with Bismuth nanoparticles	Khawla Azaiez, Rabia Benabderhmen, Wissen Dimassi

## TUESDAY

ROOM PORT CROS	2D MATERIALS (Chairman: Dietrich ZAHN)		
9H00-9H30	<b>Stephen McDONNELL</b>	Transition Metal Dichalcogenide Synthesis and Integration	Department of Materials Science and Engineering the University of Virginia, USA
9H30 - 9H50	<b>David MARTROU</b>	Stabilization of Au Monatomic-High Islands on the (2×2)-Nad Reconstructed Surface of Wurtzite AlN(0001)	CEMES / GNS, Toulouse, France
9H50-10H10	<b>Jonathan BRADFORD</b>	Lateral graphene/h-BN heterostructures from chemically converted epitaxial graphene on SiC (0001)	School of Chemistry, Physics and Mechanical Engineering, Queensland University of Technology, Brisbane, Queensland, Australia
10H10-10H40	<b>Roberto FLAMMINI</b>	A study of the interface between a trivial and a topological insulator: the case of $\beta$ -antimonene on Bi <sub>2</sub> Se <sub>3</sub>	Istituto di Struttura della Materia-CNR, Roma, Italy
ROOM LEVANT	SELF-ASSEMBLY OF ORGANIC MATERIALS (Chairman: Luc FAVRE)		
9H00-9H30	<b>Shobhana NARASIMHAN</b>	Simple but Successful Descriptors for Self Assembly of Organic Molecules on Surfaces	Jawaharlal Nehru Centre for Advanced Scientific Research, Jakkur, Bangalore, India
9H30 - 9H50	<b>Luca PASQUALI</b>	Resonant soft X-ray reflectivity for the quantitative investigation of anisotropic ultrathin organic films	Department of Engineering 'E. Ferrari', Uni of Modena and Reggio Emilia, Italy
9H50 - 10H10	<b>Hocine Khemliche</b>	Ultra-fast crystallization dynamics at an organic-inorganic interface revealed in real time by Grazing Incidence Fast Atom Diffraction	Institut des Sciences Moléculaires d'Orsay (ISMO), CNRS, Univ. Paris-Sud, Uni Paris-Saclay, France
10H10 - 10H30	<b>Anne CHARRIER</b>	"When bonding makes you stronger" Supported lipid monolayer with unprecedented mechanical and dielectric properties: Application to ISFET sensors	AMU, CNRS, CINaM, Marseille, France
10H30 - 11H00	COFFEE BREAK		



ROOM PORT CROS	2D MATERIALS (Chairman: Nunzio MOTTA)		
11H10 - 11H40	<b>Girogia FUGALLO</b>	Thermal transport, emergent phenomena in 2D materials	ETSF, LSI, École Polytechnique, Palaiseau, France
11H40 - 12H00	<b>Michel DAHER MANSOUR</b>	Si nanoribbon templates on missing row reconstructed Ag(110)	AMU, CNRS, CINaM, Marseille, France
12H00 - 12H20	<b>Natalia MASSARA</b>	Germanene on Al(111)	IS2M, Uni Haute Alsace, Mulhouse, France
12H20 - 12H40	<b>Maurizio DE CRESCENZI</b>	Raman and STM investigation of air-stable silicene nanosheets on an inert graphite surface	Dipartimento di Fisica, Università di Roma "Tor Vergata", Roma, Italy
12H40 - 13H10	<b>Geoffroy PREVOT</b>	Quest for silicene: following Si growth on metal and van der Waals substrates	Institut des NanoSciences de Paris, INSP, Sorbonne Uni, CNRS, Paris, France
ROOM LEVANT	PATTERNING AND SELF-ASSEMBLY (Chairman: Yamina ANDRE)		
11H00 - 11H30	<b>Alessandro DI MAURO</b>	ZnO nanostructures for photocatalytic applications	CNR-IMM, Catania, Italy
11H30 - 11H50	<b>Volkan KILINC</b>	Developpement of versatile and selective sensor with original dielectric layer on organic semiconductor.	AMU, CNRS, CINaM, Marseille, France
11H50 - 12H10	<b>Conor HOGAN</b>	Tuning the adsorption of organic molecules on stepped Au/Si surfaces	Institute of Structure of Matter (ISM-CNR), National Research Council of Italy, Italy
12H10 - 12H30	<b>Luc FAVRE</b>	New strategies for producing defect free SiGe strained nanolayers	AMU, IM2NP, CNRS, Marseille, France
12H30 - 13H00	<b>Lionel PATRONE</b>	Self-assembly of small organic molecules into ordered monolayers for tuning the electrical and optical properties of surfaces	AMU, Uni Toulon, CNRS, IM2NP, ISEN, France
13H10 - 16H30	LUNCH AND BREAK		
16H30 - 19H30	SESSION : POSTERS AND EXHIBITORS + DRINKS		

## WEDNESDAY

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ROOM PORT CROS	GRAPHENE (Chairman: Manuella SCARSELLI)		
9H00 - 9H30	<b>Aitor MUGARZA</b>	Bottom-up synthesis of graphene nanostructures: from 0D dots, to 1D ribbons, to 2D porous graphene	Campus UAB, Bellaterra, 08193 Barcelona, Spain
9H30 - 9H50	<b>Robertino ZANONI</b>	Integration of graphene onto silicon surface	Dipartimento di Chimica, Uni ' degli Studi di Roma 'La Sapienza', Roma, Italy
9H50 - 10H10	<b>Mattia SCAGLIOTTI</b>	Innovative Graphene/n-Si heterojunction for photodetectors applications	Physics Department - Uni of Rome "Tor Vergata", Italy
10H10 - 10H40	<b>Nunzio MOTTA</b>	Graphene Heterostructures on SiC: 2D materials towards applications	CPME School and IFE, Queensland Uni of Technology, Brisbane, Australia
ROOM LEVANT	POROUS AND TEXTURED MATERIALS (Chairman: Caroline BONAFOS)		
9H00 - 9H30	<b>Freddy KLEITZ</b>	Mesoporous Silica Nanoparticles for Drug Delivery Applications	Department of Inorganic Chemistry - functional materials, Uni. Wien, Austria
9H30 - 9H50	<b>Alexander SAMARDAK</b>	Nanoscale skyrmionic spin textures in magnetic nanostructures and ultrathin films	Far Eastern Federal Uni, Vladivostok, Russia
9H50 - 10H10	<b>Klemens RUMPF</b>	Nanostructured silicon with embedded exchange coupled bi-metal structures	Institute of Physics, Uni Graz, Austria
10H10 - 10H30	<b>Jerome LOIZILLON</b>	In-depth investigations of self-assembled nanostructured porous layers by ellipsometry porosimetry	AMU, IM2NP, CNRS, Marseille, France
10H30 - 11H00	COFFEE BREAK		

ROOM PORT CROS	2D MATERIALS (Chairman: Jerrold FLORO)		
11H10- 11H40	Jérôme LAGOUTE	Electronic interaction between organic molecules and nitrogen doped graphene measured by scanning tunnelling microscopy	MPQ, CNRS/Uni Paris Diderot, Paris, France
11H40 - 12H00	Alberto BRAMBILLA	Decoupling Graphene from Ni(111) through the Intercalation of a Chromium Carbide Ultra-Thin Film	Dipartimento di Fisica, Politecnico di Milano, Italy
12H00 - 12H20	Keivan ESFARJANI	Potential of layered materials for thermionic devices: a first-principles study	Department of Mechanical and Aerospace Engineering, Uni of Virginia, USA
12H20 - 12H40	Guillaume MONIER	Global study of self-limited plasma nitridation process for GaAs surface passivation	Institut Pascal, Université Clermont Auvergne, CNRS, SIGMA Clermont, Aubiere, France
12H40 - 13H10	Hannu-Pekka KOMSA	Engineering point and extended defects in transition metal dichalcogenides	Department of Applied Physics, Aalto University, Finland
ROOM LEVANT	INOVATIVE NANOSTRUCTURES (Chairman: M.arcoABBARCHI)		
11H00- 11H30	Jerrold A FLORO	Exchange-Coupled Ferromagnetism in Self-Assembled Co0.4Pt0.6 Nanochessboards	Uni of Virginia, Dept Materials Science, Charlottesville, USA
11H30 - 11H50	Ilan GOLDFARB	Magnetic silicide nanoislands	Department of Materials Science and Engineering, Faculty of Engineering, Tel Aviv University, , Israel
11H50 - 12H10	Hakim AMARA	Chirality phase diagrams for Single-Walled Carbon Nanotubes	Laboratoire d'Etude des Microstructures, ONERA_CNRS, Châtillon, France
12H10 - 12H30	Matteo SALVATO	Increasing efficiency of single walled carbon nanotube/n-Si photodetectors	Dipartimento di Fisica Università degli Studi di Roma "Tor Vergata", Roma, Italy
12H30 - 12H50	Elena MATEI	Biocompatible submicron fibers obtained by electrospinning	National Institute of Materials Physics, Margurele, Romania
12H50 - 13H10	Mateusz JEDRUSIK	Nanostructured LaFeO3 /YSZ thin films as mixed potential gas sensor	AGH University of Science and Technology, Kracow, Poland
13H10	LUNCH		
FREE AFTERNOON			
20H00	GALA DINNER		

## THURSDAY

ROOM PORT CROS	METALLIC NANOPARTICLES (Chairman: Dominique CHATAIN)		
9H00 - 9H30	<b>Sergio D'ADDATO</b>	Gas phase synthesis of metal@oxide, core@shell nanoparticles: a bottom-up approach for new material functionalities	Dip. FIM, Università di Modena e Reggio Emilia, Modena, Italy
9H30 - 9H50	<b>Marc RESPAUD</b>	Magnetoresistance effects in self-assembled chemically-synthesized metallic ferromagnetic nano-objects – Influence of surface chemistry	Laboratoire de Physique et Chimie des Nano-Objets, Toulouse, France
9H50 - 10H10	<b>Clémentine BIDAUD</b>	Photo-structuration at nanoscale of a composite material doped with magnetic NP: towards magneto-phonic devices	Uni Haute-Alsace, CNRS, IS2M, Mulhouse, France
10H10 - 10H40	<b>Caroline BONAFOS</b>	Three Dimensional design of silver nanoparticle assemblies embedded in dielectrics: application to plasmon-enhanced scattering and charge transfer in few-layer graphene	CEMES, Uni Toulouse, CNRS, France
ROOM LEVANT	SEMICONDUCTOR NANOSTRUCTURES PROPERTIES (Chairman: Chantal FONTAINE)		
9H00 - 9H30	<b>Luiz TIZEI</b>	Optical Spectroscopy at High Spatial Resolution with Fast Electrons	Laboratoire de Physique des Solides, Uni Paris-Sud, Orsay, France
9H30 - 9H50	<b>Alexander MILEKHIN</b>	TERS Imaging of CdSe Quantum Dots on Nanostructured Au Surfaces	A.V.Rzhanov Institute of Semiconductor Physics, Novosibirs, Russia
9H50 - 10H10	<b>Philippe RONCIN</b>	Elastic and inelastic regime in fast atom diffraction	Institut des Sciences Moléculaires d'Orsay, CNRS, Uni Paris Sud, Orsay, France
10H10 - 10H30	<b>Andrej KUZNETSOV</b>	Band gap maps beyond delocalization limit and identification of carrier traps in novel oxide semiconductors	University of Oslo, Norway
10H40 - 11H00	COFFEE BREAK		

ROOM PORT CROS	METALLIC NANOPARTICLES (Chairman: Ilan GOLDFARB)		
11H10- 11H40	<b>Andrei HONCIUC</b>	Self-Assembly of Janus Nanoparticles	Institute of Chemistry and Biotechnology, Zurich University of Applied Sciences, Switzerland
11H40 - 12H00	<b>Andrei CRISTINA-CASSIANA</b>	Direct and selective detection of bacteria using surface-enhanced Raman Scattering (SERS) imaging	Physique de la Matière Condensée, Ecole Polytechnique-CNRS , Uni Paris Saclay, Palaiseau, France
12H00 - 12H20	<b>Felicia IACOMI</b>	Tuning the gold nanoparticle coordination and bioeffects by exposure to green light	Faculty of Physics, Alexandru Ioan Cuza University, Iasi, Romania
12H20 - 12H40	<b>Iole VENDITTI</b>	Functionalized silver nanoparticles for mercury(II) detection in water	Department of Sciences, Roma Tre University, Rome, Italy
12H40 - 13H10	<b>Adriana SCARANGELLA</b>	Silver nanoparticles-based nanocomposites for biosensing using the “spectro-inside” concept	CEMES, Uni Toulouse, CNRS, France
ROOM LEVANT	SEMICONDUCTOR NANOSTRUCTURES PROPERTIES (Chairman: Philippe VENNEGUES)		
11H00- 11H30	<b>Gilles PATRIARCHE</b>	In situ growth of GaAs nanowires by molecular beam epitaxy in a transmission electron microscope	Centre de Nanosciences et de Nanotechnologies (C2N), CNRS- Université Paris Sud, Uni Paris Saclay, France
11H30 - 11H50	<b>Simona BONINELLI</b>	Strain measurements of active Phosphorous in Laser Annealed Ge	IMM-CNR, Catania, Italy
11H50 - 12H10	<b>Franck BASSANI</b>	Direct exploration of the nanoscale structure of III-V heterostructures epitaxied on 300 mm Si substrates by Atom Probe Tomography and ToF-SIMS	Uni. Grenoble Alpes, CEA LETI, MINATEC, Grenoble, France
12H10 - 12H30	<b>Hadi HIJAZI</b>	Charge and spin transport in GaAs nanowires grown by HVPE	Institut Pascal, Université Clermont Auvergne, CNRS, SIGMA Clermont, Aubiere, France
12H30 - 12H50	<b>Clara CORNILLE</b>	Strain and electronic properties of carbon-doped GaAsBi alloys grown on GaAs by molecular beam epitaxy	LAAS-CNRS, Uni Toulouse, France
13H10 - 16H30	LUNCH AND BREAK		

ROOM PORT CROS	SELF-ORGANISATION AND PROPERTIES (Chairman: Xavier WALLARD)		
16H30 - 17H00	<b>Andreas WIECK</b>	Self-organized growth of quantum dots and quantum wires by combination of focused ion beams and molecular beam epitaxy	Lehrstuhl für Angewandte Festkörperphysik, Bochum, Germany
17H00 - 17H20	<b>Kaouther DERRAJI</b>	Synthesis and characterization of nanostructured CoMoO <sub>4</sub> : Xchromic and photoluminescence properties	IM2NP, AMU, Uni Toulon, CNRS, France
17H20 - 17H40	<b>Thomas BOTTEIN</b>	Large surfaces of 2D hexagonal Ge nanocrystals by double self-assembly	IM2NP, AMU, Marseille, France
17H40 - 18H00	<b>Abdessalam BOUDDOUCH</b>	Calcination temperature effect on the structure, morphology and photocatalytic activity of the bismuth phosphate BiPO <sub>4</sub> nano-crystalline synthesized by co-precipitation method in aqueous medium	Laboratoire Matériaux et Environnement (LME), Faculté des Sciences, Université Ibn Zohr, Agadir, Maroc
18H00 - 18H20	<b>Jean-Manuel RAIMUNDO</b>	In route to SiO <sub>2</sub> /Ge <sub>3</sub> Mn <sub>5</sub> /Ge(111) heterostructures for (bio)sensor applications	CINAM, AMU, CNRS, Marseille, France
ROOM LEVANT	SEMICONDUCTOR NANOCRYSTALS (Chairman: Antoine RONDA)		
16H30 - 17H00	<b>Christophe DELERUE</b>	LEGO bricks at the nanoscale	Uni Lille, CNRS, Centrale Lille, ISEN, Univ. Valenciennes, Lille, France
17H00 - 17H20	<b>Stefano OSSICINI</b>	First-Principle Results for Undoped and Doped Silicon and Germanium Nanocrystals in Different Environments	Dipartimento di Scienze e Metodi dell'Ingegneria, Uni di Modena e Reggio Emilia and CNR-Istituto di Nanoscienze, Italy
17H20 - 17H40	<b>Paola CASTRUCCI</b>	Giant Photoluminescence yield amplification in drop-casted films of Si nanostructures	Dipartimento di Fisica, Uni di Roma Tor Vergata, Italy
17H40 - 18H00	<b>Simona BONINELLI</b>	Rayleigh instability induced formation of silicon nanocrystal chains from ultrathin Si nanowires	IMM-CNR, Catania, Italy
18H00 – 18H30	<b>Monica BOLLANI</b>	Design, characterization and lithographic application of Si nanocrystals patterns via templated dewetting	Institute for photonics and nanotechnologies (IFN) - CNR, LNESS, Milano, Italy

## FRIDAY

ROOM PORT CROS	SEMICONDUCTOR NANOSTRUCTURES (Chairman: Vincent SALLET)		
9H00 - 9H30	<b>Guy FEUILLET</b>	Nanopatterned Si substrate for reduced footprint GaN epitaxy	CEA / LETI, Dept Optique et Photonique ( DOPT), Grenoble, France
9H30 - 9H50	<b>Benjamin DAMILANO</b>	Nanoporous GaN made by selective area sublimation: efficient light emission on silicon substrate	Uni Côte d'Azur, CNRS, CRHEA, Valbonne, France
9H50 - 10H10	<b>Mohammed ZEGHOUANE</b>	Growth of InGaN nanowires with a controlled indium fraction by HVPE	Institut Pascal, Université Clermont Auvergne, CNRS, SIGMA Clermont, Aubiere, France
10H10 - 10H30	<b>Ionut ENCULESCU</b>	Nanowire based field effect transistors: Influence of geometrical properties	National Institute of Materials Physics, Magurele, Romania
10H30 - 10H50	<b>Mateusz JEDRUSKI</b>	Nanostructured LaFeO <sub>3</sub> /YSZ thin films as mixed potential gas sensor	AGH University of Science and Technology, Kracow, Poland
ROOM LEVANT	FUNDAMENTALS OF GROWTH (Chairman: Leo Miglio)		
9H00 - 9H30	<b>Madhav RANGANATHAN</b>	Role of Elastic Anisotropy in Patterned Substrate Heteroepitaxy	Department of Chemistry, Indian Institute of Technology Kanpur, Kanpur, India
9H30 - 9H50	<b>Jean-Noël AQUA</b>	When surface energy builds effective attraction between quantum dots	INSP, Sorbonne Uni, Paris, France
9H50 - 10H10	<b>Jerrold A FLORO</b>	Quantum Dot Site Selection During Annealing of Initially Conformal Si <sub>0.5</sub> Ge <sub>0.5</sub> Films on Patterned Si (001) Surfaces	University of Virginia, Dept Materials Science, Charlottesville, USA
10H10 - 10H40	<b>Dominique CHATAIN</b>	Hetero-epitaxy of FCC metal films on sapphire	AMU, CNRS, CINAM, Marseille, France
10H40 - 11H10	COFFEE BREAK		

ROOM PORT CROS	SEMICONDUCTOR NANOSTRUCTURES (Chairman: Vincent CONSINNI)		
11H10- 11H40	Jesus ZUNIGA-PEREZ	ZnO optical microcavities by MBE: from polariton lasers to polariton amplifiers	CRHEA, UCA-CNRS, Valbonne, France
11H40 - 12H00	Vincent CONSONNI	ZnO / CuCrO <sub>2</sub> core-shell nanowire heterostructures for self-powered UV photodetectors with fast response	Université Grenoble Alpes, CNRS, Grenoble INP, LMGP, Grenoble, France
12H00 - 12H20	Thomas FROMHERZ	Optoelectronics based on defect-enhanced quantum dots on Silicon	Institute of Semiconductor and Solid State Physics, Johannes Kepler University Linz, Austria
12H20 - 12H50	Xavier WALLART	Selective area growth of III-V semiconductors using atomic hydrogen during Molecular Beam epitaxy	Univ. Lille, CNRS, Centrale Lille, ISEN, Univ. Valenciennes, Lille, France
ROOM LEVANT	FUNDAMENTALS OF GROWTH (Chairman: Pierre MULLER)		
11H10- 11H40	Frédéric LEROY	Surface electromigration of Si advacancy and adatom islands	AMU, CINAM, CNRS, Marseille, France
11H40 - 12H00	Marco ALBANI	Modelling the kinetic growth mode of GaAs nanomembranes	L-NESS and Department of Materials Science, Uni of Milano - Bicocca, Italy
12H00 - 12H20	Philippe VENNEGUES	Towards the comprehension of dislocations generation in epitaxially-grown (0001) wurtzite layers	Centre de Recherche sur l'Hétéroépitaxie et Ses Applications CRHEA-CNRS , Sophia Antipolis, France
12H20 - 12H40	Thomas DAVID	SiGe condensation process used to manage strain on UT-SOI	X-FAB France SAS 224, Corbeil-Essonnes, France
12H40	LUNCH		



## ROOM GIENS

### 11h20 - Enhanced Vibrational Spectroscopies of Semiconductor Quantum Dots

#### Dietrich RT Zahn

*Semiconductor Physics, Chemnitz University of Technology, Chemnitz University of Technology, D-09107 Chemnitz, Germany*

Here strategies are discussed how to enhance the response of semiconductor quantum dots (QDs) in vibrational (Raman and infrared (IR)) spectroscopies with the ultimate aim to detect the phonon spectrum of a single QD.

For this purpose I will first introduce the typical Raman features of QDs using the example of colloidal QDs. Even though the number of QDs in an ensemble measured in a Raman experiment is quite high, already these measurements require resonant Raman scattering as a classical enhancement mechanism used whenever the scattering volumes are tiny. The Raman spectra of QDs contain a wealth of information regarding phonon confinement, electron-phonon coupling, QD surface properties, strain, or interfacial intermixing in the case of core/shell QDs.

Using the example of Langmuir-Blodgett deposited QD layers with widely varying QD areal density further enhancement mechanisms are introduced. These include interference-enhanced Raman scattering (IERS) employing an oxide layer on silicon substrates, surface-enhanced Raman scattering (SERS) with well ordered metal nanostructures fabricated by electron beam lithography and various geometric parameters, and tip-enhanced Raman scattering (TERS) combined with SERS. In the latter case the QDs require a protective cover in order to avoid interaction with the tip. MoS<sub>2</sub> monolayers are employed for this purpose. They do not only allow spectroscopy to be performed on single QDs but also provide interesting information on the field enhancement near the metallic nanostructures. Finally the surface-enhanced IR absorption (SEIRA) of QDs is measured using specially designed antenna arrays with resonances in the region of the phonon frequencies in the far IR. The IR results reveal, by comparison with the Raman spectra, a dominant contribution of surface optical (SO) phonons to the SEIRA spectra. Altogether the results of the vibrational spectroscopies clearly indicate the feasibility of single QD vibrational spectroscopy providing a breadth of information.

### 12h00 - Semimetals as potential thermoelectric materials

#### Mona Zebarjadi, Maksime Markov

*Department of Mechanical and Aerospace Engineering, University of Virginia, Charlottesville, USA*

The best thermoelectric materials are believed to be heavily doped semiconductors. The presence of a bandgap is assumed to be essential to achieve large thermoelectric power factor and figure of merit. In this talk, we study several semimetals including HgTe as an example semimetal with competitive thermoelectric properties. We show

theoretically and experimentally that semimetals can achieve large thermoelectric figure of merit. We employ ab initio calculations with hybrid exchange-correlation functional to accurately describe the electronic band structure of several semimetals in conjunction with the Boltzmann Transport theory to investigate their electronic transport properties. We show that semimetals can have Seebeck coefficient values close to those of semiconductors. Their electrical conductivity values are higher than semiconductors and they can have similar thermal conductivity values. We calculate the lattice thermal conductivity of HgTe using first principles calculations and evaluate its overall figure of merit. Finally, we prepare semi-metallic HgTe samples and we characterize its transport properties. We show that our theoretical calculations agree well with the experimental data.

### 12h30 - Designer Shape Anisotropy on Transition-Metal-Dichalcogenide Nanosheets

**B. Mennucci 1, M.C Giordano 1, C. Martella 2, E. Cinquanta 2, A. Lamperti 2, E. Cappelluti 3, A.Molle 2, F. Buatier de Mongeot 1**

1 Dipartimento di Fisica, Università di Genova via Dodecaneso 33, I-16146 Genova Italy

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3 Istituto dei Sistemi Complessi (ISC)-CNRU.O.S. Sapienza 00185, Roma

MoS<sub>2</sub> and generally speaking, the wide family of transition-metal dichalcogenides represents a solid nanotechnology platform on which to engineer a wealth of new and outperforming applications involving 2D materials. An even richer flexibility can be gained by extrinsically inducing an in-plane shape anisotropy of the nanosheets [1]. Here, the synthesis of anisotropic MoS<sub>2</sub> nanosheets is proposed as a prototypical example in this respect starting from a highly conformal chemical vapor deposition on large area templates prepatterned in a self organized fashion, aiming at the more general purpose of tailoring anisotropy of 2D nanosheets by design [2]. This is envisioned to be a suitable configuration for strain engineering as far as strain can be spatially redistributed in morphologically different regions. With a similar approach, both the optical and electronic properties of the 2D transition-metal dichalcogenides can be tailored over macroscopic sample areas in a self-organized fashion, thus paving the way for new applications in the field of optical metasurfaces, light harvesting, and photocatalysis [3].

[1] C. Martella et al. *Advanced Materials* 29, 1605785 (2017)

[2] C. Martella et al. *Advanced Materials* 30, 1705615 (2018)

[3] M.C. Giordano and F. Buatier de Mongeot, *Advanced Materials* – accepted (2018)

## ROOM GIENS

### 15h00 - Designing functional porous and nanostructured materials at multiple length scales

**Andreas Stein**

*Department of Chemistry, University of Minnesota, USA*

Templating methods employing soft templates (e.g., surfactants, block co-polymers, emulsions), hard templates (e.g., colloidal particles, colloidal crystals), or both together, are powerful approaches for controlling structure of materials, in particular porous materials, on multiple length scales to effect specific functions. Many applications require materials with complexity in both structure and composition. During synthesis and processing of complex materials, multiple interactions between templates and precursors can provide a richness in structure, but can also be exploited to influence the arrangement and distribution of separate components in a complex material. This tutorial review will highlight methods of controlling parameters of importance for functional materials, including pore geometry and shape; pore hierarchy, interconnectivity and accessibility; transport path length; material composition and component distribution in multicomponent systems; surface functionality; site isolation; and stability. The impact of these parameters on functional materials for energy storage and conversion, catalysis, sensing, and optical/photonic materials will be discussed with specific examples from our research.

### 15h40 - Photoluminescence of porous silicon influenced by magnetic metal filling

**P. Granitzer, K. Rumpf, P. Poelt, M. Reissner**

*Institute of Physics, University Graz, Graz, Austria*

In this framework luminescent porous silicon (PSi) is filled with a magnetic metal (e.g. Ni) to influence the photoluminescence due to the presence of metal deposits. This happens in two ways. On the one hand the surface plasmon of the metal deposits is exploited to modify the luminescence and on the other hand it is influenced by an external magnetic field. Due to the metal filling of the porous silicon the photoluminescence is blue-shifted and furthermore an increase of the intensity is observed. The influence of the magnetic metal filling on the optical properties is discussed and the magnetic characterization of the nanocomposites is presented. First the optical properties of the luminescent PSi are investigated, second Ni is deposited within the porous silicon samples and subsequently the nanocomposite specimens are characterized optically again and also magnetically. The samples are structurally characterized by SEM, EDX and TEM. The optical properties are investigated with respect to the shift of the photoluminescence due to the metal filling. Photoluminescence spectra of bare PSi show a maximum around 620 nm whereas in the case of Ni filled samples the peak is blue-shifted to around 580 nm and the luminescence intensity is increased. Concerning the magnetic properties of the nanocomposite the embedded Ni structures can be superparamagnetic from the size of the pore diameters but due to the branched morphology the achieved deposits tend to be interconnected and thus do not offer necessarily a superparamagnetic

behavior. Also temperature dependent magnetization measurements give no hint for superparamagnetism. Field dependent magnetization measurements performed with the magnetic field applied perpendicular and parallel to the sample surface show a high magnetic anisotropy. It can be clearly seen that the samples offer a film-like behavior due to the interconnected Ni structures which is represented by the easy axis parallel to the surface. In the frame of this work the optical characterization of luminescent PSi with respect to its photoluminescence compared with Ni filled samples is discussed in detail as well as the corresponding magnetic properties of the nanocomposites. Furthermore the influence of an external magnetic field on the optical properties is elucidated. The presented systems are promising candidates for applications in optoelectronics and also for magneto optical integrated devices.

## **16h10 - Laser Direct write of semiconducting metal oxide micro and nanopatterns**

**Olivier Soppera**

*CNRS IS2M, Mulhouse, France*

Metal Oxo-Cluster (MOC) based photoresists have emerged as a very interesting alternative material platform for the next generations of photolithography. The versatile chemical approach to prepare the MOC nanoscale building blocks opens new possibilities for integrating metal-oxide micro and nanostructure by photolithography. MOCs can indeed be crosslinked under Deep-UV light and easily converted to metal-oxide. Applications in gas sensors, biosensors, photodetectors, spintronic devices, and field-effect transistors are then possible. We describe here the synthesis, characterization and Deep-UV photolithography of MOC photoresists, based on different metals like Zr, Ti, Hf or Zn. A deep investigation of the photoinduced modification of the MOC is carried out by spectroscopic ellipsometry, FTIR, Raman, XPS, in order to describe how the MOC photoresist is crosslinked and have thus a negative tone behavior. We also show the photopatterning of these photoresists by Deep-UV laser lithography. Finally, electrical and magnetic properties of metal oxide nanopatterns are investigated, which opens doors towards applications in electronic device fabrication or sensing.

## 17h10 – Poster flash presentations

### Laser Direct write of semiconducting metal oxide micro and nanopatterns

**M.Bouchaour, R. Bensaha, F.Lekoui, N-E. Chabane Sari, N. Maloufi**

*URMER, Université de Tlemcen, Algérie.*

ZnO and GaN have attracted a great interest due to their potential applications. They have many similar properties; a wurtzite crystal structures and their lattice mismatch is only 1.8% and 1 similar room temperature wide band gap of 3.37 eV and 3.4 eV respectively. They are expected to have potential applications in function nanodevices. In this, we report ZnO thin films deposited on GaN/Al<sub>2</sub>O<sub>3</sub> using thermal evaporation. This technique is low cost and is very attractive because it is relatively simple, suitable for low melting point and low decomposition. The variations in the crystal phase and structure of ZnO layer is investigated in detail by X-ray diffraction, scanning electronmicroscopy and raman spectroscopy.

### Diamond film grown from carbon nanosheets and polymer composites for sensoric applications

**Stepan Potocky, Tibor Izak, Marian Varga, Zdenek Remes, Sukang Bae, Sungho Lee, Han-Ik Joh, Dong Su Lee, Alexander Kromka**

*Institute of Physics of the Czech Academy of Sciences, Pragu, Czech republic*

A new class of materials with unique properties is expected by combining sp<sup>2</sup>/sp<sup>3</sup> allotropic forms of carbon. However, the fabrication process is challenging due to very different processing requirements of each allotropic form. Moreover, integration with metal particles exploits resonance-based sensing methods. Chemical vapor deposition of diamond on foreign substrates is hindered due to its high surface energy. Therefore, nucleation treatment has to be employed to initialize the formation of diamond crystals. The nucleation depends on the specific nucleation enhancement method [1]. In this contribution, we present the fabrication process of thin diamond films and structures grown from polyacrylonitrile (PAN) composite or carbon nanosheets (CNS) and diamond nanoparticles (DNPs). The primary particle size of DNPs was 5-10 nm, and they were used to promote nucleation density by creating nucleation seeds. Addition of Au nanoparticles and their integration into the final film is studied as well. The same PAN polymer was used to prepare composite (PAN+DNPs) polymer films and CNS. The sp<sup>2</sup>-hybridized CNS were produced by carbonisation of PAN polymer films. The sp<sup>3</sup>-hybridized diamond films were produced by microwave chemical vapour deposition (CVD). The CVD deposition of the thin polycrystalline diamond film was performed in complementary MW PE CVD systems using either cavity resonator or the linear antenna system. We have studied a correlation between process parameters and concentration of PAN and DNPs on the formation of thin diamond films and structures with the outlook to conformal growth of fully closed ultrathin diamond films and suppression of carbon diffusion into substrates. Surface morphology was characterised by SEM and AFM. The chemical composition of grown films and structures was determined by the Raman spectroscopy. Optical properties (optical transmittance, reflectance, and absorptance spectra) were characterised by photothermal deflection spectroscopy [2]. The layer thickness was characterised by

the reflectance interferometry or from cross-section views by SEM. This work was supported by the by the CSF project 17-19968S.

[1] A. Kromka, O. Babchenko, S. Potocky, B. Rezek, A. Sveshnikov, P. Demo, T. Izak, M. Varga, in: *Diam.-Based Mater. Biomed. Appl.*, Woodhead Publishing Limited, n.d., pp. 206–255.

[2] Z. Remes, J. Holovsky, A. Purkr, J. Stuchlik, *Adv. Sci. Eng. Med.* 7 (4), 343–346 (2015).

## Au antenna arrays with different morphology for detection of CdSe nanocrystals

**I. A. Milekhin 1,2, S. A. Kuznetsov 1,3, L. L. Sveshnikova 1, T. A. Duda 2, A. G. Milekhin 1,2, E. E. Rodyakina 1,2, A. V. Latyshev 1,2, V. M. Dzhagan 4, and D. R. T. Zahn 5**

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We present the results of surface enhanced IR absorption (SEIRA) study of CdSe nanocrystals (NCs) deposited on Au nanoantenna arrays with three different morphologies. Localized surface plasmon resonance (LSPR) arises in the antennas under the action of incident radiation. If a small amount of substance is placed in the region of enhancement, then the intensity of vibrational mode increases. Nano- and microantenna arrays were used to get an enhancement of phonons response of CdSe monolayers. The LSPR frequency position depends strongly on the structural parameters of the antennas so the LSPR frequency can be varied in a wide spectral range. The geometry of dog-bone, nano- and micro linear antennas were chosen in accordance with the 3D electromagnetic simulations in order to get the overlapping frequencies of LSPR in nanoantennas and optical phonons in CdSe NCs. Au nano- and dog-bone antenna arrays on a Si substrate were fabricated using nanolithography while the microantennas were created by photolithography. All antennas were covered by monolayers of CdSe NCs with a size of about 5 nm using the Langmuir-Blodgett technology. The structural parameters of antenna arrays, size and morphology of NCs were determined by scanning electron and optical microscopies. Distribution of electromagnetic (EM) field in the vicinity of the nano- and micro-antennas show that the maximal local EM field enhancement ( $1.5 \cdot 10^3$ ) in the gaps between nanoantennas is observed for linear nanoantennas. The dog-bone shaped nanoantennas demonstrate a higher EM field enhancement averaged over the whole nanoantenna array despite of lower local EM field. Experimental SEIRA spectra of nano- and microantennas covered with monolayers of CdSe NCs reveal the feature near  $190 \text{ cm}^{-1}$  attributed to surface optical (SO) phonon modes in CdSe NCs. The local SEIRA enhancement of  $1.1 \cdot 10^6$  allowed us the observation of the phonon response from 1 ML of CdSe NCs deposited on linear Au nanoantenna arrays. Despite the theory predicts the maximal SEIRA response for the dog-bone shaped nanoantennas, our experiment evidences a stronger signal from linear nanoantennas which can be caused by the deposition process irregularities. Micro-antenna arrays show the SEIRA response lower by factor of about 10 in comparison with that of linear nanoantennas.

The reported study was funded by Volkswagen Foundation and RFBR according to the research project № 18-32-00551 and № 18-02-00615.



## Effects of non-uniform dopant distribution near Si surfaces for advanced applications

**D. Moraru,<sup>1</sup> L. Popa,<sup>2\*</sup> and F. Iacomi<sup>3</sup>**

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<sup>3</sup>Faculty of Physics, Alexandru Ioan Cuza University, Iași, 700506, Romania;

Electronics nowadays rely on the control of electronic properties of materials in nanoscale and it will extend to functionalities at molecular and atomic level in the near future. From this perspective, it becomes critical to understand the properties of ultra-thin semiconductor materials – such as silicon as a key material for electronics – from the viewpoint of doping, which is the process by which the conductivity of the material can be changed.<sup>1</sup> Here, we show that for highly-doped ultra-thin Si, the dopant distribution becomes strongly non-uniform, giving rise to new material surface properties.

In such a non-uniform dopant distribution in nanoscale, clusters of dopants can be present due to the absence of other surrounding dopants.<sup>2</sup> Such clusters work as quantum dots and control electron transport even down to the single electron level. We monitor such change of properties by electrical measurements, especially at low temperatures, in nanoscale Si transistors with two-dimensional (2D) channels fabricated in a silicon-on-insulator. The thickness of the 2D Si channel is <10 nm, while doping concentration of phosphorus (P) donors is  $> 1 \times 10^{19} \text{ cm}^{-3}$  (higher than the metal-insulator transition<sup>3</sup> for Si doped with P, i.e.,  $3.8 \times 10^{18} \text{ cm}^{-3}$ ). Even under such conditions, IV characteristics at low temperatures (<15 K) exhibit a non-monotonous behavior near the threshold voltage, which can be ascribed to single-electron tunneling through a network of dopant-induced QDs.<sup>4,5</sup> The distribution and transport in such dopant-induced 2D QD arrays are analyzed by simulations.

Based on these results, we suggest that naturally formed networks of dopant-induced quantum dots can work as a versatile platform for self-assembling other nanostructures, benefiting from the modulation of the properties near the critical surface (interface). This can open new fields of study at nanometer level for future generations of electronics.

1. T. Shinada et al., "Enhancing semiconductor device performance using ordered dopant arrays", *Nature* **437**, 1128 (2005);

2. T. Tanaka et al., "Deionization of dopants in silicon nanofilms even with donor concentration of greater than  $10^{19} \text{ cm}^{-3}$ ", *Nano Lett.* **16**, 1143 (2016);

3. B. I. Shklovskii and A. L. Efros, "Electronic properties of doped semiconductors", Ed. Springer Series in Solid-State Sciences (1984);

4. D. Moraru et al., "Tunneling in systems of coupled dopant-atoms in silicon nanodevices", *Nanoscale Res. Lett.* **10**, 372 (2015);

5. A. Samanta et al., "Single-electron quantization at room temperature in a-few-donor quantum dot in silicon nano-transistors", *Appl. Phys. Lett.* **110**, 093107 (2017).

## EPR studies on perovskite and ferrite nanoparticles and thin films

**A. Popa, D. Toloman, C. Doroffei, A. Carlescu, M. Toma, M. Irimia, G. Nedelcu, G. Bulai, E. Ware, F. Iacomì**

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Perovskites and ferrites are important magnetic materials with wide application area. We investigate the influence of structure and cation substitution on the magnetic properties of some perovskite,  $\text{LaMMnO}_3$  ( $M=\text{Pb}, \text{Sr}$ ), undoped and doped ( $\text{Ni}, \text{Zn}, \text{Gd}, \text{La}$ ) cobalt ferrite nano-powders and thin films. The nano-powders were synthesized through a sol-gel auto-combustion method and were thermally treated at different temperatures (773K/2h, 973K/2h and 1173K/2h). Perovskite and ferrite thin films were deposited on (100) Si, quartz and  $\text{Al}_2\text{O}_3$  substrates by pulsed laser deposition, rf sputtering or spin-coating methods. The information about the crystalline structure, chemical composition and morphology was obtained from X-ray diffraction, X-ray photoelectron spectroscopy, transmission electron microscopy, scanning electron microscopy, atomic force microscopy. Electron paramagnetic resonance spectroscopy measurements were carried out as a function of temperature and orientation in the magnetic field. The influence of structure, dopant elements and annealing temperature on the magnetic properties and magnetic anisotropy resulted from the angular dependence of resonance magnetic field and of EPR linewidth. The EPR investigations performed as a function of temperature (100K-450K) enabled to have a better understanding about the range of magnetic ordering and spin fluctuations. The experimental data are compared with similar results obtained by other authors.

## Nanofabrication of large scale photonic structures using Soft-Nano Imprint Lithography applied to sol-gel coatings

**Thomas Bottein, Olivier Dalstein, Magali Putero, Marco Faustini, Andrea Cattoni, Marco Abbarchi, David Grosso**

*NOVA - IM2NP – AMU, Marseille, France.*

Lithography techniques are nowadays essential to design structures at the nanoscale in numerous fields such microelectronics, sensing, photonics or microfluidics to name just a few. Most reported lithography processes are based on microfabrication methods generally requiring multiple steps that can be expensive, polluting and hard to scale up to large surfaces. In this context, Soft Nano Imprint Lithography (Soft-NIL) [1] has drawn huge interest as it requires only few simple steps in mild conditions (Tamb, Patm) and is capable of high throughput with high resolution. Applying Soft-NIL approaches to process metal oxides is highly attractive since patterned surfaces with tailored multiple functionalities can be directly produced from sol-gel coatings [2]. Recent works proved the interest of directly patterned sol-gel coatings with the example of  $\text{TiO}_2$  diffraction gratings for gas sensing transduction [3] or Mie resonator arrays for light trapping [4]. However, nanoimprinting sol-gel materials remains challenging due to the high precursor reactivity and the high viscosity of the intermediate xerogel. Both effects led to relatively low aspect ratio structures which limits the potential applications of those highly interesting metal oxide patterns. In this work, we proposed new sol-gel formulations as NIL resists. We demonstrated that, by a careful control of the environment, homogeneous replica with high aspect ratios can be obtained [5], [6]. By simply controlling the Relative Humidity, water was used as



fluidizing agent, modifying the viscosity of the coatings. A water quantity corresponding to 30%vol of the sol-gel coating was found to give optimal imprinting. An in-depth study of the imprinting parameters (RH, T, aging ...) was then performed for TiO<sub>2</sub> sol-gel coatings and extended to three other sol-gel materials (Al<sub>2</sub>O<sub>3</sub>, SiO<sub>2</sub>, Y-ZrO<sub>2</sub>). This systematic investigation confirmed that the approach adopted here, to enhance the nanoimprinting of sol-gel resists, could be extrapolated to the imprinting of most sol-gel materials. Finally, to prove the feasibility of the up-scaling of the soft-NIL technique, a large scale demonstrator with arrays of 1 x 1 mm<sup>2</sup> containing nano-sized pillars was produced. Its potential for photonic applications was further assessed: the nanostructured arrays showed sharp structural colors originating from Mie resonances.

### Combining SERS and DFT for studying surface orientation of push-pull chromophore within self-assembled monolayers

**V. Gadenne (1), C. Praveen (2), B. Grenier (2), P. Marsal (2), J. C. Valmalette (3), J. M. Raimundo (2), and L. Patrone (1)**

(1) Aix Marseille Univ, Université de Toulon, CNRS, IM2NP UMR 7334, Yncréa Méditerranée, ISEN Toulon, Maison du Numérique et de l'Innovation, Place G. Pompidou, 83000 Toulon, France, & Campus de St Jérôme, 13397 Marseille Cedex 20, France. (2) Aix Marseille Univ, CNRS, CINaM UMR 7325, Campus de Luminy, Case 913, 13288 Marseille Cedex 09, France. (3) Université du Sud-Toulon-Var, CNRS, IM2NP UMR 7334, Bât. R, BP 20132, 83957 La Garde Cedex, France.

Surface functionalisation by small organic molecules requires clear and deep information on the surface/interface of deposited molecules for the development of efficient optoelectronic molecular devices and others. With this aim, this work reports on a joint experimental/theoretical hybrid approach in order to provide information on the orientation of deposited small organic molecules within self-assembled monolayers (1) onto a gold surface. Among various pi-conjugated molecules, we have focused our attention on the extensively studied push-pull chromophores (2) that have found their slot in many optoelectronic applications (3). The latter are strongly dependent on the molecule orientation on the surface that can be controlled or hindered by several parameters such as the molecular structure, the surface itself, the method of deposition (e.g. dip coating or drop casting), the solvents used and so on. We have evidenced from an elegant Surface Enhanced Raman Spectroscopy (SERS) (4) / Density Functional Theory (DFT) joint study the possibility to probe the arrangement of deposited thin films of push-pull chromophores. According to this approach, we have also shown that depending on the experimental conditions, i.e., the solvent nature or the coating methods, noticeable differences can be highlighted by SERS allowing us to select the right conditions to tune the surface properties. In addition, by this mean it appears easy to analyse the presence or not of some defects, in terms of arrangement and/or morphology, and correlate the obtained properties to those imperfections. Based on the study we have evidenced different points: (i) the push-pull chromophores are standing perpendicularly rather than flat on the surface, (ii) the solvent impacts strongly on the structure of the chromophores promoting, in the case of dichloromethane solvent, the quinoid form, and finally (iii) drop casting favours the formation of aggregates unlike in self-assembled monolayers. We are confident that the strategy is valuable and worth pursuing because this unique combination of SERS/DFT methods makes this approach very interesting and complementary among the various surface analysis techniques.

- (1) A. Ulman, *An introduction to ultrathin organic films* (Academic Press: Boston, 1991). (2) M. Barzoukas, M. Blanchard-Desce, part 4 in *Advances in Multi-Photon Processes and Spectroscopy*, Edited by S. H. Lin, A. A. Villaeys, Y Fujimura, World Scientific Singapore, New Jersey, London, Hong-Kong, 13, 257-337 (2000). (3) J. Zhang, W. Xu, P. Sheng, G. Zhao, D. Zhu, *Acc. Chem. Res.*, 50, 165-1662 (2017); V. Malytskyi, J.-J. Simon, L. Patrone, J.-M. Raimundo, *RSC Adv.*, 5, 354 (2015). (4) L. Jensen, C. M. Aikens, G. C. Schatz, *Chem. Soc. Rev.*, 37, 1061-1073 (2008); K. Kneipp, A. Kneipp, I. Itzkan, R. Dasari, M. S. Feld, *Chem. Rev.*, 99, 2957-2975 (1999); A. Merlen, V. Gadenne, J. Romann, V. Chevallier, L. Patrone, J.-C. Valmalette, *Nanotechnology*, 20, 215705/1-215705/7 (2009).

## Self-assembled organic monolayers on Ge and GaAs : application to nanodielectrics

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Due to their high intrinsic mobility, germanium (Ge) and III-V semiconductors appear as promising alternative channel materials to replace silicon in the next generation of high mobility and high frequency transistors. However, contrary to silicon dioxide, those material oxides are neither stable nor of good quality. Preparing proper interfacial layer allowing to passivate and insulate Ge and III-V is one of the challenges still needed to be addressed. A promising way consists in using with a high dielectric constant, since it leads to uniform and nanostructurally well-defined robust thin film over large areas, but that still remains to be applied on Ge and III-V. The aim of this work is to design new self-assembled molecular monolayers (SAMs) grafted on Ge and GaAs exhibiting the best properties of insulation and passivation as Self-Assembled Molecular Nanodielectrics (SANDs) [1]. Since thiol molecules have been shown to form SAMs on Ge [2] and GaAs [3], we use alkyl/ fluorinated/ and conjugated -thiol molecules. Specially synthesized conjugated molecules are bithiophene-based push-pull molecules. Indeed, thanks to their dipole that can be aligned by the SAM deposition strategy, such chromophores are able to form a highly polarizable insulating film with dielectric constant ( $k=7-8$ ) significantly higher than that of silicon dioxide ( $k=3.9$ ) [1]. Obtained SAMs are first evaluated regarding their structure and organization. In order to obtain a high quality SAM with low defects it is essential to limit surface roughness. For this reason, as confirmed by scanning probe microscopy, we have successfully developed a grafting process without acid treatment, contrary to most of Ge functionalization methods exploited in the literature, either in one-go [2], or within two steps, i.e., oxide removal followed by SAM grafting. The passivation ability of the various SAMs is assessed by XPS to follow the oxidation of Ge or GaAs surface functionalized by dodecanethiol and perfluorodecanethiol SAMs. The electronic properties and insulation characteristics of the various SAMs are investigated by current-voltage and capacitance-voltage measurements, at the nanoscale using scanning tunneling microscopy and at the microscale using electrical contacts - either Joule evaporated using an interfacial protective layer such as Alq3 that has been characterized, or softly deposited using GaIn droplets - and analyzed notably by transition voltage spectroscopy [4] in correlation with UPS spectroscopic analyses. Further work will address multilayers of aligned organic molecules in order to increase the total dipole and therefore the whole

dielectric constant. We believe these results will help paving the way to developing new alternative high  $k$  dielectrics for the future generation of transistors. [1]. A. Facchetti *et al.*, *Adv. Mater.* 17, 1705 (2005).  
[2]. J.N. Hohman *et al.*, *Chem. Sci.*, 2, 1334 (2011).  
[3]. C.W. Sheen *et al.*, *J. Am. Chem. Soc.* 114, 1514 (1992).  
[4]. I. Bâldea, *Phys. Rev. B*, 85, 035442 (2012); J.M. Beebe *et al.*, *ACS Nano*, 2, 827 (2008).

## Morphology Studies of Gallium doped ZnO Nanowires for Plasmonics

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The MOCVD growth of various Ga-doped ZnO nanostructures for plasmonics is investigated, with a particular focus on the nanowire facet transformations induced by the addition of trimethylgallium in the gas phase. For non-intentionally doped spontaneous ZnO nanowires, the aspect ratio is strongly decreased due to residual Ga in the reactor, and the shape evolves rapidly towards Christmas-tree like and hierarchical structures upon intentional Ga doping. Regarding ZnO/ZnO:Ga core-shell structures, a change of the smooth initial M-oriented facets occurs, with the development of {20-21} surfaces, and further {10-11} and {0001} surfaces. Interestingly, a similar evolution of the lateral roughness is observed in Au-catalyzed doped nanowires. High concentrations of Ga in the grown nanostructures are revealed by photoluminescence and confirmed by Rutherford backscattering spectrometry. First photoacoustic measurements show an optical absorption at 6  $\mu\text{m}$ , evidencing that the degenerated material is suitable for plasmonics applications in the IR range. The influence of Ga doping on the facet transformations and the occurrence of unexpected {0001} polar surfaces are discussed. The results can be mainly understood by a Ga surfactant effect (at least partial) responsible for the modification of the surface energies and kinetics. Density functional calculations support the floating behavior of the negatively charged Ga- ion on the growing surface.

## MOCVD grown InAs/GaAs quantum dots on Si substrate

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III-V semiconductors (GaAs, InAs, InP ...) have remarkable intrinsic properties. They exhibit a high electron mobility and, most often, a direct band gap allowing the emission of light in a wide spectral range (from UV to infrared) with a high quantum efficiency. They are thus materials of choice for producing light sources such as light emitting diodes and laser diodes. Their integration on a silicon CMOS platform would open wide perspectives in the field of silicon photonics and optical interconnections. In this work, we will report on the realization of As-based heterostructures allowing to

make light sources emitting at 1.3  $\mu\text{m}$ . However, the hetero-epitaxy of As-based semiconductors on a silicon substrate remains a major challenge mainly due to the difference of lattice parameter and polarity of the materials. That is why in the context of this work to minimize the impact of structural defects on the emission properties of III-V materials, we are interested in InAs/GaAs quantum dots system grown on a nominal Si (100) substrate by MOCVD in a 300 mm industrial type reactor. As a result, after optimizing the growth parameters in order to have a high density of quantum dots ( $10^{11} \text{ cm}^{-2}$ ), photoluminescence studies were carried out as a function of temperature and power. As results, we have an emission around 1.3  $\mu\text{m}$  whether on GaAs substrate or on a nominal Si substrate oriented (100) all along the 300 mm.

*This work has benefited from state aid managed by the ANR, notably under the future investment program ANR-15-IDEX-02, the IRT Nanoelec ANR-10-AIRT-05, and the RENATECH network.*

## **Toward optimum N<sub>2</sub> plasma nitriding process for GaAs(100) surface passivation**

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The high density of interface and surface states that cause the strong Fermi pinning observed on GaAs surface is reduced by passivating GaN thin film on GaAs. To further develop this passivation, it is necessary to investigate the nitridation phenomena by identifying the different steps occurring during the self-limited process and to understand surface organization of GaAs nitridation under different conditions. AR-XPS measurements were carried out to identify the chemical environments and compositional profiles of the elements. In addition, the LEED patterns show a switch between cubic and hexagonal reconstruction of the GaN surface when the ion nitrogen are replaced by radical one. These results allow us to optimize the process parameters in view to obtain the best surface passivation against air exposure. This optimization was demonstrated using micro-photoluminescence and electrical measurements. These measurements show a high photoluminescence efficiency after annealing at 620°C and a low leakage current and a better ideality factor by increasing the GaN thickness.

## **Nucleation and growth mechanisms of ZnO nanowires on Au thin films by chemical bath deposition for piezoelectric nanogenerators**

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Chemical bath deposition (CBD) is an efficient way to obtain dense arrays of ZnO nanowires at low cost and low temperature (< 100°C). A pre-deposited seed layer is required to favor the nucleation of ZnO nanowires and get the desired dimension and morphology. While polycrystalline ZnO seed layers are the mostly used currently, alternative metallic seed layers are needed for specific applications like piezoelectric generators. Promising results have been demonstrated on Au thin films, which can be

further used as direct metallic contacts in these devices [1]. Nevertheless, the morphological control of the ZnO nanowire array is still limited as the understanding of their nucleation and growth mechanisms on Au thin films has not been addressed yet. In this context, several samples with varying Au thicknesses - ranging from 5 to 100 nm - are prepared, on which ZnO nanowires are grown by CBD under identical standard conditions using zinc nitrate and hexamethylenetetramine in aqueous solution [2]. The evaporated polycrystalline Au seed layers are found to be strongly oriented along the direction, which is favorable for the nucleation and growth of ZnO nanowires. The structural properties of ZnO nanowires and its relationship with the morphology of the Au seed layers are investigated by scanning electron microscopy, atomic force microscopy, x-ray diffraction, and x-ray pole figures. Furthermore, transmission electron microscopy experiments are also performed to thoroughly elucidate the properties of the grain/nanowire interfacial region, allowing us to establish a complete nucleation and growth diagram. Electron beam lithography is eventually used to implement selective area growth on top of the Au seed layers, as a pre-requisite for their integration into piezoelectric nanogenerators.

[1] S. Xu et al, *J. Mater. Res.* 2008, 23, 2072-2077.

[2] R. Parize et al., *J. Phys. Chem. C* 2016, 120, 5242-5250.

## Defect engineering in GaN epilayers on nanopatterned SOI

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Gallium nitride (GaN) has been attracting a lot of interest for the last few decades due to its successful integration in optoelectronic devices, such as light emitting diodes (LEDs), and in power electronics. However, the large lattice and thermal coefficients of expansion mismatch between the GaN epilayer and the heteroepitaxial substrate is still a major setback for GaN devices, since it affects directly the efficiency of such devices. Several techniques were developed to improve the crystalline quality of the material and reduce the threading dislocation density (TDD) based on different substrate patterning methods, such as epitaxial lateral overgrowth or pendeo-epitaxy. However, the inherent limitation of these methods rises from the fact that the crystallites originating from the different nucleation sites coalesce at some point during growth, and because of the relative misorientation between the crystallites, coalescence leads to the formation of dislocations to compensate for the misorientations. To deal with this issue, we propose a novel method based on pendeo-epitaxy of GaN on nanopatterned SOI substrates. First, nanopillars are etched down to the buried oxide with classical e-beam lithography. Second, a pyramidal growth of GaN is achieved on top of the nanopillars, leading to coalescence between adjacent GaN pyramids at a certain point. The advantage of this method lies in the deformation of the underlying nanopillars, when coalescence occurs, which will compensate for the misorientation between the grown pyramids. This entails the crystallographic alignment of the pyramids without forming coalescence defects at their boundaries. The SOI presents a top Si layer about 50 nm-thick, oriented in the 111 direction. The SiO<sub>2</sub> thickness is about 150 nm. We have tested different sizes of nanopillars with different periodicity, ranging between 100 and 500 nm in pillar diameter and 500 to 2000 nm as pitch. Growth is carried out in two phases: pyramidal growth on the nanopillars followed by 2-dimensionnal growth for coalescence. Structural investigations (TEM and X-ray



diffraction) together with optical characterizations by cathodoluminescence carried out at different stages of the growth - i.e. before and after coalescence - reveal promising results in terms of defect reduction within the coalesced layers. GaN layers were also obtained on arrays of nanopillars, with easy delamination, showing the potential of exfoliating the GaN layer.

## A low Energy Electron Microscopy study of the growth and surface electromigration of Au on Ge(111)

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This work focuses on two phenomena where the surface diffusion of Au on Ge plays an important role. The first one is the nucleation of Au islands on the  $\sqrt{3}\times\sqrt{3}$  AuGe(111) surface and their growth by Ostwald ripening; the other one is the motion of  $\sqrt{3}\times\sqrt{3}$  - 2D domains on the 1x1 Au-Ge(111) surface under the effect of an electric current passing through the sample[1]. The experiments were performed in an Ultra High Vacuum (UHV) setup equipped with a Low Energy Electron Microscope [2]. The Au/Ge(111) system follows the Stranski-Krastanov growth mode [3], after preparation of a clean Ge substrate, on Au deposition a single  $\sqrt{3}\times\sqrt{3}$  Au-Ge layer is formed on the surface, followed by the growth of 3D islands. In absence of external flux, the number of islands decreases while their size increases because of Ostwald ripening. We have measured the density of particles in different conditions of Au flux and substrate temperature. Then, using the theories developed by Venables et al. [4] for the nucleation of islands on a surface and by Chakraverty [5] for the Ostwald ripening, we have found the diffusion energy of Au on the  $\sqrt{3}\times\sqrt{3}$  Au-Ge(111) surface and the size of the critical nucleus to form 3D islands. When a direct electric current is applied to a sample, a force called electromigration may apply on the diffusion of surface atoms, resulting in a global mass transfer [6]. We have studied the drift, induced by a direct electric current ( $\sim 106$  A/m<sup>2</sup>), of 2D  $\sqrt{3}\times\sqrt{3}$  - domains on atomically flat terraces of 1x1 Ge(111). The domains velocity depends on the temperature (Joule effect) and on the electric current. Increasing the temperature between 500-640°C, the Au domains velocity varies from 30 to 800 nm/s. The effective energy for the diffusion of the domains is 0.82 eV at high temperature and 2.15 eV at low temperature. With a careful characterization of the domain motion as a function of the island size, we have found that terrace diffusion is the main mechanism controlling the displacement of the 2D domains.

[1] P.S. Ho and T. kwok, *Rep. Prog. Phys.* 52, 301-348 (1989)

[2] F. Cheynis et al. *Rev. Sci. Instru.* B 85 043705 (2014)

[3] J.A. GIACOMO, PhD Thesis, University of California, Davis (2009)

[4] J.A. Venables, G.D.T. Spiller, M. Hanbücken, *Rep. Prog. Phys.* 47 (1984) 399.

[5] B.K. Chakraverty, *J. Phys. Chem. Solids* 28 (1967) 2401

[6] C. Tao et al., *Science* 328 736-740 (2010)

## Photodegradation of rhodamine B under UV-visible light irradiation in aqueous medium by monoclinic CePO<sub>4</sub> nano-crystalline prepared by co-precipitation method

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This work deals with the study of the photodegradation of Rhodamine B using a Cerium phosphate CePO<sub>4</sub> material. The monoclinic cerium phosphate powder have been successfully synthesized via a facile co-precipitation reaction at room temperature and subsequent calcination route. The phase identification, morphology and thermal transformation were characterized by using different techniques such as, X-ray Diffraction (XRD), scanning electron microscopy (SEM), energy dispersive, X-Ray analysis (EDS), the Fourier Transform Infrared (FTIR) and TGA-DTA analysis. The XRD profile shows that the phase obtained is that of the submicronic phase CePO<sub>4</sub>. For the photocatalytic activity, TOC system was used to analyze the evolution of mineralization of rhodamine B. Finally, the photodegradation efficiency results of the pollutant by our material show that 74 % of the concentration of rhodamine B in the aqueous suspension was decomposed by the CePO<sub>4</sub> catalyst under UV-visible light irradiation after 480 min. Keywords: Cerium phosphate CePO<sub>4</sub>, co-precipitation method, photodegradation, rhodamine B, photocatalytic efficiency.

## Plasticity of silicon in low dimensions: extended defects and deformation mechanisms

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Over the last years, progress in nanomaterials design and manufacturing has revolutionized technology and opened up prospects for many scientific researches. The investigation of material properties (optical, electronic, mechanical...) at small scales has revealed that nano-objects behave differently than bulk samples. For instance, silicon, which is known to be a brittle material at low temperature, shows an unexpected ductile behaviour when the sample size decreases below a few hundreds of nanometres. The identification of the mechanisms governing this brittle to ductile transition in size is the key point to prevent the failure of microelectronic components based on the silicon strained technology. In this context, this research project aims at investigating in more details the deformation behaviour of silicon nanopillars by combining experimental techniques (SEM, FIB, HRTEM) and molecular dynamics simulations. In this work nanopillars with diameter of 100 nm and with different orientations ( , , ) were patterned by Reactive-Ion Etching. These pillars were then compressed with a slow-strain-rate (10<sup>-4</sup> s<sup>-1</sup>) at room temperature using a nano-indenter equipped with a flat punch and operated in displacement-control mode. The measured stress-strain curves evidence the first stages of plastic deformation (load drop events). Post mortem observations of deformed nanopillars performed by SEM and TEM

reveal the activation of different slip systems. The comparison between experimental and simulated HRTEM images notably evidences the simultaneous propagation of partial and perfect dislocations in  $\{111\}$  planes. In addition, unexpected plastic events have also been observed in  $\{115\}$  planes. Various possible deformation mechanisms involved during the nano-compression of the pillars are proposed, based on the microscopic observations.

*This work is performed within the framework of the ANR-funded research project « Brittle-to-Ductile Transition in Silicon at Low dimensions » (ANR-12-BS04-0003-01, SIMI4 program).*

### **Double-junction solar-cell based on two monolayers**

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We theoretically propose a double-junction solar-cell based on two monolayers of different transition metals dichalcogenide. Our calculation shows that a double-gate can open a band-to-band tunnel window (Esaki diode) in the van der Waals heterojunction. Moreover, such a double-gate allows to match the two currents generated by each junction. This proposed structure therefore avoids the two major drawbacks of the multijunction solar-cells, named lattice and current mismatches.

### **Structural properties of carbon spheres: how the iron catalyst marks the difference in their Energy and Electrochemical response**

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Carbon nanospheres are known since the first studies on the synthesis of fullerene. They are similar to fullerenes but they differ from them because of their more complex internal structure made of unclosed carbon sheets of variable orientation. Properties like size and inner and outer morphology can vary substantially, therefore the generic term carbon spheres (CSs) is used to cover all carbons that have a spherical or near spherical shape not including the fullerene family [1]. The ease of synthesizing and processing carbon nanomaterials with a special attention to sp<sup>2</sup> bonded carbon structures, may be one of the main reasons for the rapidly growing applications of carbon nanostructures [2]. In this research field, there has been a renewed attention in the CSs because their structural and electronic properties are finding new interesting nano-technological applications. This paper focuses on the structural and electronic characterization of carbon spheres obtained from a chemical vapor deposition synthesis process. Several techniques give detailed information on their structural, electronic and chemical properties. It is first observed that the Fe catalyst can be encapsulated in some of the spheres and cannot be removed. This point is not detrimental since it confers the CSs a magnetic response. Both the structural properties and the active contribution of iron mark the difference in the measured photoresponse as well as in the electrochemical behavior. The collected results underline the advantages offered by this nanomaterial for sustainable applications [3-5].

[1] Deshmukh A. A., Mhlanga S. D., Coville N. J., Carbon spheres, Materials Science and Eng. R 70 (2010) 1;



- [2] Harris P.J.F., Carbon nanotubes and related structures. New materials for the twenty first century. UK: Cambridge; 1999.
- [3] Scarselli M., et al., Influence of Iron Catalyst in the Carbon Spheres Synthesis for Energy and Electrochemical Applications, Adv. Mater. Interfaces (2018), 1800070 (10pp).
- [4] Possanza F., Scarselli M., et al, Functionalization of Carbon Spheres with a Porphyrin-Ferrocene Dyad, ChemPhysChem (2018) DOI: 10.1002/cphc.201800277.
- [5] Cinti S., Limosani F., Scarselli M., Arduini F., Magnetic carbon spheres and their derivatives combined with printed electrochemical sensors, Electrochim. Acta (2018) submitted.

## Quantitative explanation of 1D instabilities self-organisation on vicinal substrate

**Kailang Liu, Antoine Ronda, Luc Favre, Thomas David, Marco Abbarchi, Isabelle Berbezier(1), Philippe Gaillard, Thomas Frisch (2), Bernard Croset, Jean-Noël Aqua(3)**

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Strained epitaxial SiGe on vicinal Si(001) substrates develop a morphological instability perpendicular to the steps unlike the usual growth instabilities on vicinal substrates, eventually leading to the growth of planar nanowires. We assess both theoretically and experimentally the effect of strain anisotropy on the 1D elongation of the Asaro-Tiller-Grinfeld (ATG) instability. The anisotropy of strain relaxation due to the presence of step edges is considered in a continuum model with two different effective strains in the surface plane. We show that the measured in-plane strain anisotropy and the theoretical model are quantitatively consistent with the experimental morphologies. Nice network of ultrasmall aligned elongations are predicted resulting from a complex interplay of kinetic and energetic phenomena associated with strain anisotropy. Morphological evolution of ATG instability with Ge concentration and miscut angle will be presented.

## Enhancement of physical properties of porous silicon treated with Bismuth nanoparticles

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Thin films of Bismuth (Bi) (III) were deposited by sol-gel dip-coating technique on Porous Silicon (PS) prepared by electrochemical anodization of p-type (100) Si. The Bi film thickness was varied from 6nm to 20nm. The substrates were heated at 400°C for 10min in order to obtain uniform films. Variations in the structural and optical properties of PS were observed after immersion in Bi (III). The surface morphology was studied by Atomic Force Microscopy (AFM). All samples were analyzed by Fourier transmission infrared spectroscopy (FTIR). We notice a partial disappearance of Si-Hx peaks after Bi (III) thin film deposition on the PS. This is due to the replacement of hydrogen atoms by the oxygen-metal atoms. In fact, the deposited Bi (III) is not only contributing to the passivation of PS, but it also plays the role of an anti-reflective layer by reducing the light reflection. The reflectivity spectra of the samples performed in the 300-1200nm wavelength range showed a remarkable decrease of about 1.5% for PS passivated by Bi (III). Moreover an enhanced photoluminescence (PL) property of the PS/Bi Structure was clearly observed.

## ROOM PORT CROS

### 9h00 - Transition Metal Dichalcogenide Synthesis and Integration

**Keren Freedy, Peter Litwin, Nathaniel Kabat, Petra Reinke, Stephen McDonnell**

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Here we present recent work on the synthesis and characterization of two-dimensional transition metal dichalcogenides (TMDs) grown by molecular beam epitaxy as well as interface studies focused on metal-TMD interfaces. Bulk TMD crystals consist of two-dimensional layers bonded together by van der Waals interactions; the lack of primary bonds at the TMD interface allows for the growth of TMD heterostructures on a range of substrates. TMDs are grown and characterized in an all in-vacuo ultra-high vacuum system employing x-ray photoemission spectroscopy for compositional analysis and angle resolved photoemission spectroscopy for electronic characterization. Furthermore we present a unique approach to contact engineering, reliant entirely on the control of chemical composition at the metal/2D interface. We show that by controlling the sample pretreatments or metal deposition conditions we can either promote or hinder reactions between a contact metal and a 2D material. Photoemission spectroscopy and transport measurements are employed to develop a comprehensive understanding of the relationship between processing, chemistry and electronic structure, and device-relevant transport properties.

### 9h30 - Stabilization of Au Monatomic-High Islands on the (2×2)-Nad Reconstructed Surface of Wurtzite AlN(0001)

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RHEED spectra and low temperature NC-AFM images demonstrate that Au grows on the AlN(0001) (2×2)-Nad reconstructed surface as large (>100 nm) monolayer islands that form moiré patterns [1]. These experimental data allow us to build atomic models that are used as input for first-principles DFT calculations. These calculations show that the hexagonal Au adlayer interacts locally with the substrate via the acceptor and donor sites existing on the (2×2)-Nad reconstructed surface [2]. These interactions lead to local distortions of the hexagonal layer. Au adsorption is accompanied

(i) by a global vertical charge transfer from the AlN substrate, that fulfills the electrostatic stability criterion for a polar surface,

(ii) by lateral charge transfers mediated by the reaction of Au with the acceptor and the donor sites of the polar substrate.

The stabilization of the monolayer is the consequence of these two mechanisms that lead to energy gains of electrostatic and chemical origin. This study rationalizes the physico-chemical effects associated with the adsorption of metallic islands on a polar substrate with a nonstoichiometric reconstructed surface and opens routes for the fabrication of metallic pads particularly interesting in the context of molecular electronics. These 2D metallic pads can also be the seeds for the growth of thick 2D gold electrodes. Such electrodes with a controlled metal-semiconductor interface could improve the reliability of the nitride active devices.

[1] B. Eydoux et al., *Phys. Rev. Applied* 8, 044002 (2017).

[2] F. Chaumeton et al., *Phys. Rev. B* 94, 165305 (2016).

## 9h50 - Lateral graphene/h-BN heterostructures from chemically converted epitaxial graphene on SiC (0001)

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Graphene has attracted a great deal of interest due to its remarkable properties, but as a zero-bandgap semimetal its full potential for next generation electronic devices is yet to be realized. Unlocking its potential for future applications in nanoelectronics will depend critically on the development of novel approaches to introducing a bandgap while preserving carrier mobility. In-plane heterostructures of graphene and its insulating analogue, h-BN, have been predicted to allow tuning of the bandgap and carrier mobility according to the carbon concentration [1]. Such hybrid structures have previously been synthesized by CVD on metal foils, and patterned using photolithography/reactive ion etching followed by a second growth step, before transfer onto insulating substrates [2]. In this research lateral graphene/h-BN heterostructures are grown directly on 6H- and 4H-SiC (0001) by topological conversion of epitaxial graphene. Graphene can be chemically converted to h-BN upon heated exposure to ammonia (NH<sub>3</sub>) and boric acid (H<sub>3</sub>BO<sub>3</sub>) vapors, and the concentration of h-BN can be controlled by limiting the reaction time [3]. By x-ray photoelectron spectroscopy (XPS) and scanning tunneling microscopy (STM), we observe the substitution of h-BN domains in the epitaxial graphene layer. The reaction nucleates at defects or functionalized carbon atoms which we confirm by Raman spectroscopy. This technique allows the growth of semiconducting hybrid atomic layers with tunable properties directly on a substrate suitable for device fabrication.

[1] Wang, J., et. al., *Small* 9(8) 1373 (2013)

[2] Liu, Z., et. al., *Nat Nanotechnol* 8(2) 119 (2013)

[3] Gong, Y., et. al., *Nat Commun* 5 3193 (2014)

## 10h10 - A study of the interface between a trivial and a topological insulator: the case of $\beta$ -antimonene on Bi<sub>2</sub>Se<sub>3</sub>

**R Flammini 1, S Colonna 1, F Ronci 1, C Hogan 1, S K Mahatha 2, M Papagno 3, A Barla 2, P M Sheverdyeva 2, P Moras 2, Z S Aliev 4,5, M B Babanly 6, E V Chulkov 7,8, C Carbone 2**

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$\beta$ -antimonene is a 2-dimensional allotrope of Sb showing a honeycomb buckled structure when grown on bismuth selenide [1]. Thin  $\beta$ -antimonene layers possess the electronic structure of a semiconductor [2], while Bi<sub>2</sub>Se<sub>3</sub> has that of a topological insulator [3]. In recent years, a great deal of effort has been made to understand emergent phenomena occurring at the interface between a trivial insulator and a topological insulator, as encompassed by the term "proximity effect". This study aims to investigate how the electronic band structure of the antimonene layer is affected by the presence of the bismuth selenide.

We begin by studying growth mode and structure of the different phases forming at the interface using scanning tunnelling microscopy (STM). In particular, we find that the  $\beta$  phase is in the minority at RT while it becomes a majority phase upon annealing. Following this, we study the fine details of the band structure of the interface by STS and ARPES compared to ab-initio DFT calculations. A change in the semiconducting nature of the antimonene is recorded, due to the strong hybridization of adsorbate/substrate band structures.

[1] R. Flammini et al. *Nanotechnology* 29 (2018) 065704

[2] P. Zhang et al. *Phys. Rev. B* 85 (2012) 201410

[3] H. Zhang et al. *Nat. Phys.* 5 (2009) 438

## 11h10 - Thermal transport, emergent phenomena in 2D materials.

### Girogia FUGALLO

ETSF, LSI, École Polytechnique, Palaiseau, France

Heat conduction in two dimensional materials displays a wealth of fascinating phenomena of key relevance to the scientific understanding and technological applications of graphene and related materials. In this talk I will present how, by solving exactly the Boltzmann transport equation[1] in the framework of density-functional perturbation theory it is possible to study, fully from first-principles, phonon transport and heat conductivity in graphene, boron nitride, molybdenum disulphide, graphane and fluorographane[2,3]. In all these materials, at variance with typical three-dimensional solids [4], normal processes keep dominating over Umklapp scattering well-above cryogenic conditions, extending to room temperature and more. As a result, novel regimes emerge, with Poiseuille and Ziman hydrodynamics, hitherto typically confined to ultra-low temperatures, characterising transport at ordinary conditions. Most remarkably, several of these two-dimensional materials admit wave-like heat diffusion, with second sound present at room temperature and above in graphene, boron nitride and graphane[2-5].

[1] G. Fugallo, L. Paulatto, M. Lazzeri and F. Mauri, *Phys. Rev. B*, 88, 045430 (2013)

[2] G. Fugallo & #8203;; A Cepellotti, L Paulatto, M Lazzeri, N Marzari, F Mauri, *Nano letters* 14 (11), 6109-6114 (2014).

[3] A Cepellotti, G. Fugallo & #8203;; L Paulatto, M Lazzeri, F Mauri, N Marzari, *Nature Comm.* 6, 6400 (2015)

[4] M.Markov, J.Skaiste, G. Fugallo, L Paulatto, M Lazzeri, F Mauri, N Vast *Phys. Rev. Lett.* 6, 6400 (2018) [5] G. Fugallo, L. Colombo *Physica Scripta* 93, 043002 (2018)

## 11h40 - Si nanoribbon templates on missing row reconstructed Ag(110)

**Michel Mansour, Romain Parret, Lisa Michez, Laurence Masson***Aix Marseille Univ, CNRS, CINaM, Marseille, France*

In the last two decades, nanopatterning of surfaces using bottom-up approaches has proven to be an efficient way to produce high densities of homogenous nanostructures with controlled shape at the atomic scale. Moreover, investigation of their properties can be led by using either local or macroscopic integration probes. In this context, silicon nanoribbons (NRs) grown on Ag(110), since its discover in 2005 [1], have received much attention as this system produces mesoscale organization of one-dimensional regularly spaced Si nanostructures perfectly aligned on the substrate. The atomic structure of these Si NRs has recently been elucidated [2,3], revealing the formation of surprising single and double pentamer Si chains lying in the missing rows (MRs) of the reconstructed Ag substrate. Nevertheless, few studies of the growth mechanisms have been led to understand the interplay between the formation of the Si single and double nanoribbons (SNRs and DNRs) and the MR reconstructed Ag surface. Here, we present a recent nanoscale investigation of the Si growth mechanisms in the submonolayer regime at different temperature, using scanning tunneling microscopy (STM). Depending on the substrate temperature, from room temperature to 230°C, different arrangements of the Si NRs are formed. They differ by the progressive replacement of SNRs (0.8 nm in width) by DNRs (1.6 nm in width) and by the lateral organization of the NRs, perpendicularly to the ribbons. Our study evidences transitions from one- to two-dimensional growth at (i) 110°C, corresponding to the transition of isolated SNRs to SNRs locally assembled in a  $3 \times 2$  superstructure and (ii) 170°C, corresponding to the transition of isolated DNRs to DNRs assembled in a long-range  $5 \times 2$  superstructure. The statistical analysis of NRs densities from STM (300 nm<sup>2</sup>) images has been done and revealed the activation energies for the different processes (diffusion, formation of superstructures). Our results strongly suggest that the transition between SNRs and DNRs superstructures is driven by the MR reconstruction of the Ag(110) surface. Finally, results will be presented showing that these supported Si NRs can be advantageously used as a template for the self-organized growth of 3d metal nanolines exhibiting magnetic properties

[1] C. Leandri, G. L. Lay, B. Aufray, C. Girardeaux, J. Avila, M. E. Dávila, M. C. Asensio, C. Ottaviani, and A. Cricenti, *Surf. Sci.* 574, L9 (2005).

[2] J. I. Cerdá, J. Sławińska, G. Le Lay, A. C. Marele, J. M. Gómez-Rodríguez, and M. E. Dávila, *Nat. Commun.* 7, 13076 (2016).

[3] G. Prévot, C. Hogan, T. Leoni, R. Bernard, E. Moyen and L. Masson, *PRL* 117, 276102 (2016).

## 12h00 - Germanene on Al(111)

**Natalia Massara, Mickael Derivaz, Didier Dentel, Régis Stephan, Marie-Christine Hanf, Ahmed Mehdaoui, Philippe Sonnet and Carmelo Pirri**

*IS2M UMR7361 Université de Haute Alsace Mulhouse, France*

"The 2D crystal called germanene has been grown on Al(111). It is found to cover the substrate with a large coherence over the Al(111) surface [1, 2]. Low energy electron diffraction (LEED) and scanning tunnelling microscopy (STM) exhibit a  $(3 \times 3)$  superstructure with respect to the Al(111) substrate lattice. The formation of a 2D germanene layer on Al(111) has been studied by first principles calculations using density functional theory (DFT). Numerous 2D germanene models have been calculated and only two of them have the lowest (and the same) adsorption energy [2]. For these stable calculated structures, the  $(3 \times 3)$  unit cell consists of a planar Ge honeycomb network with 8 Ge atoms, in which one or two Ge atom is shifted upwards [1, 2]. The topmost Ge atoms would give the STM contrast. In agreement, experimental STM images show two well defined contrasts, i.e. a honeycomb contrast and a hexagonal contrast, depending on the imaging conditions. The STM images have been simulated and perfectly reflect those observed experimentally. Experiments suggest that the hexagonal contrast reflects the germanene layer structure of the as-grown germanene layer, while the honeycomb contrast, which reflects the other germanene structure, is induced by the interaction of germanene with the STM tip. This is in line with recent measurements performed in other experimental groups [3, 4].

The electronic structure of germanene was probed by DFT calculations and high resolution photoemission using synchrotron radiation. The sites multiplicity of the germanene atomic structure reflects in the core level Ge3d line. This line shows three Ge3d components, at least, in line with calculations for both structures [4, 5]. A charge transfer between Ge and Al surface atoms is predicted along with a charge localization at the germanene / Al(111) interface.

[1] *Continuous Germanene Layer on Al(111)*, Mickael Derivaz, Didier Dentel, Régis Stephan, Marie-Christine Hanf, Ahmed Mehdaoui, Philippe Sonnet and Carmelo Pirri, *Nano Lett.* 2015, 15, 2510–2516

[2] *Tip-Induced Switch of Germanene Atomic Structure*, Régis Stephan, Mickael Derivaz, Marie-Christine Hanf, Didier Dentel, Natalia Massara, Ahmed Mehdaoui, Philippe Sonnet, and Carmelo Pirri, *J. Phys. Chem. Lett.* 2017, 8, 4587–4593

[3] *Asymmetric structure of germanene on an Al(111) surface studied by total-reflection high-energy positron diffraction*, Yuki Fukaya, Iwao Matsuda, Baojie Feng, Izumi Mochizuki, Toshio Hyodo and Shin-ichi Shamoto, *2D Mater.* 3 (2016) 035019

[4] *Coexistence of strongly buckled germanene phases on Al(111)*, Weimin Wang and Roger I. G. Uhrberg, *Beilstein J. Nanotechnol.* 2017, 8, 1946–1951

[5] *Germanene on Al(111): Interface Electronic States and Charge Transfer*, R. Stephan, M.C. Hanf, M. Derivaz, D. Dentel, M. C. Asensio, J. Avila, A. Mehdaoui, P. Sonnet, and C. Pirri, *J. Phys. Chem. C* 2016, 120, 1580–1585"



## 12h20 - Raman and STM investigation of air-stable silicene nanosheets on an inert graphite surface

**Paola Castrucci, Filippo Fabbri, Tiziano Delise, Manuela Scarselli, Matteo Salvato, Sara Pascale, Roberto Francini, Isabelle Berbezier, Christoph Lechner, Fatme Jardali, Holger Vach, Maurizio De Crescenzi**

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Silicon belongs to the same column of the periodic table but, differently from Carbon,  $sp^3$  hybridization is much more favorable for Si than  $sp^2$  one. The challenge of designing groundbreaking systems, to connect with Si-based technology, has inspired the study of novel two-dimensional (2D) nanomaterials. Experimentally, 2D layers are obtained by depositing Si atoms on metal (M) surfaces [1]. However, due to the strong p-d mixing between Si and M atoms, it is still debated if pure 2D-Si has been actually observed [2]. To minimize interactions and/or alloy formation, we have used HOPG (highly oriented pyrolytic graphite) as substrate. Indeed, due to the C atoms,  $sp^2$  configured, this substrate approximates better than M ones the properties of a honeycomb structure and it provides a higher chemical inertness. Based on scanning tunneling microscopy (STM) and ab initio molecular dynamics simulations, we demonstrated the growth of a bi-dimensional silicon arrangement minimizing any substrate-silicon interaction. Our scanning tunneling spectroscopy [3] confirms the metallic character of the deposited silicene in excellent agreement to our band structure calculations that also exhibit the presence of Dirac cones. Raman spectra show a new feature, located at  $542.5\text{ cm}^{-1}$ , that has not been reported so far for  $sp^3$  Si modes. This suggests that we are dealing with a genuine vibrational mode  $sp^2$  and interpreted as the silicene mode with a low buckling configuration. The Raman shift of low-buckled silicene on an inert substrate has not been reported so far and it is completely different from both the one calculated for free-standing silicene and the experimental ones measured for silicene grown on Ag(111).

## 12h40 - Quest for silicene: following Si growth on metal and van der Waals substrates

**G. Prévot**

*Institut des NanoSciences de Paris, Sorbonne Université, UMR CNRS 7588, Paris, France*

The synthesis of silicon monolayers, which would possess properties similar to those of graphene is a current challenge, particularly for microelectronics applications. From a theoretical point of view, it has been shown that an hexagonal plane of silicon, with a low undulation, is metastable, and has an electronic structure similar to that of graphite, with the presence of a Dirac cone at the of Fermi. Since these works, the growth of silicene layers has been reported on many substrates such as metals (Ag, Ir, Au...), refractory ceramics ( $ZrB_2$ ) or van der Waals substrates (graphite,  $MoS_2$ ...). Growth of

silicene multilayers has also been claimed. Using Scanning Tunneling Microscopy, Grazing Incidence X-ray Diffraction and Density Functional Theory simulations, we have studied the growth of Si on metal and van der Waals substrates. In this talk, I will show that if Si/Ag(111) phases really correspond to honeycomb silicene layers, alloy formation is observed on Au(111), whereas 3D growth occurs on graphite and dichalcogenides substrates without any formation of an ordered 2D layer. Finally, I will show how the study of the growth of thick Si layers on Ag(111) allows us to understand the origin of the stability of silicene.



## ROOM LEVANT

### 9h00 - Simple but Successful Descriptors for Self Assembly of Organic Molecules on Surfaces

**Shobhana Narasimhan, Sukanya Ghosh, Pratap Zalake and K George Thomas**

*Jawaharlal Nehru Centre for Advanced Scientific Research, Bangalore, India*

Self-assembly is perhaps the most promising route to constructing devices at the nanoscale. The challenge is to predict the geometries of self-assembled architectures by utilizing only the properties of the individual molecular components. We have explored the feasibility of such an approach for a model set consisting of three host molecules (carboxylic acid derivatives of phenyleneethynylene) and five guest molecules (naphthalene, phenanthrene, benzo-c-phenanthrene, benzo-ghi-perylene, and coronene), self-assembled on highly oriented pyrolytic graphite. Using insights gained from scanning tunneling microscopy experiments and density functional theory calculations, we have formulated simple descriptors that can successfully predict the geometries of the host-guest architectures self-assembled from our palette of organic molecules. A structure map can be constructed using host and guest descriptors, with structures of the same type clustering in descriptor space. Though these descriptors can be evaluated at essentially zero computational cost, they correctly reproduce experimental observations, including the structural transitions exhibited by host assemblies upon introducing certain guest molecules. They also correctly predict the self-assembled architectures formed by certain other molecules that were not used when formulating the descriptors.

### 9h30 - Resonant soft X-ray reflectivity for the quantitative investigation of anisotropic ultrathin organic films

**Luca Pasquali**

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Reflectivity is typically carried out in the hard X-ray range to study morphology of interfaces and structure of layered systems, where electron density contrast between different materials is exploited. In the soft X-rays, reflectivity at resonance provides additional advantages in terms of atomic and depth-resolved investigation of the chemical, structural and magnetic properties of a variety of systems, including polymeric and organic materials, liquid interfaces, spintronic systems and inorganic layered materials. Element selectivity together with high contrast between different structures is obtained. The technique is non-destructive. It can be applied to conductive or insulating materials and under the effect of electric and magnetic fields. The sampling depth is not limited to the near-surface region, as for electron yield

spectroscopies, but deep buried interfaces can be accessed as well (several tenths of nm). The recent advances obtained in the application of soft X-ray resonant reflectivity at the BEAR beamline of the Elettra synchrotron will be presented. In particular, we developed a protocol to get simultaneous quantitative information on the structure, interface morphology, chemical properties and optical anisotropies of layered materials with sub-nm depth resolution. The method is based on the quantitative prediction of the spectral line-shape across specific elemental edges through: 1) the simulation from the first principles of the dielectric tensor of each material in a given layered system; 2) the simulation of the propagation of the electromagnetic field in the stack of layers and the computation of the (anisotropic) optical properties (reflectivity, transmission); 3) the comparison and fitting of the simulation to the experiment. The method has been successfully applied to study anisotropic thin and ultrathin organic films on metals and insulators and to get quantitative information on chemical composition, layer-resolved molecular orientation, optical anisotropies and overall thickness of the films, simultaneously. In particular, the following prototypical cases will be discussed: 1,4 benzenedimethanethiol (BDMT) on Au(111) [1], 3,4,9,10-perylene-tetracarboxylic dianhydride (PTCDA) on Au(111) [2], pentacene on SiO<sub>2</sub> [3], tetracene single crystal. The method transfers to the soft-X range the knowledge gained in the years in the field of visible and infrared spectroscopy of thin anisotropic films and offers a tool of quantitative investigation in those cases where electron spectroscopy cannot be applied due of the presence of nonconductive materials, poor vacuum or materials buried at distances from surfaces higher than the electron free collision path.

[1] L. Pasquali, S. Mukherjee, F. Terzi, A. Giglia, N. Mahne, K. Koshmak, V. Esaulov, C. Toccafondi, M. Canepa, and S. Nannarone, *Phys Rev B*, 2014, 89, 45401.

[2] R. Capelli, N. Mahne, K. Koshmak, A. Giglia, B.P. Doyle, S. Mukherjee, S. Nannarone, L. Pasquali, *J Chem Phys*, 2016, 145, 024201.

[3] R. Capelli, M. Nardi, T. Toccoli, R. Verucchi, F. Dinelli, C. Gelsomini, K. Koshmak, A. Giglia, S. Nannarone, L. Pasquali, *Appl. Phys. Lett.* 2018, 112, 031602.

## 9h50 - Ultra-fast crystallization dynamics at an organic-inorganic interface revealed in real time by Grazing Incidence Fast Atom Diffraction

**E. M. Staicu Casagrande, A. Momeni, A. Dechaux, H. Khemliche**

*Institut des Sciences Moléculaires d'Orsay (ISMO), CNRS, Univ. Paris-Sud, Université Paris-Saclay, France*

Organization modes of thin organic layers on inorganic substrates determine for a large part their optical and electronic properties. Being able to precisely describe and then gain control over the organization dynamics of these systems may provide a mean to select and optimize the final properties. This is an essential challenge in a context where a multitude of applications of these hybrid nanostructures are predicted. One could then be able to produce high quality organic layers in a reproducible manner. From the experimental point of view, the breakthrough may come from a new analytical approach that is highly sensitive to the last surface plane, non-invasive and able to characterize in real time the growth process. Grazing Incidence Fast Atom Diffraction

(GIFAD) seems to fulfill these requirements; its capability in identifying fine surface properties of inorganic semiconductors and their growth has been demonstrated. GIFAD relies on the scattering of  $\sim 1$  keV He atoms at grazing incidence angles near  $1^\circ$ . The scattered particles are collected on a position sensitive detector; their intensity distribution provides a wealth of information of the surface properties. A recent study on the growth of a model organic semiconductor, perylene (C<sub>20</sub>H<sub>12</sub>) on Ag(110), reveals an unexpected and complex organization dynamics. In particular, crystallization of the first layer into a very dense packing occurs quasi-instantaneously at a critical coverage reached by molecule incorporation from the second layer. Following this transition, the diffraction pattern is clearly resolved, indicating a long range order in the crystalline monolayer. The rich organization dynamics observed on this model organic/inorganic interface and its dependence on the growth conditions should offer the possibility to produce very high quality organic layers.

### 10h10 - "When bonding makes you stronger" Supported lipid monolayer with unprecedented mechanical and dielectric properties: Application to ISFET sensors

**Volkan Kilinc(1), Tin Nguy(4), Sebastien Lamant(1), Frédéric Brunel(1), Catherine Henry-de-Villeneuve(2), Guillaume Monier(3), Matthieu Petit(1), Yutaka Wakayama(4), Jean-Manuel Raimundo(1), Anne Charrier\*(1)**

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(4) NIMS, Tsukuba, Japan

The development of sensors with low limit of detection and a specificity that can be easily tuned is still a challenge in the field of sensors. We present an original platform constituted of an engineered lipid monolayer which is used as the active sensitive layer and as ultra-thin gate dielectric in field effect transistor sensors. Supported lipid layers, with thicknesses of a few nanometers indeed constitute good candidates. In living cells lipid membranes are known to constitute natural insulators which play an efficient role as barrier to both ionic and electronic transport across the membrane, associated with an electrical resistance of the order of several giga-Ohms in magnitude. However, despite excellent insulating properties, lipid bilayers and even more lipid monolayers have been poorly exploited in devices due to their inherent instability under application of an electric field, leading to damages caused mainly by an electroporation process occurring at low electric field. Furthermore a lack of mechanical stability is often observed. We show that the mechanical and chemical stability of lipid layers as well as their dielectric performances can be improved by changing the molecular structure of the lipids and by achieving intra-chain reticulations within the layer, and that surprisingly both these properties are correlated. In fact such reticulated layers with a thickness of 2.5 nm only present low leakage current even at high electric field, and a direct dielectric breakdown occurring at  $\sim 30$  MV/cm, i.e. much higher than for a silicon oxide layer of similar thickness or other high- $\kappa$  dielectrics. We show that once the lipid

monolayer on the transistor channel the specificity of the sensor given by the grafting of probes to the lipids can be tuned using simple procedure making our sensor extremely versatile.

As a proof of concept, we present here different sensors that were developed for the detection of  $\text{Fe}^{3+}$ ,  $\text{Cu}^{2+}$  and  $\text{Cs}^{+}$  ions using different materials, inorganic transistors with silicon channel and organic transistors with a Poly(3-hethyl)thiophen as channel, and different types of probes.

Our sensors present good specificities with exceptional low limit of detection down to the sub-femtomolar range, high sensitivity and a linear response over several decades. *Langmuir* 26, 2538-2543 (2010). Patent: FR2983637/WO2013083490A1. *Langmuir* 27, 13643-13647 (2011). *J. Phys. Chem. B* 116, 7190-7195 (2012). *J. Mat. Chem. B* 1, 443-446 (2013). *Biosens. Bioelect.* 54, 571-577 (2014). *Anal. Chem.* (88) 3804-3809 (2016). Patent: PCT/EP2016/074569. *Adv. Func. Mat.* 10.1002/adfm.201801024R1 (2018)

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## 11h00 - ZnO nanostructures for photocatalytic applications

**Alessandro Di Mauro, Maria Cantarella, Vittorio Privitera, and Giuliana Impellizzeri**

CNR-IMM, Catania, Italy

Water was taken for granted for centuries, until increasing pollution and reduction of potable water supplies delineated a need to protect our water reserve and develop new technologies to purify water for consumption. In recent years, semiconductor photocatalytic process has shown a great potential as a low-cost, environmental friendly and sustainable water treatment technology. In this field, ZnO is a promising material for its high photocatalytic activity, low cost, and environmental friendliness [A. Di Mauro et al. *Mater. Sci. Semicond. Process.* 69 (2017) 44–51]. The objective of this work has been to find original, easy and industrial scalable methods to synthesize ZnO nanomaterials with significant photocatalytic efficiency. Several ZnO nanostructures have been investigated: ZnO nanofibers realized through the electrospinning process [A. Di Mauro et al. *Nanoscale Res. Lett.* (2015) 10:484]; ZnO nanorods synthesized by chemical reactions; ZnO nanofilms deposited by atomic layer deposition (ALD) [M.E. Fragalà et al. *J. of Photo. and P.biology A: Chem.* 332 (2017) 497–504]. To obtain flexible materials, ZnO deposition by ALD has been performed on polymers, such as PMMA [A. Di Mauro et al. *Ap. Cat. B: Env.* 196 (2016) 68–76], and PEN [A. Di Mauro et al. *Sci Rep.* 2017 Jan 18;7:40895]. All the materials have showed a high photocatalytic efficiency, thanks to the nanostructuration. In order to realize a photocatalytic material selective for the degradation of a specific pollutant, we molecularly imprinted ZnO with paracetamol by the chemical method of co-precipitation. The remarkable photodegradation of paracetamol and the selectivity of the process have been demonstrated. These results evidence that the proposed ZnO nanostructures are promising candidates for photocatalytic applications and, in particular, for novel water treatment.

### 11h30 - Développement of versatile and selective sensor with original dielectric layer on organic semiconductor.

**Volkan Kilinc, Jean-Manuel Raimundo, Anne Charrier**

*CINaM, Aix Marseille Université, CNRS, Campus de Luminy, 13009 Marseille, France*

The fast detection and accurate quantification of ions can bring worth technical information to take early precautions to face out of global environmental pollution. The actual existing spectrometric techniques are not convenient for the accurate specific detection of low ion quantity. To fulfill this problem, we decided to design an original full organic field-effect transistor. The costless full organic design is achieved by using the Poly(3-hethyl)thiophene (P3HT) as a semiconductor channel and PMMA as supporting material. The chemical structure of this semi-crystallin polymer allowed good dielectric properties at low voltage for our sensor. The increased sensitivity of our sensor is brought by the thin dielectric gate made by monolayer lipids. First transistor measurements have showed that the picomolar range can be reachable. With the aim of increasing the mechanical and dielectric stability of the monolayer lipid dielectric gate, two-dimension radical polymerization and siloxane condensation are performed. The AFM indentation measurement of the lipid dielectric gate on P3HT channel showed a mechanical resistance multiplied by 3. The phosphocholine-head lipids are cleaved prior the deposition to allowed the option to add probe and so add a selectivity on our sensor. A new cesium probe calixarene based molecule was well synthesized. Job plot measurement showed a 1:1 stoichiometry toward Cs<sup>+</sup> ion. Association constant determination showed a better selectivity compared to another inhibitor ion such as K<sup>+</sup> and Rb<sup>+</sup>. XPS and FT-IR ATR results confirmed the well-controlled deposition of the several layers of our sensor.

### 11h50 - Tuning the adsorption of organic molecules on stepped Au/Si surfaces

**C. Hogan, S. Suchkova, F. Bechstedt, E. Speiser, S. Chandola, N. Esser**

*Institute of Structure of Matter (ISM-CNR), National Research Council of Italy*

Organic functionalization of semiconductors is an important route towards the development of novel semiconductor-based devices [1]. In contrast to metal surfaces, where weak binding to the substrate facilitates self-assembled monolayer (SAM) growth driven by inter-molecular interactions (e.g. thiolates on gold surfaces), on semiconductors strong covalent bonding to the surface may occur such that layer formation is controlled by the local surface reactivity. One promising template for investigating selective organic functionalization is the metal-stabilized Si surface. In particular, Au adsorption on nominal and vicinal Si(111) leads to formation of regular and highly tunable nanopatterned surfaces consisting of quasi-1D atomic chains of Au and Si. These 1D Au/Si surfaces thus offer unique potential for the formation of organic-metal hybrid nanostructures [2]. Here we present a first-principles DFT study of adsorption of small organic molecules on the stepped Si(553)-Au surface [3], taking into

account different possible adsorption channels. We propose a practical scheme for tuning the local surface reactivity through electronic doping in order to drive selective adsorption, and demonstrate its feasibility using optical reflectivity measurements and atomistic simulations.[4]

[1] S. F. Bent, *J. Phys. Chem. B* 106, 2830 (2002), D. K. Aswal *et al*, *Anal. Chim. Acta* 568, 84 (2006)

[2] F. Zheng, *et al*, *Nanotechnology* 19, 445303 (2008), J. Kautz *et al*, *Surf. Sci.* 632, L18 (2015)

[3] S. Suchkova, C. Hogan, F. Bechstedt, E. Speiser, N. Esser, *Phys. Rev. B* 97, 045417 (2018).

[4] C. Hogan, E. Speiser, S. Chandola, S. Suchkova, J. Aulbach, J. Schäfer, S. Meyer, R. Claessen, and N. Esser (submitted).

## 12h10 - New strategies for producing defect free SiGe strained nanolayers

**Thomas David, Jean-Noël Aqua, Kailang Liu, Antoine Ronda, Marco Abbarchi, Jean-Benoît Claude, Isabelle Berbezier, Luc Favre**

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Strain engineering is seen as a cost-effective way to improve the properties of electronic devices. However, this technique is limited by the development of the Asaro Tiller Grinfeld growth instability and nucleation of dislocations. Two strain engineering processes have been developed, fabrication of stretchable nanomembranes by deposition of SiGe on a sacrificial compliant substrate and use of lateral stressors to strain SiGe on Silicon On Insulator. Here, we investigate the influence of substrate softness and pre-strain on growth instability and nucleation of dislocations. We show that while a soft pseudosubstrate could significantly enhance the growth rate of the instability in specific conditions, no effect is seen for SiGe heteroepitaxy, because of the normalized thickness of the layers. Such results were obtained for substrates up to 10 times softer than bulk silicon. The theoretical predictions are supported by experimental results obtained first on moderately soft Silicon On Insulator and second on highly soft porous silicon. On the contrary, the use of a tensile pre-strained substrate is far more efficient to inhibit both the development of the instability and the nucleation of misfit dislocations. Such inhibitions are nicely observed during the heteroepitaxy of SiGe on pre-strained porous silicon



## 12h30 - Self-assembly of small organic molecules into ordered monolayers for tuning the electrical and optical properties of surfaces

**V. Malytskyi (1,2), Y. Dufil (1), E. Kionga-Kamau (1), V. Gadenne (1), G. Delafosse (1), Y. Ksari (1), J.-J. Simon (1), J.-M. Raimundo (1,2), and L. Patrone (1)**

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Molecular self-assembly (1,2) is one of the most promising strategy for giving surface specific properties with a nanoscale control. An important field of application of self-assembled monolayers (SAMs) (2) is the so-called "molecular electronics" within which self-assembly is a very powerful way to obtain the organization at large surface scale of molecules showing particular electro-optical properties. After the principle of SAM preparation, the motivation of developing SAMs of small organic molecules will be illustrated by some examples of controlling the molecular structuration on silicon surfaces (3,4). How organization at the molecular scale acts on electro-optical properties of molecular chromophores will then be particularly discussed through two examples: a structure-electrical properties relationship probed by STM and spectroscopy (5) where the dispersion of electrical properties has been clearly related to the disorder of the SAM, and the SAM of a novel non-charged push-pull thiophene-based chromophore (6,7). For the latter, dense SAM formation of such non-charged donor-acceptor chromophore, either by direct grafting or by using a sticking monolayer, is for the first time clearly demonstrated by spectroscopy (XPS, UV-vis, IR, SERS), ellipsometry, scanning probe microscopy (STM, AFM), and electrochemical measurements. Besides, good film quality is highlighted and local I-V characteristics measured by STM exhibit electrical rectification. Such I-V curves are correlated to UPS (filled states) and IPES (empty states) measurements and are consistent with the structure of the SAM-organized push-pull molecules standing upright at the surface (6). This unique combination of properties makes such SAM a system of choice for the foreseen applications like in the field of photovoltaic energy conversion with organized and tunable donor / acceptor moieties (8) and optical rectenna (9).

(1) G.M. Whitesides, B. Grzybowski, *Science* 295, 2418 (2002).

(2) A. Ulman, *An introduction to ultrathin organic films* (Academic Press: Boston, 1991) (3) S. Desbief, L. Patrone, D. Goguenheim, D. Guérin, D. Vuillaume, *Phys. Chem. Chem. Phys.* 13, 2870 (2011); S. Desbief, L. Patrone, D. Goguenheim, D. Vuillaume, *RSC Adv.* 2, 3014, (2012); L. Patrone, V. Gadenne, S. Desbief, *Langmuir* 26(22), 17111 (2010)

(4) V. Gadenne, L. Porte, L. Patrone, *RSC Adv.* 4(110), 64506 (2014)

(5) X. Lefèvre, F. Moggia, O. Segut, Y.-P. Lin, Y. Ksari, G. Delafosse, K. Smaali, D. Guérin, V. Derycke, D. Vuillaume, S. Lenfant, L. Patrone, B. Jousselle, *J. Phys. Chem. C* 119(10), 5703 (2015)

(6) V. Malytskyi, J.-J. Simon, L. Patrone, J.-M. Raimundo, *RSC Adv.* 5, 26308 (2015)

(7) V. Malytskyi, V. Gadenne, Y. Ksari, L. Patrone, J.-M. Raimundo, *Tetrahedron* 73, 5738 (2017)

(8) V. Malytskyi, J.-J. Simon, L. Patrone, J.-M. Raimundo, *RSC Adv.* 5, 354 (2015).

(9) C.A. Reynaud, D. Duché, C. Ruiz, U. Palanchoke, F.-X. Dang, L. Patrone, J. Le Rouzo, S. Labau, N. Frolet, C. Gourgon, A. Charaï, C. Alfonso, C. Lebouin, J.-J. Simon, L. Escoubas, *J. Nanoparticle Research* 19, 394, (2017)



## ROOM PORT CROS

### 9h00 - Bottom-up synthesis of graphene nanostructures: from 0D dots, to 1D ribbons, to 2D porous graphene

**Aitor Mugarza**

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Tailoring structural, chemical and electronic properties of graphene confers multiple functionalities to this material, making it attractive to very diverse applications in (opto)electronics, plasmonics, molecular sensing and filtering. For instance, semiconducting gaps can be induced by reducing its dimensions to the nanometer scale, whereas introducing pores of similar sizes turns impermeable graphene into the most efficient molecular sieve membrane. In both cases, the interesting scale for applications is below the ~5 nm limit of top-down fabrication techniques, a regime where bottom-up synthesis can be particularly efficient. Here I will report different on-surface methods to grow graphene quantum dots with controlled shape and edge structure [1,2], periodic arrays of nanoribbons with lengths exceeding 100 nm [3], and nanoporous graphene sheets that combine 1nm size ribbons and pores [3]. The atomically precise nanostructures are characterized by STM, enabling the correlation of novel electronic states with the particular structures. Their potential application in devices is illustrated by gate modulated transport measurements using field-effect transistors based on nanoporous graphene sheets.

[1] A. Garcia-Lekue et al., *J. Phys. Chem. C*, 119 1 (2015).

[2] S. O. Parreiras et al., *2D Mater.*, 4 25104 (2017).

[3] C. Moreno et al, *Science*, accepted.

### 9h30 - Integration of graphene onto silicon surface

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The exciting electronic, mechanical, thermal, and optical properties of graphene have switched on areas of basic and applied research in many fields worldwide.[1] The relatively recent progresses in the characterization of true graphene deposits have allowed a much better interpretation of results in the field, also allowing for a comparison between the outcomes of distinct synthetic strategies.[2] A notable goal in view of studies and applications of graphene is the obtainment of handy forms of this material, allowing for developments in real conditions. To achieve applications, a large-scale production of high quality graphene sheets in an efficient and effective way is required.[3] Wafer-scale integration of reduced graphene oxide with H-terminated

Si[111] surfaces has been recently accomplished by electrochemical reduction of a thin film of graphene oxide deposited onto Si by drop casting.[4,5] Two reduction methods have been assayed and carried out in an aqueous or acetonitrile solution. The resulting interface has been characterized in its surface composition, morphology and electrochemical behavior by X-ray photoelectron spectroscopy, Raman spectroscopy, atomic force microscopy and electrochemical measurements. The results evidence that few-layer graphene deposits on H-Si[111] were obtained after reduction, and use of organic instead of aqueous medium led to a very limited surface oxidation of the Si substrate and a very low oxygen-to-carbon ratio. The described approach is fast, simple, economic, scalable and straightforward, as one reduction cycle is already effective in promoting the establishment of a graphene-Si interface. It avoids thermal treatments at high temperatures, use of aggressive chemicals and the presence of metal contaminants, and enables preservation of Si[111] surface from oxidation.

[1] Ray, S. C. 'Applications of Graphene and Graphene-Oxide Based Nanomaterials'; William Andrew Publishing: Oxford, 2015; pp 1–38.

[2] A.C. Ferrari, A. C.; Meyer, J. C.; Scardaci, V.; Casiraghi, C.; Lazzeri, M.; Mauri, F.; Piscanec, S.; Jiang, D.; Novoselov, K. S.; Roth, S.; et al., *Phys. Rev. Lett.* 97, 187401 [2006].

[3] T. Kuila, S. Bose, A.K. Mishra, P. Khanra, N.H. Kim, J.H. Lee, *Prog. Mater. Sci.* 57, 1061–1105 [2012].

[4] A.G. Marrani, R. Zanon, R. Schrebler, E.A. Dalchiale, 'Toward Graphene/Silicon Interface via Controlled Electrochemical Reduction of Graphene Oxide', *J. Phys. Chem. C* 121 5675–5683 [2017].

[5] A.G. Marrani, A.C. Coico, D. Giacco, R. Zanon, F.A. Scaramuzza, R. Schrebler, D. Dini, M. Bonomo, E. A. Dalchiale, 'Integration of graphene onto silicon through electrochemical reduction of graphene oxide layers in non-aqueous medium', *Appl. Surf. Sci.* 445, 404–414 [2018].

## 9h50 - Innovative Graphene/n-Si heterojunction for photodetectors applications

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In recent years, graphene has been one of the most studied materials for its extraordinary electronic and mechanical properties to exploit in a wide range of applications. In particular, due to its high electrical conductivity and extremely high mobility graphene is a potential candidate for ultra-fast optoelectronic devices. However, due to its high optical transparency, a photodetector based only on graphene would present a very low responsivity. To take advantage of the graphene appealing electronic properties, in this work we present a photodetector (PD) based on graphene/n-silicon heterojunction (GSH). In this device, graphene acts as light transmitter, Schottky junction constituent and photocarrier collector. The back and front side of the n-Si substrates have been provided with metal contacts allowing either top-

down (photovoltaic mode) or three electrodes configurations (photoconductive mode). Graphene has been grown by atmospheric pressure chemical vapor deposition with  $N_2$  as a carrier gas and n-decane as a precursor and transferred through a wet-chemical room temperature process onto the surface of the n-Si substrate. In the photovoltaic configuration, the PDs exhibit an external quantum efficiency (EQE) of 40% ranging from near ultraviolet to near infrared, a responsivity and detectivity of the order of 0.7 A/W and  $10^{13}$  Jones respectively. Under a blue LED on-off light excitation, the junctions show response speed as fast as 4-5  $\mu$ s and Noise Equivalent Power of the order of  $10^{-13}$  W  $\cdot$  Hz $^{-1/2}$ . In the photoconductive mode applying a gate voltage  $V_G$  of only 7 V, the EQE hugely increases from a value of 12% up to 400%. At the same time, all the other characteristics of the detector improve, making it even more competitive. It is worth noting that, under a blue LED on-off light excitation, the time response of such devices is of few hundreds of ns. A comparison will be reported between the behavior under LED and short pulsed laser excitation. The present results are the best among those reported in literature for graphene-based PDs. Finally, most of these PD characteristics are comparable with the commercial ones and this makes the application of GSH devices promising.

## 10h10 - Graphene Heterostructures on SiC: 2D materials towards applications

**Mojtaba Amjadipour 1, Jonathan Bradford 1, Jennifer Macleod 1, Josh Lipton-Duffin 1, Francesca Iacopi 2, Nunzio Motta 1**

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Graphene has attracted a great deal of interest due to its remarkable properties, but as a zero-bandgap semimetal its full potential for next generation electronic devices is yet to be realized. Future applications in nanoelectronics will depend critically on the perfect control of the growth at the nm level and on the development of novel approaches to introduce a bandgap while preserving carrier mobility. Thermal decomposition of SiC has proven to be an excellent method to grow transfer-free wafer-scale graphene, with the advantage of being perfectly integrated to the Si microelectronic industry fabrication process. In this work we present results on two processes that are expected to lead to semiconducting nanostructures on graphene. In the first process narrow SiC mesas fabricated by patterning SiC/Si substrates using Focused Ion Beam (FIB) milling are annealed at 1250°C in UHV to form graphene. Synchrotron radiation spectroscopy and Scanning Tunnelling Microscopy confirm the presence of free standing graphene on the nanostructures after hydrogen intercalation at 600°C. The reduction of the width of the mesas by further patterning to a few nm is expected to produce semiconducting graphene. In the second process lateral graphene/h-BN heterostructures on 6H- and 4H-SiC (0001) are grown by topological conversion of epitaxial graphene on SiC. Graphene can be chemically converted to h-BN upon heated exposure to ammonia (NH<sub>3</sub>) and boric acid (H<sub>3</sub>BO<sub>3</sub>) vapors, and the

concentration of h-BN can be controlled by limiting the reaction time. By x-ray photoelectron spectroscopy (XPS) and scanning tunneling microscopy (STM), we observe the substitution of h-BN domains in the epitaxial graphene layer. The reaction nucleates at defects or functionalized carbon atoms which we confirm by Raman spectroscopy. This technique allows the growth of semiconducting hybrid atomic layers with tunable properties directly on a substrate suitable for device fabrication.

### 11h10 - Electronic interaction between organic molecules and nitrogen doped graphene measured by scanning tunnelling microscopy

**J. Lagoute, V. D. Pham, F. Joucken, C. Chacon, V. Repain, Y. Girard, A. Bellec, S. Rousset**

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Tailoring the properties of graphene is of fundamental interest to uncover new functionalities and open new opportunities for graphene based applications. Among the strategies explored to achieve this goal, substitutional doping obtained by replacing some carbon atoms by foreign atoms has focused tremendous efforts. In this context, nitrogen doping appears to be particularly interesting as it allows to perform n-doping with minor structural perturbations. This chemical doping can also modify the interaction of graphene with external material such as molecules that can be exploited for sensing or catalysis. To probe this effect at the molecular level, scanning tunneling microscopy (STM) and spectroscopy (STS) experiments have been performed on model systems with electron donor (porphyrin) [1,2] and electron acceptor molecules adsorbed on multilayer graphene on SiC(000-1). Local spectroscopy allows to measure resonances arising from the molecular states and to reveal the electronic coupling and charge transfer between the molecules and the graphene. On doped graphene, a local modification of the charge transfer between molecules and graphene occurs at the doping sites. Recent measurements on electron acceptor molecules show a similar local modification of the charge transfer. In addition, the STS measurements also show that the electric field between the tip and graphene can modify the charge transfer. This effect provide a route to tune the electronic interaction between molecules and graphene.

[1] V. D. Pham *et al.*, *ACS Nano* 8, 9403 (2014)

[2] V. D. Pham *et al.*, *Sci. Rep.* 6, 24796 (2016)

## 11h40 - Decoupling Graphene from Ni(111) through the Intercalation of a Chromium Carbide Ultra-Thin Film

**Alberto Brambilla, Andrea Picone, Dario Giannotti, Marco Finazzi, Lamberto Duò, Franco Ciccacci**

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During the last decade, graphene has been stabilized on many single crystal metallic substrates [1]. Among them, the Ni(111) surface represents an ideal template for the epitaxial growth of graphene, because the excellent lattice matching between the two materials promotes the stabilization of large-area and defect-free honeycomb monolayers. However, the hybridization between the Ni d bands and the graphene  $\pi$  states strongly modifies the electronic structure of the latter around the Fermi level. In order to obtain a quasi-freestanding graphene layer, metallic films have been intercalated between graphene and the substrate [2]. In this framework, it is reasonable to assume that an even better decoupled carbon monolayer could be obtained by intercalating insulating compounds such as carbides, oxides or nitrates [3]. Traditional techniques, such as surface exposure to a reactive gaseous environment, are not suitable to stabilize insulating compounds underneath the honeycomb monolayer, because the highly impermeable graphene membrane hinders the chemical reaction between the gas and the metal. Here, we demonstrate that it is possible to grow an ultra-thin Cr carbide between graphene and Ni(111). Auger electron spectroscopy reveals that the deposition of Cr on the graphene/Ni(111) system triggers, upon intercalation of Cr, the segregation of C atoms from the bulk of the Ni substrate, inducing the development of a crystalline Cr carbide at the interface [4]. The atomic structure of the graphene/Cr carbide/Ni(111) system has been investigated by means of Low Energy Electron Diffraction and Scanning Tunneling Microscopy. Moreover, Scanning Tunneling Spectroscopy suggests that the intercalation process restores the linear dispersion of the energy bands characterizing the freestanding graphene.

[1] Batzill, M. *Surf. Sci. Rep.* 2012, 67, 83-115

[2] Voloshina, E. *et al. New J. Phys.* 2011, 13, 113028

[3] Dedkov, Y. *et al. Carbon* 2017, 121, 10-16; [4] Picone, A. *et al. J. Phys. Chem. C* 2017, 121 (31), pp 16803-16809.

## 12h00 - Potential of layered materials for thermionic devices: a first-principles study

**Keivan Esfarjani, Xiaoming Wang, Mona Zebarjadi**

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Solid-state heat to electrical energy conversion is usually done by using thermoelectric materials, which are thought to perform better than thermionic devices. Here, we would like to show that layered materials which are usually bonded by van der Waals interactions, have considerable potential to be used for cooling or heat to electrical

energy conversion, of performance comparable to thermoelectrics. This claim is backed by first-principles calculations. The reason for this good performance is the low cross-plane thermal conductivity of these materials due to their weak bonding. Furthermore the energy barrier for electrons to cross the device can be relatively easily tuned because of the large choice of layered materials of various band gaps and the variation of the bandgap with the number of layers. This implies that the device performance can easily be optimized. We will report results on first-principles calculations of a specific Sc-WSe<sub>2</sub>-(MoSe<sub>2</sub>)<sub>4</sub>-WSe<sub>2</sub>-Sc device. It is found that the equivalent figure of merit can reach 3 at 600K and the cooling efficiency of this device can be as large as 30% of Carnot.

### 12h20 - Global study of self-limited plasma nitridation process for GaAs surface passivation

**G. Monier, H. Mehdi, C. Robert-Goumet, P. E. Hoggan, L. Bideux, V. G. Dubrovskii**

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Preparation of well-cleaned, stabilized and passivated surfaces is of relevant importance for the semiconductor processing and device performance. Indeed the passivation of III-V semiconductor surfaces and, in particular, GaAs is critical in enhancing the performance of devices since the defect states detrimentally affect the electronic and optical properties of the materials (i.e. pinning of the Fermi level and increase of surface recombination velocity). The aim of the present work was to understand the different steps occurring during the self-limited process from the very beginning to the use of the 2D grown GaN layer as surface passivation against air exposure. In this way different studies were carried out. Firstly, Attenuated Total Reflectance-Fourier Transform Infra-Red spectroscopy (ATR-FTIR) investigations during N<sub>2</sub> plasma treatment of GaAs surfaces at 500°C inside an UHV chamber using the high intensity light of SOLEIL synchrotron (SMIS beamline) was performed using DFT normal-mode frequency calculations to assist in the assignment of vibrations involving bonds to nitrogen atoms. Then a new kinetic model was built describing the GaN growth as function of the nitridation time. This model clarifies the exchange mechanism of arsenic with nitrogen atoms at the GaN/GaAs interface and the phenomenon of quasi-saturation of the process. To finish, air exposure influences was followed by AR-XPS exhibiting the high blocking of surface oxidation. Also photoluminescence and electrical measurements are brought to highlight the improving effect of nitridation on device performance.

## 12h40 - Engineering point and extended defects in transition metal dichalcogenides

**Hannu-Pekka Komsa**

*Department of Applied Physics Aalto University, AALTO, Finland*

Two-dimensional (2D) materials such as graphene, hexagonal boron nitride, and transition metal dichalcogenides have recently received lots of attention due to their unique material properties and numerous potential applications. The 2D atomic structure can also facilitate distinct defect formation mechanisms and offer new possibilities for defect engineering. In my talk, I will present the results from layered molybdenum dichalcogenides (MoS<sub>2</sub>, MoSe<sub>2</sub>, and MoTe<sub>2</sub>), where vacancy, substitutional, interstitial, and grain boundary defects are introduced by electron irradiation or by various chemical treatments. Due to the 2D nature, transmission electron microscopy and scanning tunneling microscopy imaging allows direct monitoring of formation and agglomeration of defects as well as of larger structural changes. First-principles calculations are used to provide microscopic insight into the energetics and kinetics of these processes. The gained understanding together with the computationally predicted defect properties can be used to guide future efforts in tailoring the 2D material properties via defect engineering.



## ROOM LEVANT

### 9h00 - Mesoporous Silica Nanoparticles for Drug Delivery Applications

**Freddy KLEITZ**

*Department of Inorganic Chemistry - functional materials, Uni. Wien, Austria*

Over the last decades intensive research has focused on the development of new therapeutics. Unfortunately, many new drugs are difficult to administer directly to patients due to their degradability in biological media and low bioavailability. With the help of nanoparticles as carriers, toxicity and side effects of drugs may be reduced and drug molecules can be more effectively transported into the body. Among the developed nanocarriers, mesoporous silica nanoparticles have emerged as promising materials for drug delivery. Owing to their porosity, they offer the possibility to transport large quantities of drugs into perfused organs via targeting methods (receptor mediated recognition). However, the main challenge for targeted delivery remains the design of optimal carriers that could more specifically bind to and accumulate in the targeted organs or tissues (e.g., tumors). This strategy would provide higher and more selective drug doses, while minimizing nonspecific toxicity and side effects. To achieve this goal, particle size and surface chemistry of the carriers must be carefully balanced and controlled.

### 9h30 - Nanoscale skyrmionic spin textures in magnetic nanostructures and ultrathin films

**Alexander Samardak, Alexander Kolesnikov, Maksim Stebliy, Alexey Ognev, Ludmila Chebotkevich**

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Topologically protected non-trivial spin textures like spin-spirals, skyrmions and skyrmioniums are very promising and attractive nanoscale objects for energy-efficient transfer, processing and storage of information [1]. A skyrmion is a stable magnetic configuration having a small size (10-100 nm), as well as a high propagation velocity ( $\sim 100$  m/s) under the action of low-density currents ( $\sim 1 \times 10^9$  A/m<sup>2</sup>). Due to these features, the skyrmion can be used for a new type of magnetic memory called the skyrmionic racetrack memory. However, the presence of the skyrmion Hall effect, arising due to the topological properties of the skyrmion, limits its use in narrow tracks. Under the influence of the transverse Magnus force, the skyrmion deviates from the longitudinal motion along a nanotrack, which can lead to annihilation of the skyrmion at the track's edge. To solve this problem, several methods have been proposed that can prevent touching the edges and keep the skyrmion inside the track: changing the track's profile through the creation of additional borders (kerbed track), local modification of magnetic properties of a nanotrack, such as perpendicular magnetic anisotropy

(PMA), the Dzyaloshinsky-Moriya interaction or damping constant. All these approaches allow creating a potential barrier that prevents the skyrmion's deviation. Another method is based on the topological compensation for the Magnus effect. Since the direction of the skyrmion's deflection depends on the sign of the topological charge ( $Q$ ), then spin states that have a compensated total topological charge ( $Q = 0$ ) must not deviate. Magnetic configurations consisting of two antiferromagnetically coupled skyrmions with opposite topological charges have been theoretically investigated in ferrimagnets, antiferromagnets, and synthetic antiferromagnets. However, these configurations are difficult to realize and to investigate experimentally, because of the complexity of visualization of the antiferromagnetic domain structure. In ferromagnetic media, a skyrmion-like state with zero topological charge, which is called donut skyrmion or skyrmionium, can be stabilized. A skyrmionium is a skyrmion surrounded by an annular domain wall with the opposite  $Q$ . This spin structure is elastically coupled due to magnetostatic repulsion between the skyrmion and the surrounding domain wall. In this talk, we will present our recent experimental and micromagnetic simulation results on skyrmion and skyrmionium nucleation and stability in the inversion symmetry broken ultrathin films and nanostructures with the interfacial Dzyaloshinskii-Moriya interaction [2, 3]. We explore the possibility of using a skyrmionium to implement the racetrack memory. We propose a new method for the nucleation of the skyrmionium based on a locally enhanced spin-orbit torque effect.

[1]. A. Fert, N. Reyren, V. Cros, *Magnetic skyrmions: advances in physics and potential applications* // *Nature Reviews Materials* 2 (2017) 17031.

[2]. A.G. Kolesnikov, A.V. Ognev, M.E. Steblyi, L.A. Chebotkevich, A.V. Gerasimenko, A.S. Samardak, *Nanoscale control of perpendicular magnetic anisotropy, coercive force and domain structure in ultrathin Ru/Co/W/Ru films* // *Journal of Magnetism and Magnetic Materials* 454 (2018) 78-84.

[3]. A.G. Kolesnikov, M.E. Steblyi, A.V. Ognev, A.S. Samardak, L.A. Chebotkevich, A.V. Sadovnikov, S.A. Nikitov, Y. J. Kim, I. H. Cha, Y. K. Kim, *Spontaneous nucleation and topological stabilization of skyrmions in magnetic nanodisks with the interfacial Dzyaloshinskii-Moriya interaction* // *Journal of Magnetism and Magnetic Materials* 429 (2017) 221.

## 9h50 - Nanostructured silicon with embedded exchange coupled bi-metal structures

**K. Rumpf, P. Granitzer, R. Gonzalez-Rodriguez, J. Coffey, P. Pölt, H. Michor**

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The purpose of this work is to fabricate nanostructured silicon with two different materials of embedded magnetic nanostructures to exploit the magnetic properties of both metals and gain control of the exchange coupling between the two metals especially with respect to their volume ratio. Furthermore a variation of the structure size and the proximity of the metal deposits modify the exchange coupling and thus the energy product. Finally nanocomposites with an energy product as high as possible are achieved to give rise to on-chip applications using permanent nanomagnets, especially arranged in arrays. Magnetic nanostructures of two different metals are deposited within nanostructured silicon to control the magnetic switching behavior of

the silicon/metal nanocomposite. Two different templates, porous silicon and porous silicon nanotubes are utilized to achieve such nanocomposites. The morphology (pore diameter, tube diameter) of the two systems is comparable. In the case of the utilization of porous silicon templates a mesoporous morphology with average pore diameters of 50 nm are used and these oriented and separated pores are filled with two different metals, namely Ni and Co. The two metals are deposited alternately by electrodeposition. A further approach is the chemical growth of Co nanoparticles within porous silicon nanotubes (SiNTs) and the additional deposition of a Ni layer on the outer surface of the tubes. The inner diameter of the silicon tubes is around 50 nm and the wall thickness is about 10 nm. Since the silicon wall of the tubes offers a porous structure the Co particles, which are localized near the pore surface on the wall of a given nanotube, can touch the Ni layer. An alternative structure involves the deposition of an additional Si layer (after the growth of Co particles inside the tubes) as a spacer before the Ni deposition. The morphology of the deposited bi-metal Ni/Co structures is figured out by SEM and EDX. In the presented work the dependence of the magnetic properties of a nanostructured silicon/bi-metal nanocomposite on the volume ratio of the metals, on the proximity of the nanostructures and also on the size of the metal deposits has been figured out. If the distance between the deposited bi-metal structures is small enough magnetic exchange coupling between them is present which could be observed. By tuning the bi-metal deposition an optimized energy product is achieved which gives rise to self-assembled nanocomposite systems containing permanent nanomagnets and arrays of them, respectively for on-chip applications.

### **10h10 - In-depth investigations of self-assembled nanostructured porous layers by ellipsometry porosimetry**

**Jérôme Loizillon, David Grosso**

*NOVA Team - IM2NP – AMU, Marseille, France*

Various ceramics thin films ( $\text{SiO}_2$ ,  $\text{Al}_2\text{O}_3$ ,  $\text{TiO}_2$ ...) can be elaborated on virtually any substrate including silicon, glass or gold from surfactant self-assembly combined with sol-gel process (bottom-up approach). During deposition of precursor liquid solutions (sol), the solvents evaporate, leading to the self-assembly of the surfactants and condensation of the precursors to form a tridimensional network (gel). Finally, after a thermal treatment to remove the surfactants, an organized nanoporous coating is obtained. Depending on the precursor solution and deposition conditions, these nanopores can have multiple shapes, sizes and be connected in various ways, including necks or microporosity. The assessment of this porosity is necessary to understand their interaction with their environment in many applications such as microelectronics, sensors or optics. While SEM and TEM are often used to image nanoporous materials, the samples preparation require a considerable amount of time and work and often involve milling steps that will damage the porous structure. Ellipsometry is a non-destructive spectroscopic characterization in which a polarized beam of light is

reflected on the sample and recovered in a polarization sensitive analyser. The modification of the polarization allows the determination of the refractive index, extinction coefficient, thickness and porosity of thin layers by fitting with theoretical models. Ellipsometry can be combined with an environmental cell to observe in situ the adsorption of solvents, for instance water or alcohols. This technique, called ellipsometry porosimetry, can be used to determine the pore size distribution, the transversal Young's modulus, but can also give critical insights on surface chemistry, pore organization and connectivities which are not easily accessible by other techniques. In this communication, different types of self-assembled porous silica thin layers are investigated by ellipsometry porosimetry. The evolution of the material thickness during the adsorption and desorption of water is used to determine the elastic deformation of the material and deduce its transversal Young's modulus. A new technique, desorption scanning, is also employed to get additional information on the pore connectivities.

### **11h00 - Exchange-Coupled Ferromagnetism in Self-Assembled Co<sub>0.4</sub>Pt<sub>0.6</sub> Nanochessboards**

**Eric P. Vetter, Liwei Geng, Priya Ghatwai, Yongmei Jin, William A. Soffa, and Jerrold A. Floro**

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Eutectoid decomposition of bulk Co-Pt alloys in the A1 phase, with composition near 60% Pt, can result in formation of the unique nanochessboard structure. The nanochessboard represents a self-assembled, 2+1D-periodic stacking of magnetically hard L10 nanorods embedded in a soft L12 matrix, all separated by coherent interfaces. Lateral lengthscales of the chessboard range from 20-40 nm. As such, the chessboard is a fascinating structure in which to examine exchange coupling, of intermediate complexity between epitaxial bilayers and nanocrystalline aggregates. The nanochessboard forms by a pseudo-spinodal decomposition mechanism, rather than classic coupled eutectoid growth. Two key process parameters that govern chessboard formation are the thermal cooling rate used to pass through the A1—L10+L12 eutectoid, and the final temperature reached during the ramp, prior to rapid quenching. At slower cooling rates, 40 °C/day, we varied the final temperature, and performed detailed x-ray diffraction measurements, as well as magnetometry to obtain both M-H loops and first order reversal curves (FORCs). Formation of the hard L10 phase is clearly evident in both the major-loop susceptibilities and in the FORC density plots. The data suggest incomplete exchange coupling between the hard and soft phases, including residual A1, likely due to lengthscales that are slightly too large relative to the hard-phase domain wall thickness. At higher cooling rates, 80 °C/day, however, single-phase behavior is obtained, even though x-ray diffraction confirms the presence of both hard and soft phases. Increases in both coercivity and remanence ratio are observed, relative to the slower-cooled specimens. This results from a reduction in chessboard lengthscale by more rapidly cooling through the eutectoid, resulting in rigid exchange

coupling. Micromagnetics simulations of the nanochessboard elucidate the ground-state magnetic structure, and local mechanisms for magnetization reversal. The simulations reveal unexpected softening if lengthscales are made too small, due to the formation of an effective easy axis. Support of the National Science Foundation through grants DMR-1105336 and DMR-1709914 is gratefully acknowledged.

## 11h30 - Magnetic silicide nanoislands

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Superparamagnetism describes a type of magnetism that takes place in an array of non-interacting ferromagnetic nanocrystals with sizes in the order of a single domain. Though each nanoparticle is ferromagnetically ordered, with all its spin moments aligned to create a superspin, lack of interactions with the neighbor nanocrystals in the array destroys ferromagnetic alignment between the superspins in the absence of external magnetic field, much like between the atomic spins in a paramagnet. However, we have recently realized, that superparamagnetic nanoparticles can be made of non-ferromagnetic materials, to begin with. For example, silicides are not normally considered ferromagnetic materials, let alone the Si-rich ones. Hence in this work, we used two kinds of Si-rich epitaxial binary silicide nanostructures as a model system – transition metal silicides (TMS) and rare-earth silicides (RES). The vast majority of binary TMS lack ferromagnetic order in the bulk, whereas binary RES are usually weak ferromagnets or antiferromagnets. Yet both groups show increased in-plane magnetic ordering in low-dimensional nanostructures, in particular at low temperatures, characterized by a sizeable opening of the ferromagnetic hysteresis loop. The origin of this surprising phenomenon lies at undercoordinated atoms at the nanostructure extremities, such as 2D (surfaces/interfaces), 1D (edges) and 0D (corners) boundaries. It will be demonstrated that uncompensated superspins of edge atoms increase the nanostructure magnetic shape anisotropy to the extent where it prevails over its magnetocrystalline counterpart, thus providing a plausible route towards design of a magnetic response from nanostructure arrays in Si-based devices, such as bit patterned magnetic recording media and spin injectors.

*Goldfarb et al. Phys. Rev. B 96, 045415, 2017.*

*Goldfarb et al. Adv. Mater. 2018 (in press).*

## 11h50 - Chirality phase diagrams for Single-Walled Carbon Nanotubes

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Since 25 years, significant progress has been achieved in the controlled synthesis of Single Walled Carbon Nanotubes (SWNTs), but we are still facing difficult issues concerning the yield and selectivity of their synthesis by Catalytic Chemical Vapor Deposition. The choice of a catalyst is critical, and hitherto made by trial and error. In fact, we don't know what are the required properties of a "good" catalyst for a selective SWNT growth. Here, we answer this question by developing a statistical thermodynamics model, that in the case of a perpendicular growth[1,2], enables to relate the stable (n,m) tube structure, to the tube/catalyst interfacial energies for zigzag ( $E_{int}^Z$ ) and armchair ( $E_{int}^A$ ) edges and the temperature. This model shows that, at low temperature, only zigzag or armchair tubes should be stable. Chiral tubes become stable at higher temperature because of the configurational entropy of the tube edge, that is indeed the key element of the model. This enables to produce chiral stability maps or "chirality phase diagrams" displayed in that enables to understand under which conditions, a near armchair distribution can be obtained, and accounts for the temperature evolution of the chiral distributions reported in a number of experiments. The model[3], its relevance, usefulness, implications on our understanding of SWNT growth mechanisms, and possible improvements will be discussed.

[1] Fiawoo, M.-F. C. et al. *Phys. Rev. Lett.*, 108, 195503 (2012).

[2] He, M. et al. *Nanoscale* (2018). doi:10.1039/C7NR09539B

[3] Magnin, Y. et al. *Entropy driven stability of chiral single-walled carbon nanotubes*. Submitted. <https://arxiv.org/abs/1803.07350>

## 12h10 - Increasing efficiency of single walled carbon nanotube/n-Si photodetectors

**M. Salvato, M. Scagliotti, F. De Matteis, P. Proposito, M. De Crescenzi and P. Castrucci**

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A renewed interest in carbon nanotube (CNT) thin films emerged in the last decade for photovoltaic applications. Thanks to their characteristics of optical transparency and electrical conductivity, CNT thin films were successfully considered as front windows for semiconducting based solar cells with the double purpose of charge collection and light transmission. More recently, CNT thin films have been used as semitransparent front electrode in semiconducting based photodetectors showing performances approaching the commercial level. Here we report on single walled (SW) CNT/Si photodetectors and the possibility to enhance their performances by operating on the electrical contacts and applying an external gate voltage. The SWCNT thin films were



obtained by a low vacuum filtration process and dry transferred on the top surface of a n-doped Si substrate by a printing method. Both the top and the bottom surfaces of the n-Si substrates were provided with metallic electrodes of different geometry which allowed to study the CNT/Si photodetector properties both in photovoltaic and photoconductive mode. The as obtained samples measured in photovoltaic mode showed responsivity and detectivity of the order of 1 A/W and  $10^{14}$  Jones respectively, noise levels of the order of  $10^{-14}$  W $\cdot$ Hz $^{-1/2}$  and external quantum efficiency (EQE) of the order of 10% in the whole visible wavelength range. Moreover, using nanosecond laser pulses as light source, time response as short as few tens of nanoseconds were measured. A systematic study of these parameters was performed by changing the number of top electrical contacts which delivers the photogenerated charges to the external circuit and by applying a gate voltage through the bottom contact of the Si substrate. The obtained results showed an improvement of the responsivity and detectivity of a factor of two by increasing the number of the top electrical contacts without affecting consistently the noise. Moreover, the time response resulted to be shortened by increasing the number of top contacts and an increase of the EQE up to 120% was measured when a gate voltage of 20 V was applied. All these results make our devices competitive with the commercial ones with the advantage that the fabrication process does not employ high vacuum techniques as well as high temperature processes as in traditional semiconducting devices. The high sensitivity and fast response of these devices pave the way to the possible development of new optoelectronic devices based on nanomaterials with characteristics similar to SWCNT thin films.

### 12h30 - Biocompatible submicron fibers obtained by electrospinning

**Elena Matei, Alex Evanghelidis, Mihaela Beregoi, Victor Diculescu, Ionuț Enculescu**

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Electrospinning represents one of the few methods which allow fabrication of submicronic structures, fibers in this case, in industrial quantities. Simple and relatively easy to scale – up electrospinning can be used for biocompatible materials leading to interesting applications for pharmaceutical and medical devices industries. We developed different algorithms for developing devices based on electrospun fibers. In order to do this we functionalized the electrospun fibers with different materials, including here thin metal films for electrical conductivity, conducting polymers for electroactivity, metal oxides for sensing or hydrogels. Devices with different functions were obtained, the path being, in our opinion a very promising one for a wide range of applications.



## 12h50 - Nanostructured LaFeO<sub>3</sub> /YSZ thin films as mixed potential gas sensor

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Mixed potential sensors for detecting harmful gases belong to the group of chemical sensors, in which chemical information coming from the environment is converted into a signal. The gas sensing mechanism in electrochemical sensors relies on the electrochemical catalytic reaction at the interface between the solid electrolyte and the sensing electrode. The microstructure of the sensing electrode (surface, porosity, thickness) and the interface can have a significant effect on the sensor response. The sensing electrode is a perovskite LaFeO<sub>3</sub> layer, obtained by Pulsed Laser Deposition (PLD), a technique known to produce stoichiometric, thin, polycrystalline films with good adhesion. As solid electrolytes, we used two different substrates: yttrium stabilized zirconia YSZ, cubic and tetragonal, each one [100] oriented. For comparison, layers were also deposited on Si [100]. The crystallographic structure, texture, roughness and microstructure of the perovskite layers were investigated by XRD, SEM, AFM, TEM and HREM, for the different substrates and for different deposition temperatures.

Depending on the substrate temperature during the deposition, and on the substrate, we obtained different nanostructured thin films. In the PLD process, for one given substrate, the grains growth and hence the final surface is mainly governed by the substrate temperature and the gas pressure in the deposition chamber. The nanostructuration may be linked to competition between different growth mechanisms occurring simultaneously under our deposition conditions. When the surface diffusion is not sufficient, at low temperature, the film roughness is high. The increase of the deposition temperature led to a decrease of the layer roughness, and to the formation of columnar structures. The morphology of the layer depends also on the substrate, and LaFeO<sub>3</sub> layers deposited on YSZ tetragonal exhibit different features, and columnar grains grew with (101) or (020) planes parallel to the substrate. The irregular droplets of nanometric size on the surface are also crystallized in the LaFeO<sub>3</sub> structure. They are due to the overheating of the target surface, which can lead to phase explosion phenomena, and the deposition of clusters.

## ROOM PORT CROS

### 9h00 - Gas phase synthesis of metal@oxide, core@shell nanoparticles: a bottom-up approach for new material functionalities

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Synthesis, study and applications of NanoParticles (NPs) have been playing a major role in material science and technology over the last 20 years, although some important examples of NP presence in manufactured goods can be dated back to ancient history [1]. Realization of NPs with chemical methods is nowadays mainstream, because of the cost effectiveness and scalability. Nevertheless, physical synthesis with a bottom-up approach presents some advantages, especially when a “fine tuning” of the NP properties is required. Physical synthesis can be single-step and ligand-free, and these characteristics can result in a more accurate analysis of the NP structure and of their electronic and magnetic behavior. During the last years we developed a laboratory for the NP synthesis with a magnetron based gas aggregation source and a quadrupole mass filter. The versatility of the NP source allowed us to prepare and study different types of NPs. Moreover, co-deposition and sequential layer deposition methods have been used to obtain core@shell NPs. These methods gave us the possibility of realizing non-native oxide shells [2], and to investigate metal@metal oxide core@shell NPs by varying independently the core diameter and the shell thickness. Two case studies will be reported: • An investigation of structure and magnetic properties of Ni@NiO and Ni@CoO NP films, as model systems for exploiting the exchange bias effect to “beat the superparamagnetic limit” [3,4]; • The change of redox properties of CeO<sub>x</sub> NPs induced by controlled variations of the physical properties in the synthesis procedures (defect distribution, NP size and shape etc.), of potential interest in catalysis and fuel cell production [5, 6].

[1] D.J. Barber and I. C. Freeston, *Archaeometry* 32 (1990) 33.

[2] S. D'Addato and M. C. Spadaro, *Phys. Scr.* 93 (2018) 033001 (Invited Comment).

[3] J. A. De Toro et al., *Phys. Rev. Lett.* 115 (2015) 057201.

[4] A. Ponti et al., *Phys. Rev. Materials* 1 (2018) 036601

[5] M. C. Spadaro et al., *Nanotechnology* 27 (2016) 425705.

[6] S. J. P. Cresi et al. *Nanotechnology* 28 (2017) 495702.

### 9h30 - Magnetoresistance effects in self-assembled chemically-synthesized metallic ferromagnetic nano-objects – Influence of surface chemistry

**R. P. Tan, C. Desvaux, J. Dugay, A. Meffre, J. Harmel, L.-M. Lacroix, J. Carrey, K. Soulantika, B. Chaudret, M. Respaud**

*Laboratoire de Physique et Chimie des Nano-Objets, Toulouse, France*

Chemical synthesis is a powerful way to control the size, shape and anisotropy of metallic magnetic nanoparticles (MNPs) stabilized by tuneable organic tunnel barriers. These tailored MNPs open new opportunities in spintronics related to their Coulomb blockade properties, including the fields of magnetization switching by spin transfer. Moreover weak spin-orbit interactions in organic molecules should preserve spin-coherence better than conventional materials. Thus, the versatility of chemical routes to elaborate hybrid nanostructures makes the fabrication of all-chemistry-made spintronic devices highly desirable. Here, we report on magnetoresistance (MR) effects in networks of chemically synthesized metallic ferromagnetic nano-objects. When integrating Fe nanocubes (size of 9-11 nm) stabilized by a mixture of hexadecylamine hexadecylamonium chloride, electrical properties, featuring Coulomb blockade, and magnetotransport measurements show that this MR arises from spin-dependent tunnelling. The MR persists up to room temperature. So, the organic ligands that stabilize the nanocubes are efficient spin-conservative tunnel barrier. The high reactivity of the Fe surface allowed us to decompose  $\text{Fe}(\text{CO})_5$ , leading to Fe/FeCx core shell nanoparticles with less controlled surface chemistry. This led to the disappearance of the low field tunneling MR effect. Finally, the integration of metallic Co nanorods (diameter of 6nm and 70-80nm long) with high magnetic anisotropy, stabilized by a mixture of hexadecylamine and palmitic acid, allowed us to observe anisotropic magnetoresistance effect. These results demonstrate the feasibility of an all-chemistry approach for room temperature spintronics. They evidence the key role played by the surface chemistry, and the necessity to develop elaboration and integrations routes that control and preserve the surface magnetism.

### 9h50 - Photo-structuration at nanoscale of a composite material doped with magnetic NP: towards magneto-photonic devices

**Clémentine Bidaud [1,2], Olivier Soppera [1,2], François Royer [3], Damien Jamon [3], Sophie Neveu [4], Emilie Gamet [3], Dominique Berling [1,2]**

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Structuration of magnetic materials as well as their integration on photonics platforms is still a challenge. Indeed, classical magneto-optical (MO) materials, such as garnet oxides, require specific substrate and high thermal budget to be efficient, and their micro-structuration generally requires long and expensive techniques. In this work, we propose a new composite material that possesses MO properties and can be nanostructured by a single step through photo-lithography. It is based on a sol-gel matrix doped with magnetic nanoparticles (MNP). Cobalt ferrite  $\text{CoFe}_2\text{O}_4$  MNP have been chosen for their good MO properties: in particular, a high Faraday rotation at 1.5  $\mu\text{m}$ . Thanks to its formulation flexibility, the sol-gel chemistry is a powerful way to develop new functional materials. The sol gel matrix is prepared from inorganic precursors

(mainly Si and Ti alkoxydes). The first challenge of this composite approach lies in the incorporation of crystalized MNP into the photostructurable host matrix in a randomly dispersed regime. Thanks to an appropriate stabilization of these NPs in acidic medium, the matrix can be doped up to 20 %vol, and exhibits a MO Faraday rotation of  $3500^\circ/\text{cm}$  at 1500 nm. Such value is of the same order than that of garnet oxides at this wavelength, showing the good MO potentiality of this composite. Depending on the amount of MNP in the matrix, its refractive index value varies from 1.51 to 1.67. Moreover, this MNP doped matrix has been nanostructured as a grating through direct Deep UV laser writing process, without post-annealing. The preparation of such structures with a sub-micrometer resolution (500 nm periodicity) is achieved at low power ( $37 \text{ mW}/\text{cm}^2$ ), and hence does not necessitate an important income of energy and any curing. The modulation depth reaches 150 nm for a thickness of about 300 nm. Our composite approach combined with a single step, room-temperature photostructuration is very promising. The versatility of this material allows the control of the NP content (thus, the refractive index), as well as the structuration. This can lead to functional magneto-photonics devices, integrated on glass chips or used in free space applications, with enhanced MO properties based on resonance phenomena.

### **10h10 - Three Dimensional design of silver nanoparticle assemblies embedded in dielectrics: application to plasmon-enhanced scattering and charge transfer in few-layer graphene**

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The localized surface plasmon-polariton resonance (LSPR) of noble metal nanoparticles (NPs) is widely exploited for enhanced optical spectroscopies of molecules, photothermal therapy, photovoltaics or photocatalysis. In the visible range, the most efficient metal for electromagnetic field enhancement is silver. Recently, a strategy to design and fabricate hybrid metallic-dielectric substrates for optical spectroscopy and imaging has been proposed. Different architectures consisting of tri-dimensional (3D) patterns of silver nanoparticles (AgNPs) embedded in dielectric layers are conceived to simultaneously exploit the LSPR and optical interference phenomena. These architectures are fabricated by low energy ion beam synthesis and consist of AgNPs with controlled characteristics, and embedded in transparent dielectric thin films. By forming 2D arrays (planes), these NPs can be located at nanometric distances from the dielectric surface. The dielectric matrix protects the particles from aging (oxidation) and maintains the surface planarity. In this work we will show that this technique allows the 3D control of these systems: an additional organisation in the plane of these nanoparticles is indeed possible by implanting through masks. Hence, a smart design at 3 scales/3 dimensions ("3S-3D") can be obtained. The dielectric thickness is chosen in order to have an antireflective layer and a maximum of electric field at the surface. The

double role as embedded plasmonic enhancer and charge carrier reservoir of this single plane of metallic nanoparticles has been tested on few-layer graphene (FLG) located in dedicated areas at a controlled nanometer distance from these NPs. Optical imaging, reflectance and Raman scattering mapping are used to measure the enhancement of electronic and vibrational properties of these layers. In particular electronic Raman scattering is shown as notably efficient to analyze the plasmon-assisted transfer of charge carriers between the two sub-systems (AgNPs and FLG) and the role of intrinsic and extrinsic defects.

## 11h10 - Self-Assembly of Janus Nanoparticles

**Andrei Honciuc, Chengjun Kang**

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Asymmetric Janus nanoparticles (JNPs) have attracted significant interest for their enhanced interfacial activity as compared homogeneous nanoparticles (HNPs), which makes them attractive for a plethora of new applications, such as Pickering emulsions.<sup>1</sup> In addition, due their inherent amphiphilicity they are capable of self-assembly into suprastructures and could become a platform for designing of new reconfigurable materials. Computer simulations demonstrate a rich potential and most diverse landscape of suprastructures that can be obtained from JNPs, but experimental work is lagging behind. In this work we show that snowman type JNPs are capable of self-assembly into a variety of structures, from micelles, to capsules, bilayers and giant mono-walled vesicles.<sup>2,3</sup> Some of these suprastructures find their equivalent in self-assembled structures produced by molecular surfactants, but some are you unique to JNPs. These key differences between molecular surfactants and JNPs will be discussed and compared. The structural diversity of self-assembled structures can be controlled by tuning the parameter of the JNPs, such as size, phase separation, relative ratio between the Janus lobes, etc. Even more, the obtained self-assembled suprastructures can be reversible transformed into other types of structures by controlling the self-assembly conditions, such as temperature, shear or solvent concentration. We believe this to the richest self-assembly scenario shown by snowman type JNPs to date.

(1) Wu, D.; Honciuc, A. *Design of Janus Nanoparticles with PH-Triggered Switchable Amphiphilicity for Interfacial Applications*. *ACS Appl. Nano Mater.* 2018, 34 (3), 1225–1233.

(2) Kang, C.; Honciuc, A. *Influence of Geometries on the Assembly of Snowman-Shaped Janus Nanoparticles*. *ACS Nano* 2018, DOI: 10.1021/acsnano.8b00960. (3) Kang, C.; Honciuc, A. *Self-Assembly of Janus Nanoparticles into Transformable Suprastructures*. *J. Phys. Chem. Lett.* 2018, 1415–1421.

## 11h40 - Direct and selective detection of bacteria using surface-enhanced Raman Scattering (SERS) imaging

**Cristina-Cassiana Andrei<sup>1</sup>, Anne Chantal Gouget-Laemmel<sup>1</sup>, Anne Moraillon<sup>1</sup>, Rabah Boukherroub<sup>2</sup>, François Ozanam<sup>1</sup> and Sabine Szunerits<sup>2</sup>**

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Rapid and accurate detection of pathogens is a major challenge in many areas including health, food safety or military applications. In the past decades the interest on miniaturization and development of biochips for detection of bacteria is continuously increasing. The advantages are multiples: simple handling, small amount of samples, reduced assay time etc. [1] Different methods with good sensitivities were already developed, such as fluorescence (indirect method), Electrochemical Impedance Spectroscopy or Surface Plasmon Resonance (direct methods). As far none of them are able to verify the nature of pathogens interacting with the probes or to identify their strains. We aim to develop a new architecture of biochip and to use Surface-enhanced Raman Scattering (SERS) imaging for the direct and multiplex detection of pathogens. This technique offers the possibility to work in aqueous media (since water is a weak Raman scatterer) [2], provides selectivity due to spectroscopic fingerprint and high sensitivity generally by an enhancement of the electromagnetic field in the proximity of nanostructured metal surfaces. In this presentation, we will describe our biochip designs which are mainly based on amorphous silicon-carbon alloy  $\alpha$ -Si<sub>1-x</sub>C<sub>x</sub>:H and plasmonic nanostructures. Briefly, the  $\alpha$ -Si<sub>1-x</sub>C<sub>x</sub>:H layer allows the reproducible fixation of different probes (mannosides or antibodies) via robust covalent Si-C bonds [3] and the plasmonic nanostructures are responsible for the exaltation of Raman signal of the targets. The focus will be on the study of various plasmonic nanostructures based either on gold and/or silver layers deposited by thermal evaporation on glass (with/without annealing; (un)covered with  $\alpha$ -Si<sub>1-x</sub>C<sub>x</sub>:H) or based on nanoparticle colloids. Their effects on the Raman signal will be presented for the well-studied Rhodamine B and for two different bacteria Gram- (Escherichia coli) and Gram+ (Staphylococcus aureus). keywords : biochip, bacteria, amorphous silicon carbon alloy, gold/silver nanoparticles, SERS

[1] H. Zhou et al., *Anal. Chem.* 2014, 86, 1525-1533

[2] M. Knauer et al., *Anal. Sci.*, 2010, 26, 761-766

[3] J. Yang et al., *Anal. Chem.* 2014, 86, 10340-10349



## 12h00 - Tuning the gold nanoparticle coordination and bioeffects by exposure to green light

**D. A. Pricop<sup>1</sup>, R. V. Lupusoru<sup>3</sup>, L. Ursu<sup>2</sup>, A. Arvinte<sup>2</sup>, C. Uratu<sup>2</sup>, F. Doroffei<sup>2</sup>, M. Toader<sup>4</sup>, L. Oprica<sup>5</sup>, G. Bulai<sup>1</sup>, D. E. Creanga<sup>1</sup>, F. Iacomi<sup>1</sup>**

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The design and study of gold nanoparticles (GNPs) exhibiting enhanced photophysical properties are of great interest due to their large applications. In this study, we analyse the influence of irradiation conditions with green light on GNPs coordination and their bioeffects. The nanoparticle structure and the change in the nanoparticle shape and surface functional groups were investigated by using UV-Vis, TEM, XRD, FTIR, Raman and XPS technics. Their catalytic properties were checked by investigating their eletrochemical properties and bioeffects on environmental fungi. It was established that light exposure offers a versatile tool to adjust catalytic activity of GNPs before supplying to fungal cells and increase their stability [3,4].

[1] J. R.G. Navarro, F. Lerouge, *Nanophotonics* 2017; 6(1): 71–92.

[2] H. E. Toma, V. M. Zamaron, S. H. Toma, K. Araki, J. Braz. Chem. Soc., 2010, 21(7):1158-1176.

[3] M. Andries, D. Pricop, L. Oprica, D. E. Creanga, F. Iacomi, *Int. J. Pharm.* 2016 505(1-2):255-261.

[4] R.V. Lupusoru, D.A. Pricop, M. Andries, D. Creanga, *J. Molec. Struct.* 2016 1126:192–199.

## 12h20 - Functionalized silver nanoparticles for mercury(II) detection in water

**Federico Mochi<sup>1</sup>, Paolo Proposito<sup>\*1</sup>, Mauro Casalboni<sup>1</sup>, Fabio De Matteis<sup>1</sup>, Stefano Casciardi<sup>4</sup>, Ilaria Fratoddi<sup>2</sup>, Iole Venditti<sup>\*3</sup>, Chiara Nicolafrancesco<sup>3</sup>, Giovanna Iucci<sup>3</sup> and Chiara Battocchio<sup>3</sup>**

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In these years the silver nanoparticles are arousing great interest from the scientific community due to their excellent chemo-physical properties, such as the surface plasmon resonance band (SPRB), antibacterial activity and versatile synthesis. For these reasons they are widely used in various technological fields, such as sensors, biotechnology and optoelectronics. [1-3] In the present study, functionalized AgNPs synthesized in water phase [1] were tested in presence Hg(II) in water solution to study their applications as environmental nanosensors. For high Hg(II) concentration (5 ppm), we found a consistent modification of the SPR spectral change confirming the interaction between AgNPs-Hg(II). The response to mercury ions was clearly detectable up to 0.1 ppm of contaminant. This interaction was investigated by using techniques such as Uv-vis, FTIR and XPS spectroscopies, dynamic light scattering (DLS) and electron



microscopy (TEM). Moreover, the functionalized AgNPs showed good response to Hg (II) in water solution also in presence of several different heavy metals ions, and presented good selectivity and sensibility properties for its detection in the working range of 5.0–0.1 ppm.

1. P. Proposito, F. Mochi, E. Ciotta, M. Casalboni, I. Venditti, L. Fontana, G. Testa, I. Fratoddi; *Beilstein J. Nanotechnol.* 7 (2016) 1654-1661

2. F. Porcaro, C. Battocchio, A. Antoccia, I. Fratoddi, I. Venditti, S. Moreno, I. Luisetto, M.V. Russo, G. Polzonetti; *Colloids and Surfaces B: Biointerfaces* 142 (2016) 408-416

3. I. Fratoddi, R. Matassa, L. Fontana, I. Venditti, G. Familiari, C. Battocchio, E. Magnano, S. Nappini, G. Leahu, A. Belardini, R. Li Voti, C. Sibilia; *J. Phys. Chem. C*, 121 (2017) 18110 -18119

## 12h40 - Silver nanoparticles-based nanocomposites for biosensing using the “spectro-inside” concept

**A. Scarangella, C. Bonafos, M. Soumbo, A. Mlayah, A. Pugliara, R. Carles, E. Navarro, M.-C. Sancho, M.-C. Monje, C. Roques, K. Makasheva**

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Protein adsorption on solid surfaces is of interest for many industrial and biomedical applications, where it represents the conditioning step for micro-organism adhesion and biofilm formation. In this context, nanomaterials, such as silver nanoparticles (AgNPs)-based nanocomposites, became components for bioanalytical devices, since they provide excellent way to study complex biological systems and appear well adapted for quantification of the conformational changes of bio-targets brought in contact with solid surfaces. This is made possible by the exploitation of the AgNPs antenna effect that clearly enhances the biosensing performances in terms of sensitivity and detection limits down to a single molecule. Besides, silver species possess very high antimicrobial activity yet presenting very little systemic toxicity toward humans. Since the AgNPs are in direct or indirect contact with bio-targets, a comprehensive study of the proteins/AgNPs interactions is mandatory. In this work we propose the use AgNPs as plasmonic antenna when embedded close to the free surface of thin silica layers and as toxic agents towards proteins/microorganisms. The nanocomposite structures were realized by two complementary approaches: (i) low energy ion beam synthesis and (ii) combined sputtering and plasma polymerization process, both allowing fabrication of a single layer of AgNPs embedded in SiO<sub>2</sub> films at controlled nanometric distances from the free surface. Their structural and optical properties were studied by TEM and by ellipsometry or optical reflectance spectroscopy, respectively. The short-term toxicity of embedded AgNPs to photosynthesis of the green algae *Chlamydomonas reinhardtii* was exploited using fluorometry to determine the bio-available silver release. The coupling of AgNPs and Discosoma red fluorescent proteins (DsRed), that displays exceptional photostability, is proposed as an appropriate system to detect and analyze the adhesion mechanism of bio-targets on solid surfaces. For this purpose, the optical properties of protein thin films deposited on the plasmonic substrates were studied after dehydration, evidencing that the DsRed proteins preserve their natural state after adsorption on the

nanocomposite surface. The results coming from the analysis of DsRed Raman spectra, only visible due to the SERS effect, show that DsRed proteins undergo conformational changes and make these AgNPs nanocomposites good candidates for biosensing applications.

## ROOM LEVANT

### 9h00 - Optical Spectroscopy at High Spatial Resolution with Fast Electrons

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Optical spectroscopy is traditionally performed using photon excitation (with a laser beam, for example). Typical emission experiments allow one to gather information of the different energy levels available in the system by measuring the intensity of the emitted light as a function of wavelength/energy. In a confocal optical microscopy setup, the ultimate spatial resolution is limited by the size of the detection volume (of the order of half a micrometer). In this contribution, we will discuss the benefits and difficulties of performing optical spectroscopy using fast electrons as the excitation source (either in emission, using cathodoluminescence, [2], or absorption, by measuring electron energy loss, [3]). Much higher spatial resolution (from tens of nanometers to below a nanometer) is the evident attraction. Indeed, advances in electron optics (aberration correctors, monochromators and spectrometers) and improvements in electron microscope instrumentation (stages with cryogenic temperatures, including light collection systems) have brought electron spectroscopies closer to the energy resolution and detection sensitivity of standard optical spectroscopies. To start with, we will describe cathodoluminescence (light emission from a material excited by electrons) experiments aimed at understanding exciton physics in two different systems: GaN quantum disks in AlN nanowires and hBN flakes. In the first system, we will discuss how the internal electric field present in the material influences light emission through energy band bending due to quantum confined Stark effect [4], brought by the heterostructure internal electric field. In Figure 1, a wavelength shift of 2 nm (22 meV) occurs due to the shielding of the internal field in a 1.5 nm wide (6 monolayers) quantum disk. This energy resolution is a factor of 15× better than that available in traditional electron energy loss experiments, but of the order of what is possible today with modern monochromators, as described later. For hBN, the influence of crystal stacking order on exciton emission energy [5] will be analyzed. A defect-related emission observed in the energy band gap of hBN has been identified using cathodoluminescence as a new single photon source emitting in the near UV range [6,7]. For 2D materials, excitons may also be probed using electron energy loss (EEL) spectroscopy. We will quickly revisit how an EEL spectrum is a direct measurement of  $\epsilon_2$  (imaginary part of the dielectric function), using hBN [8] as an example, which will be contrasted to cathodoluminescence experiments. Furthermore, current improvements in EELS energy resolution brought by new monochromators (energy resolution in the 5-30 meV range) give access to experiments in the optical range. To demonstrate this new possibility, we will analyze how the exciton absorption changes across the interface of a MoS<sub>2</sub>/MoSe<sub>2</sub> monolayer [9], showing that high spatial resolution (of the order of tens of nanometers) is still possible. Finally, we will discuss our perspectives for experiments with new generation electron monochromators.

- [1] M Kociak and O Stéphan, *Chem. Soc. Rev.* 43 (2014) p. 3865.  
[2] LF Zagonel et al, *Nano Lett.* 11 (2011) p. 568.  
[3] J Nelayah et al *Nat. Phys.* 3 (2007) p. 348.  
[4] LF Zagonel et al, *Phys. Rev. B* 93 (2016) p. 205410.  
[5] R Bourrellier et al *ACS Photon.* 1 (2014) p. 857.  
[6] LHG Tizei and M Kociak *Phys. Rev. Lett.* 110 (2013) p. 153604.  
[7] R Bourrellier et al *Nano Lett.* 16 (2016) p. 4317.  
[8] Z Liu et al *Small* 12 (2016) p. 252.  
[9] LHG Tizei et al *Phys. Rev. Lett.* 114 (2015) p. 107601.

## 9h30 - TERS Imaging of CdSe Quantum Dots on Nanostructured Au Surfaces

**A.G. Milekhin<sup>1,2</sup>, M. Rahaman<sup>3</sup>, T.A. Duda<sup>1</sup>, E.E. Rodyakina<sup>1,2</sup>, A.V. Latyshev<sup>1,2</sup>, D.R.T. Zahn<sup>3</sup>**

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We present the results of a tip-enhanced Raman scattering (TERS) study of CdSe quantum dots (QDs) on nanostructured plasmonic Au surfaces with nanometer spatial resolution.

Commercial surface-enhanced Raman scattering (SERS) substrates (Klarite) and Au nanocluster arrays were used to realize gap-plasmon TERS by optical phonons in CdSe QDs. Klarite substrates consist of arrays of inverted pyramids in Si covered with Au nanoclusters with a size of 50-100 nm. Arrays of Au nanoclusters with a size of about 80 nm on a Si substrate were fabricated using nanolithography.

The SERS substrates were covered by sub-monolayers of CdSe QDs with a size of 5-6 nm using the Langmuir-Blodgett technology. The structural parameters of plasmonic and semiconductor nanostructures (size and morphology of QDs and Au nanoclusters) were determined by means of scanning electron and atomic force microscopies (SEM and AFM). The energy of the localized surface plasmon resonance in the SERS substrates is located in the visible spectral range and depends on the size and morphology of Au nanoclusters.

We observed a giant plasmonic enhancement of the Raman scattering by longitudinal optical (LO) phonons in CdSe QDs (near 214 cm<sup>-1</sup>) placed in the gap between the TERS tip apex and Au nanoclusters. Additional features at 230-250 cm<sup>-1</sup> evidence the formation of Se nanoclusters due to photodegradation of CdSe QDs. TERS maps for the LO phonon mode in CdSe QDs deposited on Au nanostructures were obtained with a spatial resolution down to 2.3 nm [1]. The comparison of AFM and TERS images confirms the local distribution of the electromagnetic (EM) field intensity calculated in [2,3]. The maxima of the EM field are located at the corners of the inverted pyramids of a Klarite substrate and at the top of the Au nanoclusters in the arrays. The giant Raman enhancement of  $5.6 \cdot 10^8$  allows the observation of the Raman response from single CdSe QDs.

The reported study was funded by Volkswagen Foundation and RFBR according to the research project № 18-02-00615.

1. A.G. Milekhin et al. // *Nanoscale* (2018) in print, DOI: 10.1039/C7NR06640F

2. N.M. B. Perney et al. // *Optics express*, 14 (2006) 847-857

3. D. Meneses-Rodríguez et al. // *Small*, 7 (2011) 3317-3323

## 9h50 - Elastic and inelastic regime in fast atom diffraction

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*INSPn Sorbonne Univ., Paris, France*

The diffraction of atoms at surfaces is sensitive only to the topmost layer. GIFAD operates at keV energies and grazing incidence ( $\theta \sim \text{deg.}$ ) in the same geometry as RHEED and is compatible with on-line monitoring of growth. From the projectile point of view, the first property of a surface is its reflectivity describing the probability that a comparatively clean portion of length  $L$  is encountered on the surface where  $L \sim 6.R_c/\theta$  is the length (fwhm) of the classical trajectory with  $R_c \sim 1/\sqrt{2I_p}$  the characteristic extinction distance of the electronic density and  $I_p$  the surface work function. For simplicity we denote  $N \sim L/a$  the characteristic number of lattice sites involved in the scattering. Just as in RHEED, the reflectivity oscillates during the completion of successive layers in the Stranski-Krastanov mode, however due to the absence of penetration, this translates into a much simpler behaviour where all diffraction orders oscillate together whatever the angle of incidence. In other words, a maximum intensity of any diffraction order unambiguously signs the completion of a new layer. When no evaporation is taking place any improvement of the reflectivity indicates an increase of the surface coherence length. This property remains valid around the specular angle even if no diffraction is observed allowing gradual improvement of the surface even with a rough sample. Another very simple diagnostic of the surface ordering is the triangulation technique where the scattering profile is recorded as a function of the surface azimuthal angle  $\Phi$ . When  $\Phi$  coincides with a direction where molecules tend to align with each other, then local valleys are present at the surface that will allow larger lateral deflection of the projectile. Monitoring this lateral broadening during an azimuthal scan immediately reveals the surface crystallographic directions. Finally, when the quality of the surface in terms of mean distance between defects is large enough, diffraction can be observed that will provide an accurate measurement of the surface corrugation function which is supposed to be very close to the surface iso-electronic profile. Since the deflection is spread among several lattice site (typically  $N$ ) the Debye Waller factor specific to GIFAD is much more favourable than with single scattering at normal incidence and diffraction can be observed at elevated surface temperature as demonstrated with almost 50% coherence ratio using GaAs above 570°C directly inside the MBE chamber. Recently the Debye Waller factor has been expressed in the momentum space so that a multiple Quantum Binary Collision Model could be derived allowing quantitative prediction on the spot shape associated with inelastic diffraction. The presentation will review these recent progress both from the fundamental point of view and in the perspective of applications to thin film growth of organic layers known to have a lower coherence length.

## 10h10 - Band gap maps beyond delocalization limit and identification of carrier traps in novel oxide semiconductors

**Mads Ingebrigtsen, Wei Zhang, Lasse Vines, Øystein Prytz, Andrej Kuznetsov**

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Two recent set of data highlighting our efforts in the field of oxide semiconductors are presented. Firstly, the focus is on the high resolution band gap mapping via a combination of probe-corrected scanning transmission electron microscopy (STEM) and monochromated electron energy-loss spectroscopy (EELS). Indeed, in terms of the spatial resolution, this combination is far superior comparing to any other modern technique; however, it is still resolution-limited due to so called inelastic delocalization of the EELS signal resulting in fundamental uncertainties beyond  $\sim 6\text{nm}$  (for conventional STEM accelerating voltages). In our work, we showed how to surpass the limitation by correlating the optical band gap and the plasmon related signals; specifically, using  $\text{Zn}_{1-x}\text{Cd}_x\text{O}$  nanowires as an example, the band gap maps with unprecedented spatial resolution of  $\leq 2\text{nm}$  were demonstrated. Secondly, using a combination of deep level transient spectroscopy (DLTS), secondary ion mass spectrometry (SIMS), proton irradiation, and hybrid functional calculations, we have resolved an issue on either intrinsic or extrinsic the origin of the dominating carrier trap in  $\text{Ga}_2\text{O}_3$  (often labeled as E2 in literature). Our measurements revealed that there are actually two levels in the region of interest – E2 and a new level labeled as E2\*, having the ionization energy very close to that of E2, but exhibiting an order of magnitude larger capture cross section. Importantly, the properties of E2 and E2\* were found to be iron- and vacancy-related, respectively. As such, a bit ironically, the long standing literature debate on either extrinsic or intrinsic origin of the carrier trap in question converge accounting for different contributions from E2 and E2\* in different experimental conditions.

## 11h10 - In situ growth of GaAs nanowires by molecular beam epitaxy in a transmission electron microscope

**G. Patriarche, J.-C. Harmand, F. Glas, L. Travers**

*Centre de Nanosciences et de Nanotechnologies (C2N), CNRS- Université Paris Sud, Université Paris Saclay, France*

Molecular beams of Ga and  $\text{As}_4$  are implemented in an aberration-corrected transmission electron microscope. GaAs nanowires are grown in situ from Au catalyst particles. Real-time observation gives access to their morphological and structural parameters while growing and the formation of atomic planes at the catalyst-nanowire interface can be examined. We use various conditions which can result in solid or liquid catalyst particle. Surprisingly, the two cases lead to comparable growth rates (about  $0.3\text{ ml/s}$ ). For liquid catalyst, the contact angle of the droplet evolves rapidly with the V/III vapor flux ratio. At contact angles around  $120^\circ$ , the atomic plane stacking switches

from hexagonal to cubic, with a transition region of mixed crystal phases. In agreement with recently reported results, but using a different growth technique and higher growth rates, we observe that the formation mechanisms of the two crystal phases differ singularly. Namely, hexagonal monolayers grow by slow and continuous step flow on a flat nanowire top facet; cubic monolayers appear incrementally and concomitantly with a truncation of the nanowire top facet. At low temperature, lateral growth on the sidewall facets is observed. It proceeds by step flow of one or more lateral monolayers along the nanowire axis direction. The steps are momentarily stopped and can accumulate at stacking faults present in the nanowire core. The underlying mechanisms will be discussed.

### 11h30 - Strain measurements of active Phosphorous in Laser Annealed Ge

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In this paper, we evaluate the strain due to atomic Phosphorous located in a perfectly recrystallized Germanium after Laser Thermal Annealing treatment in melt configuration. For hot topics of nanoscience, such as laser integrated on Si, Ge needs high doping (above  $1e20$ ) and tensile strain. For this reason, there is leading technological interest for quantifying the contribution of dopants to the strain. In detail, we demonstrate that, despite its small atomic radius compared to Ge, substitutional P induces a lattice expansion. This result puts in evidence that the “electronic contribution” (which is associated to the increased hydrostatic deformation potential in the conduction band of P doped Ge) is larger than the “size mismatch contribution” (associated to the atomic radii). Such behavior is evidenced thanks to the combination of high sensitivity measurement techniques used in this work. Indeed, High Resolution X-Ray Diffraction has proved to be a powerful tool for “large scale” measurement of the strain induced by dopants within a crystalline matrix, while Convergent Beam Electron Diffraction measurements (in Scanning Transmission Electron Microscopy mode) allow to achieve strain measurements with nanometer spatial resolution. In conclusion, these studies render the LTA of widespread interest not only for applications in Ge based technology but also for conducting fundamental studies.

### 11h50 - Direct exploration of the nanoscale structure of III-V heterostructures epitaxied on 300 mm Si substrates by Atom Probe Tomography and ToF-SIMS

**Georges Beainy, Tiphaine Cerba, Reynald Alcotte, Franck Bassani, Mickael Martin, Bassem Salem, Adeline Grenier, Thierry Baron, Jean-Paul Barnes**

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Because of the limitations to the functionality that silicon can provide, integration of III-V semiconductor devices on silicon will add new functionalities in opto- and micro-electronic applications. In this work, the physico-chemical studies of III-V heterostructures directly grown on 300 mm Si wafers by metalorganic vapor phase epitaxy are addressed by the mean of Time of Flight Secondary Ion Mass Spectrometry (ToF-SIMS) and Atom Probe Tomography (APT). These two techniques have emerged as unique that are able to provide information on the chemical composition of elements together with a 3D map indicating the position of each atom from a specimen. Firstly, topography formation under oxygen irradiation of GaSb/InAs multilayers using atomic force microscopy was investigated and correlated with ToF-SIMS profiles in order to improve the depth resolution. We demonstrated that in order to obtain a smooth sputtering of GaSb/InAs, the optimal condition is to combine O<sub>2</sub> flooding and sample rotation. This allows a total suppression of surface nanopatterning induced by the incident beam thus leading to higher depth profiles resolution. Secondly, atomic composition and dopant distribution in Si-doped GaAs thin layers were analyzed by ToF-SIMS and APT and then correlated to the electrical properties. Using ToF-SIMS characterizations, we have highlighted the increasing evolution of the silicon content in the material as a function of silicon flux. On contrast, the concentration of charge carriers studied by Hall Effect decreases. Thanks to APT analyses, we have been able to link this degradation with the formation of silicon clusters in GaAs. These clusters become more and more important with increasing Si concentration.

### 12h10 - Charge and spin transport in GaAs nanowires grown by HVPE

**Hadi Hijazi, Guillaume Monier, Daniel Paget, F. Cadiz, P. A. Alekseev, V. P. Ulin, V. L. Berkovits, C. Leroux, C. Bougerol, Dominique Castelluci, Agnès Trassoudaine, Evelyne Gil, Vladimir Dubrovskii, Christine Robert-Goumet, Yamina André**

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Hydride Vapor Phase Epitaxy process has already demonstrated the growth of GaAs NWs with exceptional length and high purity cubic zinc blende structure. NWs were grown at a fast solidification rate 170  $\mu\text{m}/\text{h}$ , facilitated by the high decomposition frequency of the chloride growth precursors involved in HVPE. In VLS-HVPE, continuous and predominant feeding through the Au-Ga liquid catalyst occurs with no mass and kinetic hindrance, favoring axial rather than radial growth, and leading to twin-free NWs with a constant cylinder shape over unusual length. In this work, we present the potential of Au-assisted (VLS) growth to produce high crystalline ultra-long GaAs NWs, 40  $\mu\text{m}$  to 100  $\mu\text{m}$  long with constant diameter in the range 50-200 nm on silicon substrates. Prior to the growth, gold nanodroplets organization had been investigated by using SEM and electronic spectroscopy. In order to enhance the performance of the electronic devices, the electronic spin gained importance in the last years, it can be used as a supplementary factor to transport information. We present a charge and

spin transport investigation in ultra-long (50-80 $\mu$ m) GaAs NWs grown by HVPE on silicon (111) substrates. We have investigated individual NW at 6 K and 300 K using polarized  $\mu$ -Photoluminescence ( $\mu$ PL). This technique uses a local generation of spin-polarized photoelectrons by a tightly-focused light excitation. The light emitted from electrons after diffusive transport is then spatially and spectrally analyzed to get charge ( $L_e=5.72$   $\mu$ m) and spin ( $L_s=5.14$   $\mu$ m) diffusion lengths. A comparative study of the effect of surface nitridation using hydrazine solutions and plasma treatment in Ultra High Vacuum has been carried out.

### 12h30 - Strain and electronic properties of carbon-doped GaAsBi alloys grown on GaAs by molecular beam epitaxy

**C. Cornille, A. Arnoult, F. Cristiano, C. Fontaine**

LAAS-CNRS Université de Toulouse, France

GaAsBi alloys are emerging III-V semiconductors investigated for their singular optoelectronic properties. Incorporation of bismuth into GaAs leads to a rapid decrease of its band gap, of the order of 88 meV / %Bi [1]. However, due to its large Bohr radius, its incorporation is difficult and highly depends on the growth conditions. Here, we focus on the growth of P-type doped layers and on the influence of doping level on their properties. 1  $\mu$ m-thick carbon-doped GaAs layers, containing 2% of bismuth, doped with carbon, have been grown by molecular beam epitaxy in a 412 RIBER system on (001) GaAs substrates under similar growth conditions. During growth, we have employed an in-situ optical technique developed at LAAS, to get access to the structure curvature. This curvature originates from the strain generated by the pseudomorphic growth of a mismatched layer, and changes upon occurrence of strain relaxation. We have monitored, in real-time, the strain of the differently carbon-doped GaAsBi layers along their growth. The ex-situ analysis of these layers has been performed by X-ray diffraction, secondary ion mass spectrometry and Hall Effect. These techniques have then provided their structural (composition, crystallinity) and electronic properties. Our results show that the strain measured during the growth of these GaAsBi layers is strongly affected by their carbon doping level. Strain relaxation is observed after growth of a critical thickness, and is more or less strong depending on the initial strain experienced by the heteroepitaxial material. Accordingly to the literature [2], the carrier mobility has been found to be lower than for similarly carbon-doped GaAs layers.

[1] S. Francoeur et al., « Band gap of GaAs<sub>1-x</sub>Bi<sub>x</sub>, 0<x<3.6% Appl. Phys. Lett. 82, 3874 (2003); <https://doi.org/10.1063/1.1581983>

## ROOM PORT CROS

### 16h30 - Self-organized growth of quantum dots and quantum wires by combination of focused ion beams and molecular beam epitaxy

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The combination of focused ion beam (FIB) implantation and molecular beam epitaxy (MBE) processes allows for nm-resolution in-situ ultrahigh-vacuum (UHV) fabrication both in lateral as well as in growth direction. We exploit self-organized growth of Stranksi-Krastanov  $\text{In}_x\text{Ga}_{1-x}\text{As}$  quantum dots [1,2, Fig1a] and III-V nanowire structures [3,4, Fig.1b], both initiated by FIB-implantation of various ion species. Samples are transferred between the FIB and the MBE setup by UHV-tunnels or a separate UHV-suitcase which may link instruments far away from each other. Since the whole process is within UHV, no wet or dry chemistry deteriorates the solid-state interfaces. This increases the purity and reproducibility of the whole process. Beside Gallium, the whole metallic part of the periodic table is available as FIB ion species. Thus, this method is very versatile and covers even elements which are usually not introduced in a GaAs-MBE chamber due to purity reasons. Therefore, beside site controlled growth any doping, before, in between and after the MBE-growth becomes possible, including even all metals of the rare earths.

[1] M. Mehta et al, *Physica E* 42 (10), 2749-2752 (2010).

[2] M. Mehta et al, *Nano* 10 (4), 155049 (2015).

[3] G. Bussone et al., *Journal of applied crystallography* 46, 887 (2013).

[4] S. Scholz et al., *Journal of Crystal Growth* 470, 46–50 (2017).

### 17h00 - Synthesis and characterization of nanostructured $\text{CoMoO}_4$ : Xchromic and photoluminescence properties

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Cobalt molybdate  $\text{CoMoO}_4$  has some interesting properties such as thermochromic, piezochromic, photoluminescence and photocatalysis under UV excitation are well know. In the present study, the material has been succefully synthesized by a new EDTA-Citrate method, and various heat treatments were applied. It may exist in two polymorphic phases  $\alpha$  (green) and  $\beta$  (purple), they depend of two parameters pressure and temperature. Afterwards, the polycrystalline samples are characterized by thermogravimetric analysis, X-ray diffraction and scanning electron microscopy. The results obtained by XRD, showed the possibility of obtaining a  $\beta$  phase (at 500 °C) and a highly textured  $\alpha$  phase according to the family of planes (hh0). The results obtained by scanning electron microscopy confirmed the existence of two phases  $\alpha$  and  $\beta$  with very different morphologies. The  $\beta$  phase consists of agglomerated grains of about 200

nm. However, the  $\alpha$  phase is organized in the form of nanosheets (20 nm) and aggregate of beads nanostructured assembled into faceted crystallites of sub-micron sizes. Luminescence analyses of these polycrystalline samples were performed under UV-laser light irradiation and is characterized by 3 bands. The influence of the elaboration conditions on the emission intensity is now in progress.

### 17h20 - Large surfaces of 2D hexagonal Ge nanocrystals by double self-assembly

**Thomas Bottein, Mohammed Bouabdelaoui, Jean-Benoît Claude, Luc Favre, Thomas David, Antoine Ronda, Isabelle Berbezier, Marco Abbarchi, David Grosso**

*NOVA - IM2NP- AMU, Marseille, France*

Ceramic (e.g. semiconducting  $\text{TiO}_2$ , or insulating  $\text{ZrO}_2$ ,  $\text{Al}_2\text{O}_3$ ,  $\text{SiO}_2$ ) nanopatterned template layers can be prepared on various substrates (e.g. Si, Au,  $\text{SiO}_2$ , Cr) through simple, reproducible, low-cost and easy to scale up “bottom-up” approach, involving chemical solution deposition, self-assembly via commercial block copolymers and thermal treatment [1]. The patterns are composed of nanoporations arranged in a hexagonal lattice through which the surface of the substrate remains accessible. The typical thickness of the layer can be controlled between 5 and 20 nm, while a proper selection of chemical and processing conditions allows to perfectly tune the motif diameter and interspacing between 10 and 80 nm [2]. These heterogeneous systems constitute novel highly ordered Inorganic Nano Patterned (INP) substrates, which present a unique combination of thermal, mechanical, and chemical stability. Furthermore, they display very interesting characteristics of ordered nano-heterogeneity associated to the accessibility of the substrate surface through the perforations [3]. Such surfaces have already proved their interest for various applications such as nano in micro devices [4], self-cleaning layers [5] or for data storage [6]. In the present communication, such ceramic nanopatterned layers have been used as heterogeneous nanostructured substrates to control the nucleation and growth of Ge nanocrystals (NCs) via deposition and annealing of a thin Ge layer in Molecular Beam Epitaxy (MBE) (Figure 1). After an appropriate HF chemical etching of the native  $\text{SiO}_2$  at the bottom of the INP perforations, the chemical heterogeneity between the INP  $\text{TiO}_2$  surface and silicon at the bottom of the perforations has allowed to obtain selective nucleation of the Ge nanocrystals at the latter interface. Systematic investigations of the MBE deposition and annealing parameters have been performed and have given insight into the mechanism at stake. Precise 2D hexagonal arrangements of the Ge NCs with mean diameter of  $20 \pm 3$  nm have been achieved, and characterized by Atomic Force Microscopy, Scanning Electron Microscopy and Transmission Electron Microscopy. The Ge NCs arrangement spacing and diameter was then easily tailored by simply modifying the INP network parameter. Furthermore, a similar procedure was applied to the dewetting of gold thin layers. Using the INPs as a topographical barrier, and after an additional mechanical etching step, perfect

hexagonal arrangements of Au dots with sharp size distribution ( $28 \pm 5$  nm) have been demonstrated. This work reveals that large surfaces of periodically ordered nano-objects can be prepared through a double step procedure involving the evaporation of block copolymer templated sol-gel TiO<sub>2</sub> coating, followed by the templated dewetting of semiconductor or metallic thin layers.

### **17h40 - Calcination temperature effect on the structure, morphology and photocatalytic activity of the bismuth phosphate BiPO<sub>4</sub> nano-crystalline synthesized by co-precipitation method in aqueous medium**

**A. Bouddouch(1,2,\*), F. Guinneton (2), A. Benlhachemi (1), B. Bakiz (1), S. Villain (2), J. C. Valmalette(2), A. Taoufyq(1)**

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The main objective of the study presented in this work is to shed a light on the effect of the calcination temperature on the phases transformations, textural properties and the photocatalytic activity of bismuth phosphate BiPO<sub>4</sub> system. The bismuth phosphate powder has been successfully synthesized via a facile co-precipitation reaction at room temperature. The obtained hydrated sample was dried and then calcinated at 200, 400, 600, 900 °C for three hours. Phases identification and structures of the powders were characterized by X-ray diffraction (XRD). The diffraction patterns showed a highly crystallized powder with the crystallites that are nanometric. The functional groups were indicated by Fourier transform infrared spectroscopy (FTIR). The characterization of the BiPO<sub>4</sub> powders by Scanning electron microscopy (SEM) coupled with energy dispersive X-Ray analysis (EDS) shows a homogeneous distribution of the phases and the thermal transformation of the as prepared samples was studied by using thermogravimetric analysis coupled with differential thermal analysis (TGA/DTA). For the photocatalytic properties, UV visible spectrometry was used to analyze the evolution of photodegradation of organic pollutants. Finally, the photocatalytic efficiency of these materials has been evaluated using rhodamine B as a pollutant model under UV light irradiation. Results demonstrated that the pure bismuth phosphate BiPO<sub>4</sub> calcined at 400 °C presented the best photocatalytic efficiency due to their morphology and the presence of the monoclinic P21/n (nMBIP) phase in their structure. Keywords: bismuth phosphate, co-precipitation method, calcination temperature, photodegradation, rhodamine B, phases transformations, textural properties.

**18h00 - IN ROUTE TO SiO<sub>2</sub>/Mn<sub>5</sub>Ge<sub>3</sub>/Ge(111) HETEROSTRUCTURES FOR (BIO)SENSOR APPLICATIONS**

**Marta Kerber Schütz, Matthieu Petit, Anne Lomascolo, Jean-Claude Sigoillot, Lisa A. Michez, Vinh Le Thanh, Jean-Manuel Raimundo**

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Mn<sub>5</sub>Ge<sub>3</sub> compound has appeared in the last decade to be a potential candidate for spin injection into group-IV semiconductors due to its room-temperature ferromagnetism properties, high spin polarization, metallic character, its ability to epitaxially growth on Ge and compatibility with the already-existing Si-based technology. Nevertheless environmental stability against for instance moisture need to be improved for practical applications. To achieve such goal we present herein the first insights on functionalization of Mn<sub>5</sub>Ge<sub>3</sub>/Ge(111) with thiol molecules in order to improve surface passivation. It is well known that thiol groups (R-SH) have high affinity for different substrates such as Au, Ge and so on, which makes possible to generate well-defined organic surfaces with useful and highly alterable chemical properties, such as wettability, biocompatibility and protein adhesion. It was used alkanethiols and perfluorinated alkanethiols for surface functionalization and different reaction conditions were investigated. Our results have evidenced that thiol molecules can easily chemisorb onto the Mn<sub>5</sub>Ge<sub>3</sub> surfaces as self-assembled monolayers. In addition, the surface biofunctionalization of SiO<sub>2</sub> by laccase from *Pycnoporus cinnabarinus* BRFM 137 was studied. Laccase, an oxidoreductase enzyme, has been used for several applications in biotechnological processes due to its ability to oxidize both phenolic and non-phenolic lignin-related compounds. Among the strategies investigated for immobilization of laccase, APTES-modified SiO<sub>2</sub> has shown greater enzyme activity. The ongoing studies will be focused on the deposition of a thin layer of SiO<sub>2</sub> onto Mn<sub>5</sub>Ge<sub>3</sub> surface that will allow the deposition of the laccase as described in this work in order to provide a novel biosensor.



## ROOM LEVANT

### 16h30 - LEGO bricks at the nanoscale

**Athmane Tadjine, Daniel Vanmaekelbergh, Christophe Delerue**

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After several decades of research, semiconductor nanocrystals are now employed in everyday applications. For example, they are used to emit monochromatic light of different colors in display devices, including commercial TVs. In these applications, the semiconductor nanocrystals are used as quantum dots that strongly confine the electrons in such way that they behave as artificial atoms. In this context, it is tempting to assemble these artificial atoms in order to fabricate new materials. The synthesis of self-assembled 2D or 3D lattices of semiconductor nanocrystals was reported in a large number of works but, in these lattices, the coupling between neighbor nanocrystals is usually very weak because the nanocrystals remain capped with molecular ligands. However, recent progress in colloidal chemistry allowed to synthesize 2D lattices using the oriented attachment approach in which the nanocrystals are epitaxially connected. This leads to the formation of new crystals in which the nanoscale patterning has a profound impact on the electronic structure of the superlattice. In this talk, I review recent experimental and theoretical studies in this field. I show that the semiconductor nanocrystals can be seen as LEGO bricks which can be used not only to make new materials but also to design original band structures [1,2].

[1] Colloidal nanocrystals as LEGO® bricks for building electronic band structure models, Athmane Tadjine, Christophe Delerue, *Physical Chemistry Chemical Physics* 2018 | DOI: 10.1039/C7CP08400E.

[2] Transport Properties of a Two-Dimensional PbSe Square Superstructure in an Electrolyte-Gated Transistor, M. Alimoradi Jazi, V. A. E. C. Janssen, W. H. Evers, A. Tadjine, C. Delerue, L. D. A. Siebbeles, H. S. J. van der Zant, A. J. Houtepen, D. Vanmaekelbergh, *Nano Letters* 2017 | DOI: 10.1021/acs.nanolett.7b01348.

### 17h00 - First-Principle Results for Undoped and Doped Silicon and Germanium Nanocrystals in Different Environments

**Stefano Ossicini and Ivan Marri**

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In recent years particular attention has been devoted to Silicon and Germanium nanocrystals, a powerful class of nanostructures which is opening new substantial opportunities for optoelectronics and photovoltaics. They present unique size dependent structural, electronic and optical properties that are intrinsically associated with their low dimensionality and quantum confinement effect. We have performed several ab-initio calculations in the framework of Density Functional Theory and Many-Body Perturbation Theory for free and matrix embedded Si and Ge nanocrystals. Among the different results we will concentrate, here, on the role of



dimensionality, doping and interface terminations in order to tune the optoelectronic properties. Moreover we will show the outcomes of multiple exciton generation calculations for these nanostructures, highlighting the possibility to foster application in photovoltaics.

### **17h40 - Rayleigh instability induced formation of silicon nanocrystal chains from ultrathin Si nanowires**

**S. Boninelli, M. Agati, P. Castrucci, V. Paillard, R. Dolbec, and M. A. El Khakani**

*IMM-CNR, Univ. Catania, Italy*

The interest in nanomaterials, such as thin-films, quantum dots and nanowires has rapidly increased in the recent past decades from both theoretical and technological points of view. In particular, silicon nanowires (SiNWs) have received a great attention from the scientific community since electrons and holes occupy discrete energy levels, demonstrating remarkable electrical and optical properties in this laterally quantum-confined structures that have not been observed in the corresponding bulky materials. Moreover, as Si is the leading material in microelectronics, the perspective to exploit its already well-established technology makes the interest toward SiNWs crucial for technological applications. In this work we present the Inductively Coupled Plasma (ICP) as an innovative and high throughput technique suitable for the synthesis of ultra-thin SiNWs (as thin as 2 nm) at the industrial level. The investigation of their structure, conducted by Transmission Electron Microscopy (TEM) based techniques, allowed us to elucidate that their growth was induced by two competitive mechanisms: Oxide Assisted Growth (OAG) and Vapor-Liquid-Solid (VLS). Some OAG synthesized SiNWs were found to present an intriguing internal nanostructure, made of "chapelet-like" Si nanocrystals (ranging between 3 and 6 nm), eventually connected by an extremely thin SiNW (~2 nm) and embedded into an otherwise continuous silica nanocylinder. This structure is demonstrated to result from Rayleigh instability due to rapid post-synthesis heating of the SiNWs before their cooling down in the final part of the ICP reactor. Finally, we studied the effect of post-thermal annealing on the nanostructural changes of SiNWs. In this way, we were able to reach the Rayleigh instability conditions and structurally transform the SiNWs into a spherical Si nanocrystal (SiNC) chain embedded in a silica wire. Such Si nanostructures provide a new kind of nanocomposite, where quantum confinement effects are expected. Indeed, our photoluminescence studies confirmed the occurrence light emission in over all the 620-950 nm spectral range. These results prove the ICP as a genuinely bulk process, which can be advantageously exploited for large scale production of ultra-thin SiNWs needed to integrate Si into attractive large-area optoelectronic devices and flexible electronics.

## 18h00 - Design, characterization and lithographic application of Si nanocrystals patterns via templated dewetting

**M. Bollani 1, M. Salvalaglio 2, M. Lodari 1, M. Naffouti 3, A. Benkouider 3, A. Voigt 2, T. David 3, I. Fraj 3, L. Favre 3, A. Ronda 3, I. Berbezier 3, D. Grosso 3, M. Abbarchi 3**

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Silicon-based nanocrystals represent a promising resource both for next generation electronic devices and for nano-photonics applications but require precise size, shape and position control [1,2]. However owing to their large surface-area-to-volume ratio, thin semiconductor solid films are often unstable upon annealing. Under the action of surface diffusion the film breaks eventually forming isolated islands. This is one of the main factors impeding the use of ultra-thin silicon films on insulators (UT-SOI) for the further miniaturization of electronic components. Here, with an e-beam lithographic method, we demonstrate the ultimate control of UT-SOI dewetting for the precise formation of complex nano-architectures featuring extremely reduced fluctuations of size, shape and positioning (a few %) over hundreds of repetitions and on large scales [3,4]. The solid state dewetting initiated at the edges of the patterns controllably creates the ordering of nanocrystals (NCs) with ad hoc placement and periodicity [5,6]. The NC size is tuned by varying the nominal thickness of the film while their position results from the association of film retraction from the edges of the layout and Rayleigh-like instability. Islands formation, organization, positioning and composition are studied by dark-field, atomic force and transmission electron microscopy (Figure 1 and 2). Predictive phase-field simulations of the mass transport mechanism, assess the dominant role of surface diffusion providing a tool for further engineering this hybrid top-down/bottom-up self-assembly method. Finally, we show its potential by fabricating nano-transfer molding for nanoimprinting lithography of titania and silica xerogels on silicon and glass substrates.

[1] M. Aouassa et al, *Appl. Phys. Lett.* 101, 013117 (2012)

[2] I. Berbezier et al., *J. Appl. Phys.* 113, 064908 (2013)

[3] M. Naffouti et al, *Science Advance*, Vol. 3, n°11, eaao1472 (2017)

[4] M. Abbarchi et al., *Microelectronic Engineering*, Volume 190, Pages 1-6 (2018)

[5] M. Abbarchi et al., *ACS Nano* 8, 11181 (2014) [6] N. Meher et al., *Small* 12, n°. 44, 6115-6123 (2016)

## ROOM PORT CROS

### 9h00 - Nanopatterned Si substrate for reduced footprint GaN epitaxy

**Rami Mantach<sup>1,2</sup>, Roy Dagher<sup>1,2</sup>, Blandine Alloing<sup>2</sup>, Philippe de Miery<sup>2</sup>, Virginie Brändli<sup>2</sup>, Sébastien Chenot<sup>2</sup>, Maud Nemoz<sup>2</sup>, Jesus Zuniga Perez<sup>2</sup>, Philippe Vennegues<sup>2</sup>, Guy Feuillet<sup>1</sup>**

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2) CRHEA - CNRS, Sophia Antipolis, France

Considering GaN epitaxy for emissive applications, mostly hetero-substrates such as sapphire and silicon are used since GaN substrates are still of low dimension and high cost. In nitrides, heteroepitaxial growth proceeds through nucleation of islands with dimensions not exceeding 100nm, followed by coalescence of the islands. Hence two types of dislocations are formed: misfit dislocations at the substrate/nuclei interface and grain (or sub-grain) boundary dislocations which compensate for the misorientation of the nuclei with respect to each other. The latter will thread within the epilayer up to the active region, acting as non-radiative centers. In this presentation, we illustrate a method to drastically reduce the dislocation densities in GaN epilayers on Si substrates, consisting in nanopatterning the substrate in order to reduce the areas on which growth is carried out. Indeed, since threading dislocations are directly related to the nucleation process, one way of limiting their overall density consists in resorting to as small nucleation areas as possible; in this case, dislocations originate from the (sub) grain boundaries of very few nuclei. We will consider two cases. One is related to the growth of semi polar GaN on Si. In order to limit and better control the dimension of the chemically etched Si facet on which semi polar growth is carried out, we use SOI substrates, with thin top Si layers (about 150nm). This top Si layer is oriented so as to favor semipolar growth on the etched (111) Si facets (ref M. Khoury). Pyramidal growth on the Si facets results in dislocation bending towards the surface in the inclined c-plane. We will show how reducing the size of the facet results in drastically reducing the width of the area where dislocations intersect the surface. If the nucleation areas are well apart, the defects (dislocations, stacking faults) associated to the coalescence of the crystallites originating from the adjacent Si facets will also be reduced. The second example is also based on the use of SOI substrates. In this case, the top about 20 nm thick Si layer is 111 oriented which results in c-oriented GaN growth. The SOI substrates are nanopatterned in the form of nanopillars down to dimensions of about 100nm. Pendeo-epitaxial growth is achieved on the nanosized surface: dislocations arising from the side walls propagate in the c-plane. Pyramidal growth is also at work on the top of the pillar, which ensures that dislocation bending will also occur. These processes leave very few dislocations threading within the epilayer. Further, we exploit the fact that SiO<sub>2</sub> from the buried oxide (BOX) can creep at the usual growth temperature: through the deformation of the SiO<sub>2</sub> pillars, the slightly misoriented pyramids originating from adjacent pillars align without the formation of coalescence defects. This reduces the constraint related to the apparent necessity to have as few nucleation sites as possible. We will evaluate the structural and optical properties of 2D layers grown along these reduced footprint epitaxy methods and compare them with those of layers grown along more traditional ways.

### 9h30 - Nanoporous GaN made by selective area sublimation: efficient light emission on silicon substrate

**B. Damilano, S. Vézian, J. Massies**

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Nanoporous GaN and (Ga,In)N/GaN single quantum well layers are fabricated using a selective area sublimation (SAS) technique from initially smooth and compact 2-dimensional(D) layers grown on Si(111) or c-plane sapphire substrates. The photoluminescence properties of these porous layers are measured and compared to reference non-porous samples. Whatever the substrate used, the porosity leads to an increase of the room temperature photoluminescence intensity. The magnitude of this increase is related to the initial defect density of the 2D epitaxial layers and to the degree of carrier localization prior to the SAS process. For thin ( $\leq 0.3 \mu\text{m}$ ) GaN-on-Si epitaxial layers, this morphologic change from a 2-dimensional flat layer to a nanostructured material presents the unexpected property of a huge increase ( $> 3$  orders of magnitude) of the GaN band edge photoluminescence intensity. Furthermore, the integrated photoluminescence intensity of such mesoporous GaN layers is comparable to a high quality  $3.5 \mu\text{m}$ -thick GaN-on-sapphire epitaxial layer or a  $350 \mu\text{m}$ -thick GaN substrate.

### 9h50 - Growth of InGaN nanowires with a controlled indium fraction by HVPE

**Mohammed ZEGHOUANE, Geoffrey AVIT, Yamina ANDRE, Catherine BOUGEROL, Evelyne GIL, Pierre FERRET, Dominique CASTELLUCI and Agnès TRASSOUDAIN**

*INSTITUT PASCAL, Clermont-Ferrand, Aubière, France*

InGaN material is promising for high performance optoelectronic devices due to its tunable bandgap from IR to UV by varying the indium fraction in the alloy. However, the growth of InGaN with high and controlled indium concentration is still challenging. This could be overcome by the use of the nanowire geometry that enables the growth of indium-rich InGaN material with a low density of defects on different substrates. In this context, HVPE shows unique features regarding the growth of InGaN nanowires. The full range of indium composition is achieved by controlling the input partial pressures of group-III elements. Homogenous InGaN nanowires are obtained whatever the In composition in the solid. This is demonstrated by EDS profiles on single nanowires and XRD measurements on nanowire ensembles. Selective area growth (SAG) of InGaN and InN nano- and microwires has been achieved by HVPE. Thanks to the use of chloride precursors, this process allows large growth rate anisotropy and high selectivity on masked substrates. The experimental results are supported by thermodynamic calculations of the vapor phase composition at homogeneous thermodynamic equilibrium. These findings provide a convenient method to grow homogenous InGaN

nanowires with high indium composition and could stretch further the limits of nano-optoelectronic devices.

### 10h10 - Nanowire based field effect transistors: Influence of geometrical properties

**Camelia Florica, Andreea Costas, Melania Onea, Elena Matei, Ionut Enculescu**

*National Institute of Materials Physics, Magurele, Romania*

Field effect transistors are electronic components on which are based all of today's ICT devices. New devices are designed every day with the aim of improving performances and adding new functionality. Nanowire channel based field effect transistors are a relatively new type of such devices. Their main advantages are given by the confined geometry of the channel and an important field of potential applications is the area of sensors. Due to its nature, geometrical properties including channel length and diameter are essential characteristics of the device, enabling extended functionality. Several types of nanowire devices were developed and tested the results being presented in the present work. A relation between structure and geometry of the channel versus the transport properties of the device will be given.

### 10h30 - Nanostructured LaFeO<sub>3</sub> /YSZ thin films as mixed potential gas sensor

**M. Jędrusik a,b, Ł. Cieniek b, A. Kopia b, Ch. Turquat a, Ch. Leroux a**

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*b Aix Marseille Univ, Univ Toulon, CNRS, IM2NP, Toulon, France*

Mixed potential sensors for detecting harmful gases belong to the group of chemical sensors, in which chemical information coming from the environment is converted into a signal. The gas sensing mechanism in electrochemical sensors relies on the electrochemical catalytic reaction at the interface between the solid electrolyte and the sensing electrode. The microstructure of the sensing electrode (surface, porosity, thickness) and the interface can have a significant effect on the sensor response. The sensing electrode is a perovskite LaFeO<sub>3</sub> layer, obtained by Pulsed Laser Deposition (PLD), a technique known to produce stoichiometric, thin, polycrystalline films with good adhesion. As solid electrolytes, we used two different substrates: yttrium stabilized zirconia YSZ, cubic and tetragonal, each one [100] oriented. For comparison, layers were also deposited on Si [100]. The crystallographic structure, texture, roughness and microstructure of the perovskite layers were investigated by XRD, SEM, AFM, TEM and HREM, for the different substrates and for different deposition temperatures.

Depending on the substrate temperature during the deposition, and on the substrate, we obtained different nanostructured thin films. In the PLD process, for one given substrate, the grains growth and hence the final surface is mainly governed by the

substrate temperature and the gas pressure in the deposition chamber. The nanostructuration may be linked to competition between different growth mechanisms occurring simultaneously under our deposition conditions. When the surface diffusion is not sufficient, at low temperature, the film roughness is high. The increase of the deposition temperature led to a decrease of the layer roughness, and to the formation of columnar structures. The morphology of the layer depends also on the substrate, and LaFeO<sub>3</sub> layers deposited on YSZ tetragonal exhibit different features, and columnar grains grew with (101) or (020) planes parallel to the substrate. The irregular droplets of nanometric size on the surface are also crystallized in the LaFeO<sub>3</sub> structure. They are due to the overheating of the target surface, which can lead to phase explosion phenomena, and the deposition of clusters.

### 11h10 - ZnO optical microcavities by MBE: from polariton lasers to polariton amplifiers

**J. Zuniga-Perez, O. Jamadi, C. Deparis, F. Réveret, X. Lafosse, S. Bouchoule, M. Leroux, P. Disseix, F. Médard, M. Mihailovic, D. Solnyshkov, G. Malpuech, and J. Leymarie**

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Semiconductor-based microcavities have arisen as a prolific system for studying light-matter interaction between a spatially-confined photonic mode and an excitonic resonance. The quasiparticles resulting from this coupling, microcavity-polaritons, have enabled the observation of Bose-Einstein condensates in a solid state environment. In this context, ZnO appears as an alternative material to more mature ones (e.g. GaAs or CdTe), with larger oscillator strengths and enhanced exciton stability. These two properties render ZnO very interesting for studies and applications where large particle densities and/or high temperatures are required. However, the fabrication of ZnO-based planar microcavities is still challenging and it often requires the use of either nitrides and/or dielectric materials for fabricating Distributed Bragg Reflectors. These cavities differ largely from those allowing to study more fundamental polariton physics, mainly based on GaAs-based technology, in which both the active region and DBRs are grown monolithically on GaAs substrates. In this talk we will introduce monolithic ZnO-based optical microcavities (i.e. based solely on ZnMgO/ZnO materials) grown by molecular beam epitaxy on m-plane ZnO substrates. To illustrate the feasibility of the monolithic approach the linear optical properties of ZnO/ZnMgO-based DBRs and microcavities will be first analyzed, highlighting the strong improvement of their optical figures of merit, especially in terms of photonic inhomogeneous broadening. This quality improvement has been further exploited in the fabrication of polaritonic waveguides as well as in the fabrication of the first polaritons lasers based on propagating polaritonic modes. Indeed, up to now all polaritons lasers had been designed in a vertical-cavity geometry. In this talk we will discuss the properties of the first edge-emitting polaritons lasers, which operate in the strong-coupling regime from low to room-temperature, and



will present the implementation of in-plane polariton amplifiers. These two bricks open the door for the development of integrated nonlinear polaritonic circuits.

### 11h40 - ZnO / CuCrO<sub>2</sub> core-shell nanowire heterostructures for self-powered UV photodetectors with fast response

**Thomas Cossuet<sup>1</sup>, Joao Resende<sup>1,2</sup>, Laetitia Rapenne<sup>1</sup>, Odette Chaix-Pluchery,<sup>1</sup> Carmen Jimenez<sup>1</sup>, Ngoc Duy Nguyen<sup>2</sup>, Gilles Renou<sup>3</sup>, Andrew Pearson<sup>4</sup>, Robert L. Z. Hoyer<sup>4</sup>, Danièle Blanc-Pelissier<sup>5</sup>, Estelle Appert<sup>1</sup>, David Muñoz-Rojas<sup>1</sup>, Jean-Luc Deschanvres<sup>1</sup>, and Vincent Consonni<sup>1</sup>**

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ZnO nanowire (NWs) based core-shell heterostructures have been attracting considerable attention for optoelectronic devices owing to efficient light trapping and charge carrier management [1]. These type II heterostructures have recently been integrated into self-powered nanoscale UV photodetectors [2] by combining wide band gap p-type semiconducting shells, such as CuSCN [3], with ZnO NWs. These devices benefit from the photovoltaic effect in the UV region to operate at zero bias. Among the delafossite group, CuCrO<sub>2</sub> is a promising direct wide band gap p-type semiconductor that has previously been integrated into p-n diodes with ZnO thin films, but with relatively low rectifying behavior [4]. In this work, we present the fabrication of an original ZnO / CuCrO<sub>2</sub> core-shell NW heterostructure and its integration into efficient self-powered UV photodetectors. The ZnO NW arrays are grown by the low-cost, low temperature chemical bath deposition technique on commercial ITO/glass substrates, while the CuCrO<sub>2</sub> shell is deposited by aerosol-assisted chemical vapor deposition at 400°C. A 35 nm-thick CuCrO<sub>2</sub> shell with high conformity and uniformity is deposited on the ZnO NWs. The structural morphology of the CuCrO<sub>2</sub> grains and their composition are characterized by automated crystal phase and orientation mapping with precession in a transmission electron microscope as well as by energy-dispersive x-ray spectroscopy. The ZnO / CuCrO<sub>2</sub> core-shell NW heterostructures exhibit a significant diode behavior, with a rectification ratio approaching 12000 at  $\pm 1$  V, which is strongly improved over similar devices based on thin film heterostructures, as well as a high absorptance above 85% in the UV region. The related UV photodetectors show high UV responsivity at zero bias under low-power illumination, alongside a high selectivity with a UV-to-visible rejection ratio around 100. The short rise and decay times around 30  $\mu$ s, both measured at zero bias, further establish these devices as promising candidates for cost-efficient, all-oxide self-powered UV photodetectors.

[1] E.C. Garnett et al. *Annual Review of Materials Research* 41 (2011), 269-295.



[2] W. Tian et al. *Small* 13 (2017), 1701848.

[3] J. Garnier et al. *ACS Applied Materials & Interfaces* 7 (2015), 5820–5829.

[4] L. F. Chen et al. *Japanese Journal of Applied Physics* 52 (2013), 05EC02.

## 12h00 - Optoelectronics based on defect-enhanced quantum dots on Silicon

**Thomas Fromherz, Lukas Spindlberger, Patrick Rauter, Friedrich Schäffler, Martyna Grydlik and Moritz Brehm**

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Silicon Photonics aims to enable optical data communication compatible with CMOS-technology. Today, several active and passive components for Silicon Photonics such as e.g. modulators, waveguides, and detectors are well developed. However, the search for arguably the most fundamental element is still ongoing: A practical, low-cost and monolithic light source that allows for straightforward implementation on CMOS-based microprocessors and that can be easily coupled to existing active and passive Silicon photonics components. Here, we will demonstrate an alternative approach to hybrid III-V on Si and strained bulk group-IV (Ge, GeSn) light emitters. This concept makes use of epitaxially grown Ge quantum dots (QDs) in a defect-free crystalline Si matrix, as they are known since the early nineties. However, we will show that the light emission properties of such Ge/Si QDs can be enhanced by intentional, low-dose and low-energy implantation of heavy ions (such as Ge and Si) into the QDs [1-3]. We demonstrate CMOS-compatible lasing from these novel QDs in which defined point-defects states spatially confine electrons after their tunnelling into the nanostructures. This leads to optically direct transitions and, hence, efficient light emission. In contrast to conventional epitaxial Ge/Si QDs - these defect-enhanced QDs (DEQDs) exhibit shortened carrier lifetimes and negligible thermal quenching of the photoluminescence up to room-temperature (RT) [1-4]. Embedding the DEQDs into microdisk resonators leads to lasing characteristics up to RT upon optical excitation. Contact doping and hence fabrication of electrically driven devices is relatively straightforward in this nanosystem since DEQDs are embedded into a defect-free Si matrix. Light emitting diodes containing DEQDs show bright emission up to 100°C, the temperature limit of the measurement setup [5].

[1] Grydlik, M.; Hackl, F.; Groiss, H.; Glaser, M.; Halilovic, A.; Fromherz, T.; Jantsch, W.; Schäffler, F.; Brehm, M. *ACS Photonics* 2016, 3 (2), 298–303

[2] Grydlik, M.; Lusk, M. T.; Hackl, F.; Polimeni, A.; Fromherz, T.; Jantsch, W.; Schäffler, F.; Brehm, M. *Nano Lett.* 2016, 16 (11), 6802–6807

[3] Brehm M. and Grydlik, M. *Nanotechnology* 2017, 28, 392001

[4] Groiss H., Spindlberger L., Oberhumer P., Schäffler F., Fromherz T., Grydlik M. and Brehm M, *Semicond. Sci. Technol.* 2017 32 (2), 02LT01

[5] Rauter P., Spindlberger L., Schaffler F., Fromherz T., Freund J., and Brehm M., *ACS Photonics* 2018 5 431–438

## 12h20 - Selective area growth of III-V semiconductors using atomic hydrogen during Molecular Beam epitaxy

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Low electron effective mass III-V nanostructures are key elements for the fabrication of innovative devices in electronics, optoelectronics or quantum technologies. Different approaches have been proposed for their elaboration including top-down fabrication, VLS growth or selective area (SA) epitaxy. For this latter, Metal Organic Chemical Vapor Deposition (MOCVD) is the most popular technique thanks to the selective decomposition of precursors. In this work, we focus on the atomic hydrogen assisted SA-Molecular Beam Epitaxy of III-V semiconductor in-plane nanostructures. We will discuss two cases: i) lattice-matched InGaAs on InP; highly mismatched InAs/GaSb hetero-nanostructure on GaAs. Both cases are particularly relevant to microelectronics applications for the achievement of ultra-low source and drain ohmic contact resistances to the channel and the improvement of the gate electrostatic control. Selective area growth can address these two points since it allows the formation of raised heavily doped source and drain contacts using a SiO<sub>2</sub> dummy gate and the growth of in-plane nanowires for a gate all-around MOSFET fabrication.

MBE growths have been performed with an atomic hydrogen plasma cell, used for surface deoxidization before epitaxy as well as during the growth to promote the selectivity with respect to a 10 nm thick silicon oxide mask. This mask, deposited by PECVD on a GaAs or InP (001) semi-insulating substrate has been patterned using e-beam lithography to define stripes with a typical width ranging from 1  $\mu$ m down to 50 nm and length from 10  $\mu$ m down to 500 nm.

In the case of InGaAs/InP, we will show how the use of atomic hydrogen improves the InP surface deoxidization step through the comparison of the PL intensity of an InGaAs quantum well grown near the substrate. More, we will demonstrate that atomic hydrogen does not alter the n-type doping of InGaAs using Si as a dopant, making then the SA-MBE of n-type InGaAs an efficient way to get low access resistance source and drain regions. In the case of InAs/GaSb/GaAs, we will evidence the GaSb relaxation within the stripes, leading to nearly perfectly relaxed material. The formation of a regular array of misfit dislocations at the interface between GaSb and the substrate is evidenced by Scanning Transmission Electron Microscopy observations. After the growth of 10-nm thick InAs on top of these GaSb nanotemplates and GaSb selective etching in an ammonia-based solution, free standing InAs nanowires are revealed, available for further GAA-device fabrication.



## ROOM LEVANT

### 9h00 - Role of Elastic Anisotropy in Patterned Substrate Heteroepitaxy

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We have also explored the dynamics of quantum dot formation in Si-Ge islands grown on pre-patterned Si substrates, using a continuum model. We consider sinusoidal and pit-patterned substrates. Unlike earlier studies which treated elastic effects using isotropic elasticity, we explicitly consider the cubic anisotropy of the system. As shown in earlier work, elastic anisotropy affects the alignment of the quantum dots in the linear regime. This plays a role in the resulting patterns which is most striking when the pattern wavelength is comparable to the natural size of the quantum dots. For example, we show that for pit-patterned substrates, we see that quantum dots form around pits in the sets of four islands when. The shift of island positions from 'inside-pits' to 'around-pits' also takes place when pit width is increased at constant pattern-wavelength. We show in our analysis that the shift of quantum dot positions, which is inherently associated to the pattern-inversion during evolution, provides the possible underlying mechanism for some experimental observations, unexplained otherwise.

### 9H30 - When surface energy builds effective attraction between quantum dots

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Experiments evidence the possible correlated growth of SiGe quantum dots that tend to cluster in low-density assemblies, indicating some attractive phenomena. We investigate this phenomena through the interactions between quantum dots via their elastic fields, that significantly alter their self-organization. The dots interactions are subject simultaneously to the direct elastic energy but also to the strain-dependent surface energy. If the former is mostly repulsive, we theoretically show that the latter can lead to a significant attractive effect. Indeed, the decrease in the surface energy close to an existing island reduces the nucleation barrier and thence increases the nucleation probability close to an existing island. We show by Monte-Carlo simulations that this effect describes well the experimental results, evidencing a new mechanism that can rule the quantum dots nucleation.

## 9h50 - Quantum Dot Site Selection During Annealing of Initially Conformal Si<sub>0.5</sub>Ge<sub>0.5</sub> Films on Patterned Si (001) Surfaces

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Strain-driven self-assembly of heteroepitaxial Group IV quantum dots on Si (001) surfaces can be directed by imposed lithographic patterns on the substrate surface. It is well-established that for discrete pits surrounded by (001) terraces, quantum dots homogeneously populate the pits as long as the surface diffusion length exceeds the inter-pit spacing. However, recent theories predict more complex behaviors when the surface is continuously height-modulated. We fabricated patterns using electron beam lithography, which feature a programmed variation in surface morphology, across a range of periodicities relative to the strain-driven instability. We grow Si<sub>0.5</sub>Ge<sub>0.5</sub> alloys at 450 C on these patterns, resulting in an epitaxial and fully conformal wetting layer. We then raise the temperature to 650 C in situ, to promote surface diffusion during annealing. Off the pattern, no quantum dots form, as the wetting layer is fully stable. However, on the patterns, quantum dots readily nucleate during the anneal. For discrete pits, results are identical to the prevailing literature, in which dots form one per pit. However, for the pattern regions with a more continuous height modulation, SiGe quantum dots selectively form only on the saddle points. This requires that the dots bifurcate in volume, going from one dot per pit to two. We find that the annealing process can control the size of the quantum dots simply by modifying the annealing time. However, we also find that extensive interdiffusion occurs, greatly diluting the alloy composition. This process seems to be greatly enhanced by the presence of the pattern itself. Support by the National Science Foundation under award DMR-1410839 is gratefully acknowledged.

## 10h10 - Hetero-epitaxy of FCC metal films on sapphire

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Thin films of fcc metals (Al, Cu, Ni) deposited and annealed on densely packed planes of sapphire adopt a <111> texture with a limited number of orientation relationships (ORs) to the substrate. We propose an explanation for the origin of these ORs using previous HRTEM data and EBSD experiments performed on the c- (0001) and the r- (1-102) planes of sapphire.

It will be shown that the OR is driven by the 3D structure of the oxide and can be chosen by controlling the steps on the substrate (i.e. the miscut). This new approach completes the usual 2D description of the OR using the parallel interfacial planes and a parallel direction within each of them.

## 11h10 - Surface electromigration of Si advacancy and adatom islands

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When a direct electric current is applied to a material, it may induce a biased mass transport. This effect, called electromigration [1], can play an important role on the dynamics and the morphology of nanostructures at surfaces. It also determines the stability of a working device, and eventually its lifetime. Indeed, it can be responsible for hillocks or voids that may respectively shorten or disrupt electronic circuits. Moreover in the context of size reduction of electrical interconnects the role of electron scattering at surfaces becomes even more crucial [2]. Surface science tools can open the study of electromigration to atomic scale characterization. It has been recently shown [3] that electron scattering at step edges or kink sites may be responsible for a local resistivity increase and an enhanced electromigration force. Also the complex behaviour in the evolution of Si vicinal surfaces under electromigration [4,5] led to a deep theoretical effort [6,7]. However despite the development of kinetic theoretical models and the important role of electromigration in future nanoelectronics, experimental investigation of the migration of surface nanostructures under an applied electric current are still scarce [3] whereas they are probably the corner stones for a quantitative understanding of basic mechanisms of electromigration. We have recently undertaken the investigation of the electromigration of 2D islands at surfaces. As model system we have studied Si surfaces, which fundamental properties have been explored by an abundant literature. We have developed an experimental setup to measure in operando by low energy electron microscopy (LEEM) the drift motion of adatom and advacancy islands on terraces under an applied direct current. In that purpose extremely large Si (100) and (111) monoatomic terraces (> 10nm) have been prepared on two different orientations,.

- On Si(111), at the (7x7) - (1x1) surface reconstruction transition temperature, a (1x1) atomic height advacancy island can be stabilized under a metastable state surrounded by a (7x7) reconstructed terrace. The large difference of diffusivity of species on (7x7) and (1x1) surfaces confines atom exchanges inside the (1x1) vacancy islands unravelling the mass transport mechanisms. Velocity of islands as function of their size shows that a kinetic length of attachment-detachment at step edges of 550 nm is measured. More importantly the electromigrating islands develop faceted step edges and anisotropic shapes depending on the applied current direction. We show that a highly anisotropic kinetics of attachment-detachment at step edges is responsible for this behaviour.

- On Si(100) surface, we have shown that when the electric current is applied along direction, i.e. along or perpendicular to dimer rows, reconstructed (1x2) and (2x1) terraces move in opposite directions. Surprisingly if the electric current is applied at 45° with respect to dimers rows then terraces move perpendicular to the electric current. The shape of these terraces is stationary and size independent. These results suggest that the main mechanism controlling the motion is the biased diffusion of

species on terraces combined with a highly anisotropic diffusivity along or perpendicular to dimer rows.

[1] A. Blech, *J. Appl. Phys.* 47, 1203 (1976)

[2] G. Gardinowski et al., *Appl. Phys. Lett.* 89, 063120 (2006)

[3] C. Tao, W.G. Cullen, E.D. Williams, *Science* 328 736 (2010)

[4] A.V. Latyshev, A. L. Asev, A.B. Krasilnikov, S. I. Stenin, *Surf. Sci.* 213, 157-169 (1989)

[5] F. Leroy, P. Müller, J.-J. Metois and O. Pierre-Louis, *Phys. Rev. B* 76, 045402 (2007)

[6] O. Pierre-Louis and T.L. Einstein, *Phys Rev. B.* 62, 13697 (2000) [7] P. Khun, J. Krug, F. Hausser and A. Voigt, *Phys Rev Lett.* 94, 166105 (2005)

## 11h40 - Modelling the kinetic growth mode of GaAs nanomembranes

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Selective Area Epitaxy is a widely used technique to achieve the growth of three-dimensional (3D) nanostructures. The confinement of the growth by a patterned oxide mask placed on top of the substrate gives the possibility to control the morphology of the growing 3D structures. Here we focus on the homoepitaxial growth of GaAs fins on a (111)B substrate [1], patterned by slits elongated up to several microns and aligned along a circular arrangement. The detailed analysis of the experimental result shows that, by changing the slit orientation, it is possible to obtain different fin morphologies, ranging from vertical nanomembranes to slanted and multifaceted shapes. The main goal of this work is to determine the growth mechanism leading to these structures. Indeed, as we will show, the prominent vertical growth here recognized is not compatible with the well established thermodynamic criterion of surface energy minimization, providing the GaAs Wulff shape [2]. Here we demonstrate that a kinetic growth regime is needed to properly describe the growth of fins. To this purpose, we have developed a continuum model based on the combined effect of the incorporation dynamics on the crystal facets and of the surface diffusion of adatoms. To solve numerically the evolution of the system, we have used a phase-field description [3], which enables to trace efficiently the fin morphologies in 3D. A systematic comparative analysis between experimental data and simulation results allows us to investigate in details the main features of the growth dynamics and to provide a consistent description of the morphological changes induced by the variation of the slit along a circular pattern. As a major result, our study allows to extract quantitative information on kinetic microscopic parameters, such as the incorporation time for the main GaAs crystal facets.

[1] Tutuncuoglu, G.; De la Mata, M.; Deiana, D.; Potts, H.; Matteini, F.; Arbiol, J.; Fontcuberta i Morral, A. *Nanoscale* 2015, 7 (46), 19453–19460.

[2] Moll, N.; Kley, A.; Pehlke, E.; Scheffler, M. *Phys. Rev. B* 1996, 54 (12), 8844–8855.

[3] Rätz, A.; Ribalta, A.; Voigt, A. *J. Comp. Phys.* 214, 187 (2006)



## 12h20 - SiGe condensation process used to manage strain on UT-SOI

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Si MOSFET enhancement can be obtained by strain in channels. Several methods have been proposed to produce strained channels: "Global" processes where strain in the active layer comes from a lattice misfit (i.e. by epitaxy with another material), and more "local" processes where the strain comes from "stressors" smartly placed around the channel. For instance for n-type transistors, it was shown that tensile silicon in the direction of the channel would bring a mobility enhancement up to a factor of two for a strain around 1 %.

We demonstrate here that a relaxed SiGe layer with a Ge atomic concentration of 25% can be obtained using a combination of epitaxy and "condensation" steps. The condensation process consists of selective oxidation of silicon in silicon germanium (SiGe) alloys during thermal oxidation. This process allows precise control over structures with high Ge content which would otherwise not be attainable by 2D growth.

In this work, we use an ultra-thin Si top layer (around 10nm thick). SiGe layers are epitaxially grown on this SOI substrate by MBE and are then thermally oxidized at high temperature to produce an enriched SiGe layer. Typically, the epitaxial SiGe has a Ge content around 10% and after oxidation and high temperature anneal we obtain a fully relaxed homogeneous SiGe layer on insulator with higher Ge content (30%). During the thermal treatment, the Ge content is homogenized between the SiGe layer and the Silicon On Insulator (SOI) layer. At the end the process a fully relaxed SiGe layer, perfectly flat, with a homogeneous Ge concentration around 30% is obtained. Advanced transmission electron microscopy is used to characterize the structure, strain and composition of obtained layers.

Si re-epitaxy on top of this SGOI layer would produce Si tensile-strained layers which could be used as active layer for devices fabrication.

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