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Material Session

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Biography
Johan Dekoster received the M.S. degree in Exact Sciences (Physics) in 1988 from the KU Leuven, Belgium. In 1993 he received the Ph.D. degree (Physics), also from the KU Leuven. From 1993 till 1999 he held postdoctoral fellowships from the Research Council and the Fund for Scientific Research at the Institute of Nuclear and Radiation Physics of the KU Leuven. In 1999 he joined the OTN business unit of Siemens. He was project leader for several development projects for data, voice, video and LAN. In 2007 he became program manager OTN at Nokia Siemens Networks. In April 2008 he joined imec as R&D manager of the Epitaxy group with responsibility on epitaxial deposition of group IV and III-V semiconductor materials. Since November 2012 he is program manager of the equipment and materials suppliers collaborations within the Semiconductor Technology and Systems unit at imec.

Molecular self-assembly from liquids on atomically flat surfaces: from fundamentals to applications

B. Hirsch
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Abstract
Nanostructured monolayers of molecules can be formed at a variety of interfaces. At a liquid-solid interface, such two-dimensional (2D) molecular assemblies can be created by depositing a solution of the compound of interest on top of the substrate (drop casting) or by immersing the substrate into a solution (dip coating). Advanced interfacial analysis methods such as scanning tunneling microscopy (STM) and atomic force microscopy (AFM) provide nanoscale structural information of the assemblies.

In this presentation, we focus on several aspects of molecular self-assembly at the interface between liquid or air, and surface substrates such as highly oriented pyrolytic graphite and graphene. Highly oriented pyrolytic graphite can be considered as excellent model surface for adsorption and self-assembly of molecules on graphene. We will reveal novel concepts of 2D

crystal engineering including the effects of solvent, solute concentration, temperature, and other external stimuli. Self-assembly controlled under nanoconfinement conditions also delivers insight into thermodynamic and kinetics aspects of these systems.

We will demonstrate molecular self-assembly based functionalization of graphite and graphene. Various applications will also be presented.

Biografie
Brandon E. Hirsch obtained his Ph.D. in physical and materials chemistry in 2016 from Indiana University (USA) under the supervision of Professor Steven L. Tait and Amar H. Flood. His doctoral work focused on the investigation of stimuli-dependent surface confined supramolecular self-assemblies. Currently, he is a post-doctoral fellow at KU Leuven in the De Feyter group where his research involves chemisorption on graphene surfaces.

2D and graphene - Status of the Graphene Flagship and the potential applications

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Abstract
With a budget of €1 billion, the Graphene Flagship forms Europe's biggest ever research initiative. The Graphene Flagship is tasked with bringing together academic and industrial researchers to take graphene from the realm of academic laboratories into European society in the space of 10 years, thus generating economic growth, new jobs and new opportunities. The core consortium consists of over 150 academic and industrial research groups in 23 countries. The Graphene Flagship is implemented as four divisions and a total of 15 research Work Packages. A brief overview of these work packages and the related innovation activities is given. The most promising application areas are also discussed.

The excellency in science and technology for graphene and related 2d materials developed within the Graphene Flagship pave the way for future innovations and applications. While the main graphene applications are still several years into the future, there are already a number of promising emerging application areas and concrete advances towards commercialization. These include the latest developments in the work packages for electronic devices, photonics and optoelectronics, flexible electronics and wafer-scale system integration.

Biografie
Kari Hjelt, Head of Innovation, Graphene Flagship
PhD (Eng.), MBA

Kari Hjelt has extensive experience in ICT and over 15 years career in corporate venturing and research. At Nokia he established a number of ventures and two research laboratories. His last tenure at Nokia was Director, Research Innovations. Since then he has been a co-founder and advisor to several high-tech SMEs. He currently works in Graphene Flagship as the Head of Innovation and is a member of the Management Panel and the Executive Board.

He received his PhD in 1997 with “Photoluminescence and growth of compound semiconductors” from Helsinki University of Technology. He earned his Executive MBA from London Business School in 2010. Kari holds 7 patents and has published 40+ reviewed publications.

Advanced materials processing with ALD and CVD precursors

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Abstract
Chemical vapor deposition and its more recent offspring Atomic Layer deposition are workhorse technologies for thin film deposition in the semiconductor industry. The critical dimension shrinkage and the move to ever more aggressive wafer topography is further accelerating the adoption of CVD and more particularly of ALD processes, owing to its capability to deposit perfectly conformal films, whether conductive or dielectric. The versatility of the technology has also enabled the introduction of multiple elements and materials in advanced chips, and of multiple flavors of well know material like SiO or SiN to meet specific integration needs.
While hardware engineers worked on tool improvements to extend CVD capabilities and make ALD production worthy, a new breed of process chemists started designing molecules to meet process and integration challenges from the chemistry angle. Such challenges were generally related to at least one of the following aspect: a- decreasing thermal budgets, b- the need for highly conformal films, c- the need for films with more extreme electrical properties (higher k, lower k, lower resistivity, better EM barriers), and the need for ancillary and sacrificial films to support complex lithography schemes.
Addressing these challenges means resolving a multivariable equation of finding in time a molecule that meets all requirements related to process performance, scalability, safety, and affordability.
The presentation will illustrate through a few examples how chemical innovation has enabled recent advances in chip manufacturing, such as the tuning the ligands of a molecule to facilitate it’s delivery, or the design of a brand new substance to double the throughput of SiO2 ALD in multiple patterning schemes.

Biografie
Jean-Marc Girard graduated from the Ecole Normale Superieure de Lyon in 1992 and holds a PhD in plasma physics from the CEA (French nuclear research institute). Joining Air Liquide in 1995, he held different R&D management positions in Europe and Japan, all related to semiconductor materials and applications. In 2002 he became Marketing Manager for Advanced Semiconductor Materials, and founded in 2005 the ALOHA™ ALD/CVD precursor product line, which he managed until 2010. Thereon, as CTO of the Electronics World Business Line and Air Liquide Fellow, Jean-Marc contributed to the acquisition and merger of Voltaix with the ALOHA organization to create Air Liquide Advanced Materials. Now CTO and Director of R&D, Jean-Marc's role is to define the technology roadmap, the IP and the collaboration strategy of Air Liquide Advanced Materials, to drive the associated R&D and to manage the product development execution.

III-V selective area growth on Si: from Logic to Photonic applications

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Abstract
Driven by fabrication cost reduction and device performance improvement, the Silicon semiconductor industry continues its never-ending pursuit of new approaches for fabricating integrated circuits. In this context, the monolithic integration of III-V semiconductors epitaxially grown on Si substrate have been attracting much attention as building blocks for next-generation electronics and photonics due to their potential intrinsic properties.
Direct heteroepitaxy of III-V compound semiconductors on Si has traditionally represented a formidable challenge, due to the high material mismatch (lattice parameter, polarity, thermal coefficient, ...) between Si and III-V semiconductors generating high density of defect density during the epitaxial process. To overcome this, selective area growth of III-Vs in a pre-patterned Si substrate by Selective Area Metal-Organic Vapor Phase Epitaxy allow the possibility to obtain high quality and reduced defect density III-V based active layers onto standard Si(001) substrate.
Using this approach we integrate III-V materials monolithically on Si while focusing on both ultimate trench widths (W < 20 nm) scaling as well as relaxed trench dimension in function of the targeted application. We report here on the heteroepitaxy of InP buffer on initiated from a < 111 > V-groove Si surface and discuss the unique relaxation mechanism of such compound with respect to Si substrate. We derived a fundamental understanding and theoretical modeling of the growth mechanisms in STI trenches as well as the determining role of the InP nucleation layer. The subsequent growth approach of InGaAs active layer, used for both nFET or Laser applications, is further studied.
Finally, III-V based electronic and photonic devices realized using selective area growth technique are presented and benchmarked to the current state of the art.

Biografie
Clement MERCKLING received the Dipl.-Ing. degree in Microelectronics in 2004 from the Superior Institute of Electronic and Numeric (ISEN) and the M. S. degree in Material Sciences in 2004 from the University of Lille. He obtained his Ph. D. graduation in Material Sciences from the Ecole Centrale de Lyon in 2007. His researches were focused on the Molecular Beam Epitaxial (MBE) growth of High-k dielectrics on Si for CMOS devices. In 2007, as postdoctoral research associate from the Katholieke Universiteit of Leuven, he joined IMEC Ge/III-V program. During the period 2008 - 2013, he was research and then senior scientist at IMEC, driving the Molecular Beam Epitaxy (MBE) activities including III-V semiconductors epitaxy, high-k oxides growth and high-□ channels (Ge, III-As, III-P & III-Sb) passivation studies. Since 2013, as a principle scientist, he took responsibility of all Group III-V epitaxy activities, focusing on selective area growth of III-V compounds by Vapor Phase Epitaxy (MOVPE), key step for future CMOS technology nodes. He is the author or co-author of more than 100 papers in scientific journals and more than 120 contributions to international conferences. He received in 2008 the “Young Scientist Award” from the City of Lyon as well as the Researcher (CR2) CNRS entrance exam from France.

Hot-Wire Assisted ALD: From Idea to Realization

A. Kovalgin
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Abstract
Atomic Layer Deposition (ALD) was conventionally developed as a purely thermal process to deposit two-element films such as oxides and nitrides. ALD of single-element films (metals and semiconductors), with a few exceptions, is still a difficult task. Plasma-enhanced ALD (PEALD) can enable deposition of certain single-element films but has a reduced step coverage compared to thermal ALD, can cause damage to the wafer under treatment and involve a large variety of chemical reactions. As a result, the wafer surface may be exposed to many ions, radicals and atoms, as well as UV photons. This makes the composition and structure of the growing film not trivial to predict and control.

This work explores alternative techniques to generate radicals without plasma. We choose processes where dissociation of a certain precursor, to form radicals, can be achieved by collisions with a hot tungsten wire heated up to a temperature in the range of 1600-2000 oC. We use in situ real-time spectroscopic ellipsometry in combination with ex-situ techniques, to characterize deposition. The successful generation of atomic hydrogen (at-H) by the hot wire and its delivery to the substrate over a distance of 70 cm have been confirmed by etching of tellurium (Te) films at room temperature.

In this presentation, the concept will be explained and discussed; several examples of the radical-enhanced processes, enabled by utilizing a hot wire instead of using a plasma, will be given. The main example concerns hot-wire atomic layer deposition (HWALD) of tungsten (W) films. The films were grown on a 100-nm thick thermal SiO2 with a proper seed layer. Two different reactor configurations were employed: a large-volume reactor (70 cm distance between the HW and the substrate) and a small-volume reactor (3-5 cm distance between the HW and the substrate). In my presentation, I will further look into the chemistry behind these and other examples.

Biografie
Alexey Y. Kovalgin obtained the M.Sc. degree in Physics in 1988 and the Ph.D. degree in Electronic Materials Technology in 1995. He is currently an Associate Professor with the Chair of Semiconductor Components, University of Twente, The Netherlands. His fields of expertise include Chemical Vapor Deposition (CVD), Plasma Enhanced CVD, Atomic Layer Deposition (ALD), Hot-wire ALD, growth and investigation of 2D materials (silicene, graphene), properties of ultra-thin (metallic) films, chemical modelling of plasma reactors containing silane, semiconductor device fabrication at low temperatures; CMOS post-processing, contact resistance of metal-to-semiconductor junctions, and low-power hot-surface silicon devices for chemical sensors and micro-reactors. He has contributed to over 160 reviewed international journal and conference papers.

Dr. Kovalgin has been a reviewer of 20 international journals, leader of 6 scientific projects, member of the editorial board of The Open Electrical & Electronic Engineering Journal, Journal of Recent Patents on Electrical Engineering, jury member of STW VENI 2010 program and two Open Technology Programs (NL), international jury member of Romanian Evaluation Process in 2012, International Board Member of EUROCVD conference and Technical Program Committee member of ICMTS conference. He is the main lecturer of 2 Master courses at the University of Twente, and is strongly involved into the Problem-Based Learning approach of the bachelor

education since last 2 years.

Atomic Layer Deposition and Etching of Thin Films - Research and Application

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Abstract
The continuing down-scaling of dimensions in modern microelectronics as well as a huge number of applications beyond semiconductor technology lead to an increasing need for advanced deposition and etching technologies. Atomic Layer Deposition (ALD) is a method for thin film deposition, which is based on self-limiting monolayer by monolayer growth. ALD offers outstanding process properties like excellent step-coverage, film thickness control in the sub-nm range, pore-free deposition as well as a high thickness uniformity over large area substrates. Complementary to ALD, Atomic Layer Etching technology (ALE) removes material monolayer by monolayer. Like in ALD, sequential self-limiting surface reactions play a crucial role and potentially result in sub-nm etch depth control and a high anisotropy of etching.
In our presentation we will give an overview of research and applications for both ALD and ALE technology. Based on experiences and possibilities at IHM and ALD Lab Saxony we will present selected results on ALD or ALE for e.g. device encapsulation, through silicon via, organic field effect transistors, 3D structures or memory devices. Thereby, a key component is the application of in situ and in vacuo metrology, which enables a detailed understanding of growth or etching processes.

Biografie
Christoph Hossbach obtained the M.Sc. degree in Electrical Engineering in 2005 and the Ph.D. degree in Electrical Engineering in 2013. He is currently a Senior Scientist at the Institute of Semiconductors and Microsystems of Technische Universität Dresden, Germany. His fields of expertise include Atomic Layer Deposition (ALD), Plasma Enhanced ALD, Molecular Layer Deposition (MLD), Chemical Vapor Deposition (CVD), Plasma Enhanced CVD, process, film and growth characterization with in situ and ex situ metrology, as well as tool and component design. Dr. Hossbach is co-founder and university representative of science network ALD Lab Saxony. He is author or co-author in more than 30 publications and involved in organization of workshops, teaching and consulting.

Development of block copolymers to create complex

M. Morris
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AMBER, Trinity College Dublin, Chemistry, Dublin, Ireland

Abstract
The development of block copolymer self-assembly techniques as on-chip lithographic masks can provide methods to form regular nanopatterned substrates. Block copolymer (BCP) lithography is nearing a point where it could be transferred into industrial fabrication and complement traditional UV and E(xtreme)UV lithographies. As feature sizes decrease, pattern transfer from an etch mask to the substrate is becoming more critical. Thus, whilst BCP based methods can yield ultra-small feature sizes, can they be used to create hi-fidelity, hi-quality silicon features? Here we show that BCP methods can be used to create patterns of inorganic oxides on a substrate that can act as hard masks. These materials should have high etch contrast (to silicon) and so allow high aspect, high fidelity pattern transfer whilst being readily integrateable in modern semiconductor fabrication (FAB friendly). Here, we show that ultra-small dimension hard masks can be used to develop large areas of densely packed vertically and horizontally orientated Si nanowire arrays. Ni, NiO and ZnO hard masks of different morphologies and dimensions were formed using microphase separated polystyrene-b-poly(ethylene oxide) (PS-b-PEO) block copolymer (BCP) thin films. The self-assembled polymer patterns were solvent processed and metal ions included into chosen domains via a selective inclusion method and subsequent inorganic oxide nanopatterns were developed using standard techniques. It is shown by high resolution transmission electron microscopy studies that high aspect pattern transfer could be affected by standard plasma etch techniques. The masking ability of the different materials was compared in order to create the highest quality uniform and smooth sidewall profile of the Si nanowire arrays. Notably, good performance of metal masks were seen and this could impact the use of these materials at small dimension sizes where conventional methods are severely limited.

Biografie
Prof Michael Morris is the Director of AMBER and Professor of Surface and Interface Chemistry at Trinity College Dublin. AMBER is the national material research centre and is co-funded by government and industry to provide disruptive science into industry partners. Prof. Morris was at University College Cork for over 20 years before moving to Trinity and he retains a research group in Cork and the Tyndall National Institute. He has worked in the area of self-assembly for over 20 years and has published over 200 papers in this area. These self-assembly methods have been used to generate ultra-low dielectric constant thin films and create nanowires and nanowire arrays. His current work focuses on the development of block copolymer techniques to nanopattern surfaces for electronic device applications. Prof. Morris has also applied some of these techniques to the development of food packaging materials in both film and membrane form where nanopatterns can improve antimicrobial and hydrophobic properties of polymers. Prof. Morris is a partner on the EU sponsored PLACYD programme aiming to insert block copolymer lithography into device fabrication. Prof. Morris has worked closely with collaborators at Intel both in Ireland and in Components Research in Portland. He also works with a number of other industrial partners including, Alcatel-Lucent, Merck Millipore and Glantreo in examining how inexpensive nanopatterning and nanostructure may be used in other applications which include advanced surface cooling and antimicrobial surfaces.