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TechARENA: Advanced Materials Session1

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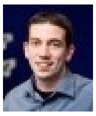
ASM

Biography

Hessel Sprey received his M.Sc. in experimental physics from the University of Leiden (The Netherlands) in
1989, and joined ASM in 1990. He has been active in equipment and process R&D at various ASM locations
for almost all of ASM product lines, since 1996 in project and team leader positions. He has been project and workpackage leader for several European projects, is (co-)author of more than 60 scientific papers and conference contributions on deposition processes, equipment and applications, and holds 12 patents and patent applications. He is currently responsible for the coordination of ASM's External R&D activities and cooperative programs.

Area-selective atomic layer deposition for self-aligned fabrication



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Abstract

Because nanomanufacturing using conventional top-down processing based on photolithography and etching is becoming extremely challenging at sub-10 nm dimensions, there is currently a strong desire in the semiconductor industry to move towards self-aligned and bottom-up fabrication schemes. Area-selective atomic layer deposition (ALD) aims at the deposition of material only on specific surfaces, and therefore has the potential to eliminate alignment issues, while reducing the number of required lithography steps.

In this presentation, several approaches for achieving area-selective ALD will be presented and discussed. Special attention will be given to a recently developed method based on using inhibitor molecules in ABC-type ALD cycles. In this method, an inhibitor molecule is chosen that selectively adsorbs on specific materials, and subsequently blocks the precursor adsorption, resulting in area-selective deposition on those materials on which the inhibitor does not adsorb. It will be shown that an ALD process consisting of acetylacetone inhibitor, bis(diethylamino)silane precursor, and O_2 plasma pulses, enables area-selective ALD of SiO_2 on for example GeO_2, SiN_x, or WO_x, without coating Al_2O_3, HfO_2, or TiO_2. The opportunities for using such an area-selective ALD process in self-aligned fabrication schemes will be discussed.

Biografie
Adrie Mackus (1985) is an assistant professor in Applied Physics at Eindhoven University of Technology, TU/e. He earned his M.Sc. and Ph.D. degrees (both cum laude) in Applied Physics from TU/e in 2009 and 2013, respectively. Adrie worked as a postdoc at the department of Chemical Engineering at Stanford University in 2014-2015, after which he returned to TU/e in 2016. His research covers the field of thin film deposition by atomic layer deposition (ALD) for applications in nanoelectronics, with the focus on area-selective deposition and on the study of the underlying reaction mechanisms.

Epitaxial Growth of Low Defect SiGe Buffer Layers for Integration of New Materials on 300 mm Silicon Wafers

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Abstract

Strain-relaxed SiGe buffer layers are attracting renewed interest as an important platform for integration of high-mobility channel materials in advanced CMOS device nodes. A number of options are explored to either extend the life of FinFETs or use GAA devices. Different approaches are under investigation involving monolithic integration of SiGe, Ge and III-V materials. A common challenge is the need to manage layer strain and crystal defects especially misfit and threading dislocations. The relaxed SiGe lattice can be used to combine control of strain in the active areas with low defect density and is therefore attractive as starting template for strained-layer growth. The various aspects of epitaxial growth of strain-relaxed SiGe buffer layers with different Ge Content on 300mm wafers will be discussed.

Biografie

Peter Storck received his PhD in Physical Chemistry from the TU Darmstadt, Germany, and has more than 20 years of experience in semiconductor epitaxy. Starting in 1996, he worked three years for Wacker Siltronic in Portland, Oregon, focusing on Epi process technology for Power Applications. From 1999 to 2003, he was responsible for the start-up of 300mm Epi technology at Siltronic, Germany. Since 2004 he is the manager of Siltronic’s Innovation Projects group developing advanced materials. His research topics include Si, SiGe, rare-earth oxide and III-N epitaxy. He is the author or co-author of more than 40 publications and 20 patents.

Solmates Pulsed Laser Deposition systems enable the integration of critical novel thin film materials for the MEMS & 5G market

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Abstract
Solmates is increasing its installed base of PLD systems worldwide at well-established research institutes and noted CMOS, MEMS and Sensors manufactures. After the introduction of Atomic Layer Deposition in thin film manufacturing it is now Solmates PLD to challenge the limits of thin film deposition of novel materials in a production environment.

It is well known that Pulsed Laser Deposition (PLD) is a very flexible and versatile technique allowing fast optimization of new and complex material thin films. The unique features of PLD allow for the integration of “Beyond Moore” materials in CMOS, MEMS and sensors. Up to now, the developed materials and processes in PLD only just make it into demonstrator devices. In order to make it into commercial applications, next generation PLD equipment is needed to bridge the gap between demonstrator and the prototype to production.

Since 2006 Solmates developed PLD systems for large substrate dimensions and stable processing. The current Solmates PLD platform is the next step beyond fundamental PLD research. The reliable hardware is flexible for fast process optimization and allows uniform thin film deposition up to 200 mm wafers or 200 mm2 glass panels with high reproducibility. The automated software ensures easy operation and stable performance. These characteristics enable the integration of PLD thin films in applications for (pilot) production and commercialization.

In this contribution the Solmates core technology will be presented. As a first example wafer-level integration of epitaxial PZT and PMN-PT thin films on silicon is demonstrated. The results of this work are the first milestone in the development of a piezoelectric memory.
In another example, the PZT is integrated in silicon photonics for strain-optical modulators. These devices are a key component for phased-array antennas that will enable 5G data communication. Production of these devices that rely on PLD-deposited piezo materials is scheduled for 2019.

Biografie
Solmates is a fast growing and ambitious OEM company, with its mission to position PLD as a mainstream deposition technology equal to ALD and sputtering.

Solmates is a spin-off company of the MESA+ Institute for Nanotechnology, located at Science Park Twente, in Enschede, the Netherlands. It was founded from a specialized PLD research group (IMS) chaired by prof. Dave Blank and prof. Guus Rijnders. Its employees are highly recognized specialists in PLD of which many have a semiconductor industry background.

Since Solmates was established in 2007 it has generated multiple patents and has brought pulsed laser deposition from lab scale to production level. Currently Solmates has over half a dozen development and pilot production systems running at various customers worldwide.

Arjen Janssens is responsible for the overall leadership and strategy of the company. He started his career as strategic consultant at Arthur D. Little, after one year he became shareholder and consultant of Quintel Management Consultancy (spin-out of Arthur D. Little). In 2004 he enrolled into his PhD. at the University of Twente focussing on Piezo materials and pulsed laser deposition. During his PhD. he assisted MESA+ in business development, completed the Executive MBA at TSM business school of technology, and co-founded Solmates.

END-OF-CMOS AND BEYOND CMOS, APPLICATIONS FOR ALE

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Abstract

The continuous increment of pattern density with the aim of following Moore's law has brought many challenges to the integration processes involved in the manufacturing of integrated circuits (IC). Specifically, sub-N7 technologies require self-aligned processes to overcome lithography overlay (OVL) limitations. Atomic layer etch (ALE) or quasi-ALE approaches provide the means to develop high selective and self-aligned etch processes. For example, the patterning of contact to active in a N7 technology faced tight OVL requirements and tough litho-etch bias restrictions. These issues were solved thanks to a quasi-ALE process.

In semiconductor technology roadmap, the usage of 2D (MX2) materials is foreseen as an alternative to Si, Ge, SiGe and III-V channels. The integration of 2D materials in a hetero-structure such as required by a tunneling field effect transistor (TFET) will bring etch challenges; for example:

a) selective etch of Silicon and dielectrics to MX2.
b) layer-by-layer etch of MX2 (MX2 thinning).

In a first part, this presentation will cover some patterning approaches where quasi-ALE was successfully used. In a second part, the emphasis will be put on the etch challenges driven by the integration of 2D materials for future technology nodes, and how ALE can enable it.

Biografie

Efraín Altamirano-Sánchez is a Chemical Engineer and holds a PhD from the Metropolitan University of Mexico (UAM). He has more than 15 years of experience in nanotechnology R&D in Europe. He joined imec in 2006, where he holds a Principal position (PMTS). He is a specialist on Front-End-of-Line (FEOL) and Middle-of-Line (MOL) patterning. His current interest is focused on multiple patterning using either 193i or EUV lithography, selective deposition and Atomic-Layer-Etch.

All-printed thin-film transistors from networks of liquid-exfoliated nanosheets

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Abstract

The development of printed electronics (PE) is becoming increasingly important, with much research focusing on new materials. A number of material sets have been studied, including organics, inorganic nanoparticles and nanotube/nanowire networks. High operating voltages (up to 50V), low mobility (< 10 cm2/Vs) and poor current injection are still challenges for organic thin film transistors (OTFTs). Networks of inorganic nanoparticles or nanotubes have demonstrated mobilities and on:off ratios of >10 cm2/Vs and >106 respectively, but may face problems with scalability and integration. These problems have led a number of researchers in the field of 2D materials to attempt to produce printed transistors where the channel material is a network of semiconducting nanosheets. Because of the relatively high mobility of 2D materials, such a network might display mobilities which are competitive or even superior to those achievable with printed organics. In addition, one could envisage all-printed transistors consisting of interconnected networks of semiconducting, conducting and insulating 2D nanosheets. However, switchable nanosheet networks have not been demonstrated. Here, using electrolytic-gating, we demonstrate all-printed, vertically-stacked transistors with graphene source, drain and gate electrodes, a transition metal dichalcogenide channel and a BN separator, all formed from nanosheet networks. The BN network contains an ionic liquid within its porous interior that allows electrolytic gating in a solid-like structure. Nanosheet network channels display on-off ratios of up to 600, transconductances exceeding 5 mS and mobilities of >0.1 centimeters squared per volt per second. The on-currents scaled with network thickness and volumetric capacitance as well as the network mobility. In contrast to other devices with comparable mobility, large capacitances, while hindering switching speeds, allow these devices to carry higher currents at relatively low drive voltages.

Biografie

Jonathan Coleman is the Professor of Chemical Physics in the School of Physics and the CRANN and AMBER Research centres, all at Trinity College Dublin. His research involves liquid exfoliation of layered compounds such as graphene, boron nitride and molybdenum disulphide. Exfoliation of these materials gives 2D nanosheets which can easily be processed into thin films or composites from applications from energy storage to sensing to electronics. He has published approximately 250 papers in international journals including Nature and Science, has a h-index of 72 and has been cited ~30000 times. He was recently listed by Thomson Reuters among the world's top 100 materials scientists of the last decade and was named as the Science Foundation Ireland researcher of the Year in 2011. Prof Coleman has been involved in a number of industry-academic collaborative projects with companies including Hewlett-Packard, Intel, SAB Miller, Nokia-Bell Labs and Thomas Swan.

Simulating mechanism at the atomic-scale for atomically precise deposition and etching

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Abstract

Ongoing scaling in the semiconductor industry is increasingly dependent on the rapid introduction of processes for novel materials at sub-nanometre precision - every atom counts. To solve many of these processing challenges the industry is looking to atomic layer deposition (ALD) and atomic layer etch (ALE), and especially to area-selective versions of these processes that can add or remove material only from the substrate of choice. Some important advances have recently been made in area-selective ALD and substrate-selective thermal ALE, but this research has also illustrated how our lack of understanding hampers development.

Here we present our recent computational studies of area-selective deposition of Si-based materials and of the mechanism of ALE of oxides, using density functional theory to establish the chemical mechanism, limiting factors and growth/etch rates. In particular, we compute relative reaction kinetics on various substrates, which ultimately determines selectivity. We illustrate how simulations can narrow down options for laboratory studies and provide mechanistic insight that is difficult to deduce experimentally, thus helping to accelerate the introduction of novel processes.

Biografie

Dr Simon Elliott leads the Materials Modelling for Devices group at Tyndall National Institute, Ireland. He studied chemistry in Trinity College Dublin (B. A. Mod., 1995) and theoretical chemistry in Karlsruhe Institute of Technology (Dr. rer. nat., 1999), and carried out postdoctoral research in Trinity College (1999-2001) before joining Tyndall in 2001. He has 75 publications, has been an invited speaker at meetings of the American Vacuum Society, Electrochemical Society, European Materials Research Society, China-ALD and American, Canadian and Finnish chemical societies, as well as communicating science to wider audiences on TV, radio, stage and online. He is a Fellow of the Royal Society of Chemistry and a member of the Project Management Institute. He was co-chair of the 16th International Conference on Atomic Layer Deposition (2016) and is chair of the European COST Action on ALD (2014-2018).