DS 22: Trends in atomic layer deposition I (Focused session – Organizer: Nielsch)

Time: Wednesday 15:00–17:15 Location: H 0111

Invited Talk DS 22.1 Wed 15:00 H 0111
Trends in Atomic Layer Deposition — •Helmut Baumgart — Dept. of Electrical and Computer Engineering, Old Dominion University, Norfolk, Virginia 53529, USA — Applied Research Center at Thomas Jefferson National Accelerator Labs, Newport News, Virginia 23606, USA

Atomic Layer Deposition (ALD) is recognized by the International Technology Roadmap for Semiconductors (ITRS) as the preferred method to deposit technologically important thin films of novel high-k dielectric metal oxides or semiconducting metal oxides for CMOS and MEMS technology with Angstrom accuracy. ALD has been accepted by the microelectronics industry for mainstream Integrated Circuit (IC) processing technology primarily for high-k and metal gate stack engineering and DRAM capacitor development. Continuous device scaling serves as the technology driver and the trend is to develop very high-k oxides by ALD such as perovskites for future applications. In order to extend Moore*s Law another trend in CMOS technology is the increased interest in 3-D devices such as FIN-FETs and nanowire MOSFETs, which call for ALD technology for the realization of Gate-All-Around structures. There is an increasing demand for new and more complex nano-scaled films that are deposited with uniform composition, high conformality and superior thickness accuracy over increasingly severe surface topographies with high aspect ratios. An overview of recent trends in ALD thin film technology will be presented with examples in IC and non IC applications.

Topical Talk DS 22.2 Wed 15:30 H 0111
Energy conversion devices made using ALD — •Julien Bachmann — University of Hamburg, Hamburg, Germany

The interconversion of solar, electrical, and chemical forms of energy relies on the separation and recombination of charge carriers at interfaces. Because the transport of electrons, holes, and ions to and from the interface may be the factor limiting the overall device efficiency, nanostructuring often serves to increase the specific surface area of a device without elongating the diffusion distances excessively. The unique ability of atomic layer deposition to coat substrates of complex geometries — highly porous ones in particular — makes it particularly suited to the preparation of model systems in which to study the influence of geometric parameters on the efficiency of energy conversion devices.

We applied ALD to the creation of extremely thin antimony sulfide absorber layers in solar cells based on nanocrystalline titanium oxide. As a result, we were able to found an optimal thickness of the intrinsic absorber which maximizes the photovoltaic efficiency. In the area of electrolysis, we established the preparation of structured iron oxide surfaces the specific area of which is defined by cylindrical pores. The current density obtained for the oxidation of water at such electrodes depends on pore length and diameter linearly.

Topical Talk DS 22.3 Wed 16:00 H 0111
Role of substrate chemistry in ALD revealed by in-situ techniques — •Massimo Tallarida, Marcel Michling, Chittaranjan Das, Daniel Friedrich, Matthias Städter, and Dieter Schmeisser — Brandenburgische Technische Universität Cottbus, Konrad-Wachsmann-Allee 17, 03046 Cottbus, Germany

We show recent results of our in-situ investigations where the role of substrate chemistry in ALD is outlined. While the usual strategy to develop new properties of ALD films is to find new precursors or new procedures, the influence of substrate chemistry on the growth properties of ALD films has been often underestimated. This has principally a technical reason, as the usual characterization methods (QMS, FTIR, ellipsometry) are only weakly sensitive to the substrate, and a characterization of substrates before ALD is often not possible. Thanks to the use of in-situ characterization methods, including photoemission and X-ray absorption spectroscopy with synchrotron radiation, we are able to determine chemical properties of substrates before ALD and after either half or complete ALD cycles. The substrate chemistry influences the standard Al_2O_3 ALD with TMA and water [1,2], as well as the TiO_2 ALD with TTIP and either water, O_2 or O_2-plasma.

[1] M. Tallarida, K. Kukli, M. Michling, M. Ritala, M. Leskelä and D. Schmeisser, Chem. Mater. **23**, 3159 (2011);
[2] M. Tallarida, C. Adelmann, A. Delabie, S. van Elshocht, M. Caymax, and D. Schmeisser, Appl. Phys. Lett. **92**, 042906 (2011).

DS 22.4 Wed 16:30 H 0111
Highly Efficient Embedded Transmission Gratings — Stephan Ratzsch[1], •Frank Fuchs[2], Adriana Viorica Szeghalmi[1], Ernst-Bernhard Kley[1], and Andreas Tünnermann[2] — [1]Institut für Angewandte Physik, Friedrich-Schiller-Universität Jena, 07745 Jena — [2]Institut für optische Feinwerktechnik, Fraunhofer-Gesellschaft, 07745 Jena

We present a new approach for realization of a highly efficient transmission grating for TM polarized light operating at 1030 nm wavelength. It had been theoretically shown that it is possible to reach 100 % diffraction efficiency for a fused silica grating embedded within a high refractive index material. High quality, homogenous and void free coatings are required to achieve high optical efficiency. Plasma enhanced atomic layer deposition (PEALD) meets the enormous demands posed by these embedded gratings; however, film thickness homogeneity (less than 2% non-uniformity) and low surface roughness are essential. Titanium (IV) oxide (TiO2) is a potential candidate for the high index embedding material because of its adequate optical properties in the near infrared spectral range. The grating parameters (period, height, line width, etc.) have been optimized by rigorous coupled wave analysis (RCWA). These parameters depend on the refractive index of the titania layer. Therefore the refractive index and extinction should be precisely controlled. The refractive index of titania deposited by thermal ALD processes is generally highly sensitive to the temperature of the substrate. In contrast, the titania films produced by PEALD between 80°C and 210°C have a high refractive index.

DS 22.5 Wed 16:45 H 0111
Optical applications of atomic layer deposition thin films — •Adriana Szeghalmi[1], Thomas Weber[1], Mato Knez[2], Ernst Bernhard Kley[1], and Andreas Tünnermann[1] — [1]Institute of Applied Physics, Friedrich Schiller University, Jena, Germany — [2]Max-Planck Institute of Microstructure Physics, Halle (Saale) Germany

Thin films produced by atomic layer deposition (ALD) are very promising optical layers for the development of highly efficient optics. Here, a broad overview of optical elements developed based on ALD thin films and multilayers will be presented. ALD nanolaminates with a period below 10 nm have very low interlayer diffusion and roughness and can be applied as X-ray mirrors. Nanostructured optical elements can highly benefit of conformal ALD coatings. Metal wire polarizer elements for UV applications with high polarization extinction ratio at ca. 250 nm wavelength have been obtained by a frequency doubling technique using ALD deposition of iridium. Coating high aspect ratio linear gratings with high refractive index dielectric materials, guided mode resonance grating (GMRG) optics can be easily achieved. These resonant waveguides respond by a large spectral shift of the guided mode resonance peak in the reflectance or transmittance spectra to changes of the local dielectric environment. These elements find application as filters, mirrors, sensors, etc. The optical properties and sensitivity of GMRG optics have been optimized by rigorous coupled wave approach calculations. Using highly sensitive GMRG elements, the ALD growth of sub-nanometer thin films has been monitored in situ for the first time.

DS 22.6 Wed 17:00 H 0111
Templated ALD for Synthesis of Magnetic Nanotube Suspensions — •Robert Zierold[1], Zhenyu Wu[2], Carl E. Krill III[2], and Kornelius Nielsch[1] — [1]University of Hamburg — [2]Ulm University

Commercial ferrofluids usually consist of spherical, superparamagnetic nanoparticles suspended in a carrier liquid. The application of an external magnetic field, however, can trigger network formation and a concomitant increase in the liquid's viscosity—its so-called *magneto-viscosity*. Herein, we show how magnetic nanotubes can be prepared by ALD in porous alumina templates. In this process, the iron oxide deposited from the reaction of ferrocene with ozone is sandwiched between two silica layers (APTES, water, ozone) for protective reasons. The combination of a template, the sub-nm layer thickness control afforded by ALD, and proper adjustment of the H_2 reduction parameters for the converting amorphous iron oxide to magnetite allow the experimentalist to tailor all geometric tube parameters (length, diameter, wall thickness) as well as the type of magnetism manifested by the nanotubes—superparamagnetism/ferromagnetism. Viscosity measurements performed on mixtures of commercial ferrofluids (consisting of spherical particles) with nanotubes reveal a significant enhancement in the strength of the magnetoviscous effect compared to samples without additives. The different fluid-mechanical properties of such *hybrid* ferrofluids might pave the way for new engineering applications.

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