ALD Applications
Room Plaza F - Session AA+AF-TuM

Displays and Flexible Applications (8:00-10:00 am)/ALD Fundamentals: In-Situ Monitoring and Analysis (10:45 am-12:00 pm)

Moderators: Hyungjun Kim, Yonsei University, Korea, Jin-Seong Park, Hanyang University, Han-Jin Lim, Samsung Electronics, Tom Knisley, Applied Materials

8:00am **AA+AF-TuM-1 Functional Materials using Atomic Layer Deposition for Emerging Display Applications***, **Jin-Seong Park,*** Hanyang University, Republic of Korea **INVITED**

Atomic Layer Deposition (ALD) has remarkably developed in semiconductor and nano-structure applications since early 1990. The unique properties, including controlling atomic-level-thickness, manipulating atomic-level-composition control, and depositing impurity-free films uniformly, may accelerate ALD related industries and applications in functional thin film markets. One of big commercial industries, display market, just starts to look at the potential to adopt various functional inorganic/organic/hybrid films based on ALD/molecular layer deposition (MLD) techniques in emerging applications, such as transparent, flexible, and wearable electronics.

In this talk, I will take the brief emerging display market trend and forecast to understand what they are looking for. In fact, the AMOLED (active matrix organic light emitting diode) Television markets are just starting at early 2013. There are a few possibilities and needs to be developing for AMOLED, flexible and transparent Display markets. Then, firstly, the functional oxide conductor/semiconductor films deposited by ALD will be discussed for applying transparent conductor and thin film transistor as an active layer even on flexible substrates, including InOx, SnOx, ZnSnO, and InZnOx. Secondly, functional oxide and organic thin films, deposited by ALD/MLD have been demonstrated in emerging applications (flexible, transparent, and wearable things). In particular gas diffusion barrier property such as water and oxygen water vapor is important for passivation and encapsulation applications.

8:30am **AA+AF-TuM-3 Flexible Platinum Nanoparticle-based Piezoresistive Transducers Elaborated by Atomic Layer Deposition***, **Etienne Puyoo**, C Malhaire, D Thomas, R Rafaël,* Institut des Nanotechnologies de Lyon, France*; M R'Mili, A Malchère, L Roiban, S Koneti, M Bugnet,* MATEIS, France*; A Sabac, M Le Berre,* Institut des Nanotechnologies de Lyon, France

For the last ten years, the research on piezoresistive transducers has mainly been focused on the use of nanomaterials to optimize sensitivity, power consumption and sensor miniaturization. For instance, strain gauges based on Si nanowires, carbon nanotubes, graphene, MoS_2, Ag nanowires and metallic nanoparticle (NP) assemblies[1-4], have been developed at the laboratory scale to achieve very large gauge factors (GF) that compete with those of the state-of-the-art bulk Si gauges. Although the use of nanomaterials has attracted a lot of attention in literature these past few years, many technological obstacles (manipulation of individual nanostructures, complexity of the process, sensor reproducibility etc.) have yet to be overcome to make nanomaterials the preferred material for strain sensors. Consequently, alternative reliable technologies for the fabrication of nanostructured strain gauges with high GF are still sought-after by the industry.

In this work, platinum NP-based strain sensors are elaborated by means of Atomic Layer Deposition (ALD) on flexible polyimide substrates (Fig. 1). Pt NPs are grown by Plasma Enhanced ALD from ($MeCpPtMe_3$) precursor and O_2 plasma on thermal ALD alumina in subsequent process steps at 200°C in an Ultratech FIDJI F200 reactor. As presented in Fig. 1, several Pt NPs layers and Al_2O_3 tunnel oxide layers are stacked on polyimide in order to fabricate the flexible strain sensors. Their electro-mechanical response is tested under mechanical bending in both buckling and conformational contact configurations. A maximum gauge factor of 70 is reached at a strain level of 0.5% (fig.2). Although the exponential dependence of the gauge resistance on strain can be attributed to tunneling effect, it is shown that the majority of the junctions between adjacent Pt nanoparticles are in short circuit state. Finally, we demonstrate the feasibility of an all-plastic pressure sensor integrating Pt nanoparticle-based strain gauges in a Wheatstone quarter-bridge configuration (fig. 3).

[1]J. Herrmann, K.-H. Muller, T. Reda, G.R. Baxter, B. Raguse, G. J. J. B. de Groot, R. Chai, M. Roberts, and L. Wieczorek, Appl. Phys. Lett. **91**, 183105 (2007)

[2]N. M. Sangeetha, N. Decorde, B. Viallet, G. Viau, and L. Ressier, J. Phys. Chem. C **117**, 1935 (2013)

[3]H. Schlicke, M. Rebber, S. Kunze, and T. Vossmeyer, Nanoscale **8**, 183 (2016).

[4]C.-W. Jiang, I.-C. Ni, S.-D. Tzeng, and W. Kuo, Scientific Reports **5**, 11939 (2015).

8:45am **AA+AF-TuM-4 Color Coating of Electronic Textiles via Control of Refractive Index by Atomic Layer Deposition***, **Hyun Gu Kim,** W Kwon, H Lee,* Incheon National University, Republic of Korea

Attempts to integrate various electronic systems and sensors into textiles have been made for future wearable electronics. Conducting textile which is a key component for these wearable electronics is called by electronic textiles (e-textiles). Since most of conventional textiles are electrically insulator, metallic materials should be added to textiles during or after synthesis processes of textile. In the aesthetic point of view, however, the addition of metal for fabrication of e-textiles has a big disadvantage that is grey and black color of textile from the reflection and scattering of metal components. In addition, the conventional dying technology could not be applied to the e-textile systems after addition of metals. In our recent paper, we reported that conventional cotton textiles were successfully changed to e-textiles by Pt coating by atomic layer deposition (ALD). In this work, we report a novel approach to change the color of e-textile by using TiO_2/Al_2O_3 multilayer structures prepared by ALD. The various color combinations of the TiO_2/Al_2O_3 multilayer were simulated on planar Pt surface by computer simulation software that is based on change of refractive index. In the computational work, the film structures of TiO_2/Al_2O_3 multilayers and thickness of each layers were controlled to obtain desire colors. The simulation results were applied to experiments on planar structure as well as textile structures. The mechanical durability and optical properties of the TiO_2/Al_2O_3-multilayer-coated e-textiles were characterized. This approach for color coating of e-textiles presented here could provide more opportunities for the application of ALD-based e-textiles to other wearable electronics.

9:00am **AA+AF-TuM-5 Comprehensive Studies of Atomic Layer Deposited InGaO Thin Films using InCA-1, TMGa and H_2O_2 for Oxide Semiconductor Thin Film Transistor Applications***, **Jiazhen Sheng,*** Hanyang University, Republic of Korea*; B Shong,* Chungnam National University, Republic of Korea*; J Park,* Hanyang University, Republic of Korea

Oxide semiconductor thin film transistors (TFTs) have been extensively researched as a backplane technology in display industry, and among the well-known TFT active layer materials, including IZO, IGZO and ITZO, indium gallium oxide (IGO) has been suggested as a promising one due to its attractive performance. IGO thin films were deposited by ALD with different sequences at $200^{o}C$ using [1,1,1-trimethyl-N-(trimethylsilyl)silanaminato]indium (InCA-1) as the indium precursor, Trimethylgallium (TMGa) as the gallium precursor, and hydrogen peroxide (H_2O_2 30%) as the reactant, that reactant pulse was launched before and after sequential metal precursor pulse to get a clear understanding on ALD multicomponent growth for oxide semiconductor materials. The gallium oxide shows successful deposition at $200^{o}C$ when accompany with InCA-1-H_2O_2 sequence (Ga% ~ 20.6 to 28.3%), while no growth appeared without indium oxide deposition. The potential energy of InCA-1 and TMGa precursors on the hydroxylated Si(100) surface and hydroxylated trivalent indium on Si(100) surface were calculated by DFT, that revealed TMGa cannot adsorb on hydroxylated Si while was able to adsorb on hydroxylated InO_x surface. The ALD IGO shows controllable atomic composition and electrical characteristics, such as carrier concentration and resistivity, by adjusting supercycle in certain sequence. Thus, IGO thin film by ALD was applied to the active layer of TFT and the performance was optimized by adjust the supercycle, with mobility $9.45 cm^2/Vs$, threshold voltage -1.57V and subthreshold slop 0.26 V/decade.

Table 1. The growth rate and atomic composition of ALD growth thin film with various sequences (Growth rate obtained by SE and atomic percentages with AES)

Sequence	Growth rate (Å/cycle)	at. %C	at. %Ga	at. %In	at. %O
GaO	-	-	-	-	-
InO	0.97	0.5	0	42.8	56.7
In-Ga	0.77	0.7	3.8	39.6	55.9
Ga-In	0.33	0.4	28.3	14.9	56.4

InO-GaO	0.42		0.6	20.6	22.7	56.2

9:30am **AA+AF-TuM-7 Highly Sensitive VOCs Sensor Based on Atomic Layer Deposition of TiO_2 on Carbon Nanotubes*, Michela Sainato,*** University of Illinois at Chicago*; R Divan, L Stan, Y Liu,* Argonne National Laboratory*; I Paprotny,* University of Illinois at Chicago

Volatile organic compounds (VOCs) are largely used in industries as reaction intermediates for the synthesis of chemicals and in research laboratories as solvents. The probability of over-exposure to such toxic agents is very high; therefore, the development of gas sensors for early detection of toxic VOCs is necessary. So far, attempts have been focused on the development of thin-film n-type semiconducting metal oxide-based gas sensors, such as SnO_2, ZnO, TiO_2.[1]

Our approach targets the fabrication of low-cost low-power chemi-resistor sensors based on multiwalled CNTs (MWCNTs) functionalized by ALD with metal-oxide(MOX). Specifically, we report the design and synthesis of high-surface-area TiO_2 functionalized MWCNT based sensors. Prior to ALD TiO_2 deposition on MWCNTs surface, we performed site-specific O_2-plasma activation on the MWCNTs surface. The creation of physical active sites is an effective way to enhance and spatially control the growth of TiO_2NCs (not limited to ZnO, SnO_2). By varying the deposition temperature during the ALD process, the morphology and crystallinity of the TiO_2 varies. At 175°C, a continuous amorphous TiO_2 layer on the MWCNT is observed (Figure 1a).

The TiO_2 /MWCNT heterostructure chemi-resistive sensor arrays for the selective detection of low concentrations of different VOCs at room-temperature (RT) have been tested. The resulting TiO_2 (at 200°C)/MWCNT sensors operate at RT and show fast and reliable responses to benzene (C_6H_6) and to toluene (C_6H_5-CH_3) (Figure 1b) while TiO_2 (at 175°C)/MWCNT sensors show no response (Figure 1c).

In this talk we will discuss the role of the TiO_2 deposition temperature on the morphology and crystallinity of the TiO_2 and its influence on the VOCs sensing.

Our aim is to elucidate the mechanism by which the ALD coating increases sensitivity to the final composite materials, thus paving a way toward the integration of chemi-resistor sensors with improved selectivity, lifetime, and reliability toward specific VOCs, as well as improved environmental sustainability.

[1] Leidinger, M., Sauerwald, T., Conrad, T., Reimringer, W., Ventura, G., & Schütze, A. (2014). Selective Detection of Hazardous Indoor VOCs Using Metal Oxide Gas Sensors. Procedia Engineering, 87, 1449-1452.

Use of the Center for Nanoscale Materials, an Office of Science user facility, was supported by the U. S. Department of Energy, Office of Science, Office of Basic Energy Sciences, under Contract No. DE-AC02-06CH11357. The research was in part sponsored through a grant from Kanomax Inc.

10:45am **AA+AF-TuM-12 *In-situ* Real-time and *in-vacuo* Study of the Temperature Impact on the Al_2O_3 ALD Nucleation upon Pristine Monolayer Graphene*, Marcel Junige,*** Technische Universität Dresden, Germany*; J Kitzmann, C Chavarin,* IHP GmbH, Leibniz-Institut für Innovative Mikroelektronik*; M Geidel, J Reif, M Albert,* Technische Universität Dresden, Germany*; G Lupina, C Wenger,* IHP GmbH, Leibniz-Institut für Innovative Mikroelektronik, Germany*; J Bartha,* Technische Universität Dresden, Germany

Graphene (G) has attracted attention for THz switching capabilities in novel electronic device concepts: in a G-Base Transistor, a voltage at a sandwiched G-Base has been devised to control vertical electron tunneling through an emitter-base dielectric below, and hot electron tunneling through a base-collector dielectric above a G monolayer, respectively. This study strives for achieving these ultra-thin, demanding dielectrics by TMA–H_2O/–O_3 ALD.

Dielectric ALD has been applied to various types of G: either as-grown over the SiC/metal-catalyst substrate or transferred to another support substrate. Very distinct nucleation has been observed, largely depending on the G|substrate interaction, which in turn determines the energetic landscape of the G surface, i.e. the probability for initial precursor adsorption. SiC or metal underneath monolayer G have significantly enhanced dielectric ALD nucleation upon such G surfaces. In contrast, conducting ALD upon G over a dielectric or graphitic underground, substrate-inhibited island growth has commonly been exhibited due to G's intrinsic lack of dangling bonds, i.e. missing nucleation sites. However, such dielectric underlay is the relevant case for electronic applications. Accordingly, G has been pre-treated, functionalized, or seeded, entailing some additional effort along with the risk of defect generation. A rather simple approach for directly growing continuous, pinhole-free, and smooth films upon monolayer G over SiO_2 has recently been achieved by TMA–H_2O ALD at 100°C without any other G modification. This low-temperature method has based on self-terminating surface reactions with physisorbed H_2O molecules. Building on this, we systematically investigate here Al_2O_3 ALD nucleation phenomena upon pristine monolayer G in dependence on the deposition temperature by *in-situ* real-time Spectroscopic Ellipsometry (cf.Fig.) and complementing *in-vacuo* techniques, namely photoelectron spectroscopy as well as scanning probe microscopy.

On the downside of reduced deposition temperatures, ALD films then have exhibited lower mass densities, higher hydrogen concentrations (at unaffected Al:O ratios, indicating Al hydroxide), and lower electrical breakdown fields. Hysteresis in our I-V measurements also indicated charges at the interface or within the coating, pointing out insufficient electrical film quality for desired application as tunnel barrier. Therefore, we split the ALD process into two steps, switching from initially 100°C for better nucleation to subsequently higher temperatures for improved electrical properties. Likewise, we tested switching from initial H_2O to following O_3, as well as post-deposition anneals.

11:00am **AA+AF-TuM-13 Investigation of the Influence of Plasma Parameters During Aluminum Nitride Atomic Layer Epitaxy using Grazing Incidence Small Angle X-ray Scattering*, Virginia Anderson,*** *N Nepal, S Johnson, D Boris, S Walton,* U.S. Naval Research Laboratory*; Z Robinson,* SUNY College at Brockport*; A Kozen,* U.S. Naval Research Laboratory*; A Nath,* George Mason University*; S Rosenberg,* U.S. Naval Research Laboratory*; C Wagenbach,* Boston University*; J Hite,* U.S. Naval Research Laboratory*; K Ludwig,* Boston University*; C Eddy, Jr.,* U.S. Naval Research Laboratory

III-nitride semiconductors are tunable band gap materials, already in use in LEDs, and have additional uses in electronic switches and photovoltaics. Molecular beam epitaxy and metalorganic chemical vapor deposition (MOCVD) are performed at high temperatures, with AlN MOCVD growth requiring well over 1000°C. Early research investigating low-temperature plasma assisted atomic layer epitaxy (ALEp) to see if it could be added to the techniques able to produce high quality nitride semiconductor films is underway. Compared to conventional growth methods, ALEp offers elimination of miscibility gaps in ternaries and reduced thermal coefficient of expansion mismatch in heterostructures. Already published work shows that ALEp of AlN with high crystalline quality can be achieved at lower temperatures than those required for MOCVD[1], but more study is necessary to lower percentages of impurities and improve mechanistic understanding. Grazing incidence small angle X-ray scattering (GISAXS) can be carried out at ALEp process pressures in real time, and is sensitive to changes in surface morphology during nucleation, thus providing insight into the growth mode.

At the Cornell High Energy Synchrotron Source (CHESS) GISAXS probing of AlN ALEp on sapphire was performed. The AlN precursors were trimethylaluminum and either nitrogen/argon or hydrogen/nitrogen/argon plasma. Examination of the surface features during AlN growths at various growth temperatures and plasma conditions took place. The kinetics of the plasma were altered by changing the ratio of nitrogen-to-argon in the plasma feed gas, leading to differences in the relative production of nitrogen species. The GISAXS offers information about the surface feature evolution over the course of the film growth, and avoids *ex situ* surface oxidation of AlN, while atomic force microscope (AFM) measurements offer a final look at the surface once the samples are removed from the reactor.

Growths below 450°C were shown with *ex situ*, post-growth X-ray photoelectron spectroscopy to have higher impurities than samples grown at 480°C, and GISAXS shows an increase in short correlation lengths at the lower temperatures. Changing the plasma nitrogen/argon ratios also changed the impurity levels in the final films.

1. N. Nepal et al., *Appl. Phys. Lett.***103**, 082110 (2013)

11:15am **AA+AF-TuM-14 Studies of Surface Structure and Surface Chemistry During Plasma-Assisted Atomic Layer Epitaxial Growth of InN Semiconductor Thin Films on GaN Substrates*, Samantha Rosenberg,*** U.S. Naval Research Laboratory*; D Pennachio,* UCSB*; V Anderson, N Nepal,* U.S. Naval Research Laboratory*; C Wagenbach,* Boston University, USA*; A Kozen,* U.S. Naval Research Laboratory*; Z Robinson,* SUNY College at Brockport*; J Logan, S Choi,* UCSB*; J Hite,* U.S. Naval Research Laboratory*; K Ludwig,* Boston University*; C Palmstrøm,* UCSB*; C Eddy, Jr.,* U.S. Naval Research Laboratory

III-N semiconductors such as GaN, AlN, and InN are the basis for creating compound ternary and quaternary semiconductor materials well suited for applications in several important technological areas including high current, normally-off power switches.[1-3] However, the full range of ternary and quaternary III-N semiconductors cannot be achieved with conventional growth methods due to the high temperatures required. While atomic layer deposition (ALD) is a versatile low temperature growth technique and has gained wide use, it does not offer the required level of crystallinity and purity needed for high-performance III-N semiconductor devices. Therefore, we have developed a technique adapted from ALD, called plasma-assisted atomic layer epitaxy (ALEp).[2] Using surface science techniques we are working to develop a fundamental understanding of the ALEp growth process to further enable the method as a powerful new growth technique for semiconductor materials.

Here we employ *in-situ* and *in-vacuo* surface studies of GaN substrate preparation and InN ALEp heteroepitaxial growth to advance our fundamental understanding of the ALEp process. We conduct *in-situ* grazing incidence small angle x-ray scattering (GISAXS) experiments at the Cornell High Energy Synchrotron Source, utilizing morphological evolution monitoring to investigate the growth surface during sample preparation and film deposition. GISAXS results have shown that bulk GaN surfaces develop a correlated surface feature at finite q_y during the ALEp-based emulated Ga flash-off cleaning, while ALEp-based H_2 cleaning introduces additional short range order features. Neither of these features are found on Epi GaN surfaces suggesting they are associated with polish damage in the substrates. For both surfaces, features from ALEp-based preparations dominate the GISAXS scattering during subsequent ALEp InN growth and are quite different from ALEp InN growth on sapphire. GISAXS information is complemented with *in-vacuo* x-ray photoelectron spectroscopy and reflection high-energy electron diffraction studies conducted at the Palmstrøm Lab at UCSB. Initial results have shown a partial surface reconstruction after exposure to TEG and atomic H_2 commensurate with a reduction in carbon and oxygen from the surface. Further studies will consider traditional molecular beam gallium flash-off and further atomic hydrogen etching as ways to produce the most suitable GaN surface for our ALEp-based approach.

1. N. Nepal, et al., Appl. Phys. Lett. 103, 082110 (2013)
2. C. R. Eddy, Jr, et al., J. Vac. Sci. Technol. A 31(5), 058501 (2013).
3. R. S. Pengelly, et al., IEEE Trans. Microwave Theory Tech. 60, 1764 (2012).

11:30am **AA+AF-TuM-15 Plasma Gas Chemistry Influence on Growth of InN Films by Atomic Layer Epitaxy*, Neeraj Nepal,*** *V Anderson, S Johnson, S Rosenberg, A Kozen,* U.S. Naval Research Laboratory, USA*; C Hoskin,* Boston University*; D Meyer, B Downey, J Hite, V Wheeler,* U.S. Naval Research Laboratory, USA*; R Zachary,* SUNY College at Brockport*; D Boris, S Walton,* U.S. Naval Research Laboratory, USA*; K Ludwig,* Boston University, USA*; C Eddy, Jr.,* U.S. Naval Research Laboratory, USA

III-N semiconductors have been used in a variety of technologies such as high power transistors, emitters, detectors, and solar-cells. The relatively high growth temperature of III-N semiconductor synthesis techniques has impeded further development and application of the materials due to challenges with miscibility gaps for ternaries and strain related to thermal expansion mismatch with non-native substrates. To address these challenges, plasma-assisted atomic layer epitaxy (ALEp) offers a new approach with growth temperature less than half of those needed for conventional growth methods. Since growth using this technique is far from thermodynamic equilibrium, understanding the effects of ALEp growth parameter space on growth kinetics is essential to further improving the method and the resulting electronic materials.

In this paper, we report on the effect of plasma gas chemistry on growth of crystalline InN semiconductor films by ALEp on a-plane sapphire substrates at temperatures below 250 °C. First, the optimal ALEp growth windows and growth parameter space is identified. These studies involve variations in substrate surface preparation for epitaxy, plasma gas chemistry, growth temperature, precursor pulse/purge time. The effect of these parameters is assessed using different *ex situ* characterization methods such as atomic force microscopy, x-ray photoelectron spectroscopy, x-ray diffraction and four-point free carrier transport measurements. To further understand/develop plasma gas chemistry these optimal conditions are then applied to film growth monitored by real-time grazing incidence small angle x-ray scattering (GISAXS) measurements revealing changes in the growth mode through morphological evolution of the surface. It will be shown that the nature of GISAXS evolution directly relates to the material quality. Both *ex situ* and *in situ* growth studies show that the starting surface, N_2/Ar flow ratio, plasma time/pressure and H_2 content of the plasma significantly affects the surface chemistry, nucleation and growth of InN. For example, decreasing Ar flow through plasma source from 200 sccm to 25 sccm for constant N_2 flow of 75 sccm and adding H_2 at the last fraction of the plasma pulse in the ALEp cycle reduces impurities and increases the saturated growth rate. Based on various *ex situ* characterization methods, the quality of the ALEp grown semiconducting InN films is found to be similar or better than the material grown by conventional growth methods, such as molecular beam epitaxy, at much higher temperatures.

11:45am **AA+AF-TuM-16 Spectroscopic Ellipsometry of WO_3 Thin Films from ALD: *In-situ* Layer-by-Layer Growth Monitoring and *ex-situ* Optical Characterization*, Ufuk Kilic,*** *D Sekora, A Mock, M Schubert,* University of Nebraska Lincoln

Within the last two decades, tungsten tri-oxide (WO_3) ultra-thin films have been the subject of research for photovoltaic, gas sensing, and electrochromic applications due to its large band gap (3.4 eV) and photocatalytic properties [1,2]. In this study, we fabricated WO_3 ultra-thin films on silicon substrates by means of atomic layer deposition (ALD). Precise and accurate control of deposition conditions throughout the growth process is a critical challenge surmountable by integration of spectroscopic ellipsometry (SE). By utilizing in-situ SE monitoring of WO_3 depositions, we obtain thickness, film roughness, and substrate temperature throughout the layer-by-layer growth.

By implementing pressurized precursor control, WO_3 was deposited by subsequent exposures of $(tBuN)_2(Me_2N)_2W$, nanopure H_2O, and oxygen plasma to the substrate surface while under continuous SE observation. Due to lack of detailed reports on broad range optical properties of WO_3 thin films, a multi-sample analysis is necessary for accurate thickness and optical constant determination from SE [3]. Thus, two films are deposited for 75 and 150 cycles under the same conditions and ex-situ SE data is collected in the spectral range from 0.7-8.5 eV. The as-grown WO_3 dielectric function is determined along with the respective film thicknesses. Roughness was considered and verified by atomic force microscopy. With this information, the in-situ SE data is retroactively analyzed to attain inherent layer-by-layer deposition parameters.

We report the dielectric function of as-grown WO_3, accurate film thicknesses and growth rate. Further implementation of this method allows for precise control and real-time optimization of deposition parameters ultimately providing us with the ability to develop ALD recipes in-situ.

[1] Ping, Y., Rocca, D., & Galli, G., Physical Review B, 87(16), 165203, (2013).

[2] Liu, Rui, et al., Angewandte Chemie, 123.2: 519-522, (2011).

[3] Jarrendahl, K., and H. Arwin, Thin Solid Films, 313: 114-118, (1998).

Author Index

Bold page numbers indicate presenter