DS 53: Postersession DS/HL

Presenters are kindly requested to be near their poster for at least one hour during poster session or leave a note about their availability for discussions.

Time: Thursday 16:00–19:00 Location: Poster A

DS 53.1 Thu 16:00 Poster A

Metallic Chains on Ge (001) Surface and Their Manipulation — •Deniz Aşan Acar[1], Umut Kamber[1], Dilek Yildiz[2], and Oğuzhan Gürlü[1] — [1]Istanbul Technical University, Istanbul, Turkey — [2]University of Basel, Basel, Switzerland

One dimensional, single atom thick wires present an exotic playground. We investigate the surface structure formed by adsorption of Pt and Au on Ge(001) surface. It is well known that upon annealing of Pt deposited Ge(001) surface at 1000 K atomic chains form along with two different types of terraces. Similar structures form due to Au deposition on Ge(001). In this study we have experimented on the co-deposition of Au and Pt on to Ge(001) surfaces. We will report on our findings related to the formation of novel atomic scale structures. (This study was funded by a TUBITAK 1001 project with grant number 112T818.)

DS 53.2 Thu 16:00 Poster A

Mask-less Selective Area Epitaxy of self-catalyzed GaN-microrods on silicon — •Christian Blumberg, Dennis Jansen, Werner Prost, and Franz-Josef Tegude — University Duisburg-Essen, Faculty of Engineering, Solid-State Electronics Department, Duisburg, Germany

3D GaN microrod structures offer the potential to fabricate electro-optical devices that may outperform their 2D counter parts. Promising candidates are the GaN/InGaN microrod-LEDs. These m-planar GaN/InGaN-LEDs are not limited by quantum-confined Stark effect at the GaN/InGaN interface (long charge-carrier lifetimes and less radiative efficiency at high intensities). A major issue by producing a macro sized usable LED from microrod-structures is the inhomogeneous distribution among the microrods: length, diameter and distance between each rod changes from rod to rod. As a result each rod-device has different electro-optical properties, which leads e.g. to a broadening of emission spectrum of a LED, consisting of parallel electric-powered microrod-LEDs. In order to reach a high homogeneity selective area epitaxy (SAE) of the rods is necessary. In this work we discuss the high-density seeding of rods on Si (111). We have developed a new method of the SAE for self-catalysed GaN-rods, which is based on pattering the Si-surface by nanoimprint technology. In contradiction to other methods for SAE we did not use a dielectric mask (like SiNx or SiOx). By adapting the Si-surface pattern (depth of etched holes and surface cleaning) and the epitaxial parameters (silane-flow and V/III) we were able to grow position controlled GaN-rods on Si.

DS 53.3 Thu 16:00 Poster A

Stability of misfit dislocations in axial-heteroepitaxial 3C-SiC/c-GaN nanopillars and nanomesas — •Thomas Riedl[1], Ricarda Kemper[1], Andras Kovacs[2], Doris Meertens[2], Donat As[1], and Jörg Lindner[1] — [1]University of Paderborn, Department of Physics, Warburger Straße 100, 33098 Paderborn, Germany — [2]Ernst-Ruska Centre for Microscopy and Spectroscopy with Electrons, FZ Jülich, 52425 Jülich

GaN represents the most important compound semiconductor for realization of highly efficient blue LEDs and lasers. The cubic modification of GaN (c-GaN) has attracted growing interest due to the absence of internal electric fields. For the fabrication of high-quality semiconductor devices defect-free epilayers are essential. One way to avoid defects arising due to misfit is to reduce the lateral dimension of the layer to the nanoscale, which leads to a purely elastic relaxation in three dimensions.

In order to investigate the effect of the lateral size of axial pillar or mesa shaped heterostructures on the stability of misfit dislocations for the 3C-SiC/c GaN system, we apply various analytic approaches based on linear continuum elasticity theory. We find that the approaches of Glas and Ertekin predict the stability zone of misfit dislocations to exist at significantly smaller lateral dimensions and slightly larger layer thicknesses in comparison to the model of Zubia and Hersee. The former approaches yield a reasonable agreement with high-resolution TEM observations of c-GaN layers that have been grown on top of 3C-SiC mesa posts of different edge lengths.

DS 53.4 Thu 16:00 Poster A

Spectroelectrochemical Response of Half Cells for Solid-state Electrochromic Devices — •Christian Lupo[1], Yurong Su[2], Angelika Polity[2], and Derck Schlettwein[1] — [1]Institute of Applied Physics, Justus Liebig University Giessen, Heinrich Buff-Ring 16, 35392 Giessen, Germany. — [2]1st Physics Institute, Justus Liebig University Giessen, Heinrich Buff-Ring 16, 35392 Giessen, Germany

Electrochromic devices made by solid-state components only could provide longer lifetimes or faster switching speeds compared with currently produced devices ("smart windows", "smart mirrors") with polymeric or liquid electrolytes. Lithium phosphorous oxynitride ($LiPON$) is a promising candidate as a solid electrolyte for use in electrochromic devices. Thin films of $LiPON$ could replace the relatively thick electrolytes based on a Lithium salt in liquid or polymeric compounds because of a high chemical stability and good transparency of $LiPON$. In the present study, $LiPON$ is used in combination with tungsten oxide (WO_x) or nickel oxide (NiO), both well-known electrochromic materials which become colored upon chemical reduction or oxidation, respectively. On the way to an all-solid-state device, the first challenges consist in reaching a good ionic conducting solid electrolyte and well-working solid contacts. Electrochemical and spectroelectrochemical measurements are used to characterize the response and the coloration performance of electrochromic half cells consisting of combinations of $WO_x/LiPON$ or $LiPON/NiO$ solid layers prepared via combinations of sputtering and/or chemical bath deposition methods.

DS 53.5 Thu 16:00 Poster A

Spectroscopic Ellipsometry and MOKE as a Probe for Structural Properties of Spinel Oxide Thin Films — •Vitaly Zviagin[1], Peter Richter[2], Yogesh Kumar[1], Israel Lorite[1], Michael Lorenz[1], Daniel Spemann[1], Jan Meijer[1], Dietrich R.T. Zahn[2], Georgeta Salvan[2], Pablo Esquinazi[1], Marius Grundmann[1], and Rüdiger Schmidt-Grund[1] — [1]Universtät Leipzig, Institut für Experimentelle Physik II, Linnéstr. 5, Germany — [2]Technische Universtät Chemnitz, Semiconductor Physics, Reichenheiner Str. 70, Germany

Normal, disordered, and inverse spinel oxide ferrite and cobaltite thin films were grown at different temperatures on MgO (100), $MgAl_2O_4$ (100), and $SrTiO_3$ (100) substrates by pulsed laser deposition. Assigned electronic transitions visible in diagonal and off-diagonal elements of the dielectric tensor show a clear dependence on growth temperature corresponding to the crystal quality of the films. Silicon irradiation of $ZnFe_2O_4$ films caused inversion of normal spinel structure as well as lattice distortion with further treatment, clearly visible in the dielectric function. The $Zn_xFe_{3-x}O_4$ composition was found to contain defects such as presence of Fe^{2+} ions. Magneto-optical Kerr effect spectroscopy was employed to investigate magneto-optically active transitions, and in combination with spectroscopic ellipsometry we obtained detailed information of site occupancy related to crystal inversion and disorder. We relate optical properties to magnetic properties to show a direct correlation between site occupancy of tetrahedral sites by Fe^{3+} ions to saturation and remanence magnetization.

DS 53.6 Thu 16:00 Poster A

Growth-of p-type nickel oxide on different substrates and surface orientations — •Carsten Tschammer and Oliver Bierwagen — Paul-Drude-Institut, Hauvogteiplatz 5-7, 10117 Berlin, Germany

NiO belongs to the transparent semiconducting oxides with unintentional p-type conductivity. Currently, NiO is used in batteries and capacitors, and is considered for future applications in UV-detectors, all-oxide hetero pn-diodes, and organic solar cells. For the latter, NiO is an excellent candidate for an interfacial layer between the ITO anode and active organic layer, serving as electron blocking and hole transport layer. Doping NiO with Nitrogen as an acceptor should increase the p-type conduction.

Here NiO thin layers were grown by plasma-assisted MBE using RHEED as in situ monitoring tool. For the growth of well-defined NiO layer and surfaces MgO was chosen as substrate due to its com-

mon crystal structure and low lattice mismatch to NiO. Thus, NiO was grown on MgO(100), MgO(110), MgO(111) to help investigating the interface to the active organic layer on differently oriented surfaces. Growth on epitaxial ITO and In_2O_3 was performed to come closer to the solar cell application and application in pn-diodes, respectively. The film crystal and surface structure were investigated by AFM, XRD, XRR. The electronic properties were investigated by Raman, PL and transport measurements.

DS 53.7 Thu 16:00 Poster A

Intermediate tin oxide phases from first principles — Bianca Eifert and •Christian Heiliger — Institut für Theoretische Physik, Justus Liebig University Gießen, D-35392, Germany

The two stable tin oxides, SnO and SnO_2, are semiconductors with bandgaps of different types and sizes. Both of them are therefore of great interest for applications, and may even be used together for tin-only devices. It has also been known for over a century that when SnO disproportionates, mixed-valence oxides of other stoichiometries can be formed as intermediates. These phases are also accessible from elementary precursors, for instance through thin-film deposition techniques. The intermediate oxides have, however, eluded conclusive analysis in the past. Using density functional theory (DFT) and phonon calculations, we can predict the electronic structures and Raman spectra for different candidate crystal structures. Comparing these new insights with experimental results, we are now able to determine the identity and properties of the intermediate tin oxide.

DS 53.8 Thu 16:00 Poster A

Pseudomorphic growth and relaxation of alpha gallium oxide on sapphire substrate — •Zongzhe Cheng[1], Patrik Vogt[1], Robert Schewski[2], Oliver Bierwagen[1], Martin Albrecht[2], Achim Trampert[1], and Michael Hanke[1] — [1]Paul-Drude-Institut für Festkörperelektronik (PDI), Berlin, Germany — [2]Leibniz-Institut für Kristallzüchtung (IKZ), Berlin, Germany

Alpha phase gallium oxide is a transparent semiconducting material with an indirect wide band gap of around 5eV. The heteroepitaxial growth of alpha phase gallium oxide on insulating c-plane sapphire (band gap = 8.8ev) can be realized by molecular beam epitaxy since they have the same corundum crystal structure and small lattice mismatch (4.6% in a-axis and 3.3% in c-axis). However under ambient conditions, the beta phase gallium oxide with a monoclinic structure is thermodynamically more stable than the alpha phase, so normally beta phase gallium oxide starts to grow after a three atomic layer of alpha phase gallium oxide on the c-plane sapphire substrate in molecular beam epitaxy growth. So it is important to stabilize the growth of alpha phase gallium oxide trying to get pure alpha phase gallium oxide layer on the substrate in case of device applications (eg. 2deg). In this work, we use mainly synchrotron radiation and high resolution transmission electron microscopy in order to understand the pseudomorphic growth and relaxation of the alpha phase gallium oxide on c-plane sapphire substrate. In addition, an annealing experiment on a low-temperature-deposited amorphous gallium oxide layer is performed trying to crystallize the gallium oxide layer and stabilize the alpha phase.

DS 53.9 Thu 16:00 Poster A

Transmission Electron Diffraction on a really free-standing heterostructure and analysis of the resulting Moiré pattern — Marlene Adrian, •Arne Senftleben, Silvio Morgenstern, and Thomas Baumert — Institut für Physik und CINSaT, Universität Kassel, Heinrich-Plett-Straße 40, 34132 Kassel

The combination of various 2D layered materials in multilayer heterostructures arises great interest in the current science. Due to the large variety of electronic properties of the group of 2D layered materials the combination opens a new pathway towards ultrasmall electronic devices. In this contribution we present a preparation method to obtain free-standing samples of multilayer heterostructures and a full characterisation of their diffraction images. A 20 nm thick MoS_2–graphite heterostructure was produced and analysed with the methods presented. Additionally, the ultrafast lattice dynamics after optical excitation of the sample will be discussed.

DS 53.10 Thu 16:00 Poster A

Silicene-based spin-filter device: Impact of random vacancies — Cesar Nunez[1], Francisco Dominguez-Adame[2], Pedro Orellana[1], Luis Rosales[1], and •Rudolf A. Römer[3] — [1]Universidad Tecnica Federico Santa Maria, Valparaiso, Chile — [2]Universidad Complutense, E-28040 Madrid, Spain — [3]University of Warwick, Coventry, CV4 7AL, UK

We propose a hybrid spin-filter device based on a silicene nanoribbon. A ferroelectric polymer grown on top of the nanoribbon splits spin-up and spin-down electron bands and gives rise to spin polarisation of the conductance. In particular, we study the effects of a random distribution of vacancies on the performance of this spin-filter device. Disorder induces Anderson localisation of electrons and we find that the localisation length strongly depends on the electron spin. By adjusting the Fermi level of the source contact, only electrons with one spin orientation can reach the drain contact because their localisation length is larger than the length of the device. Electrons with opposite spin are largely back-reflected. Electric conductance then becomes spin polarised and the device behaves as a quasi-half-metal. We conclude that a moderate concentration of vacancies has little impact on the spin-filter capabilities of the device, opening the possibility to using it as a tuneable source of polarized electrons.

DS 53.11 Thu 16:00 Poster A

Stacking different two-dimensional materials to fabricate a high mobility transistor — •Himani Arora[1,2], Gotthard Seifert[3], Gianaurelio Cuniberti[4], Manfred Helm[1,2], and Artur Erbe[1] — [1]HZDR, Bautzner Landstrasse 400, 01328 Dresden — [2]Technical University Dresden, Faculty of Mathematics and Natural Sciences, 01062 Dresden — [3]Technical University Dresden, Institute for Physical Chemistry and Electrochemistry, 01062 Dresden — [4]Technical University Dresden, Institute for Materials Science and Max Bergmann Centre of Biomaterials, 01062 Dresden

In recent years, several two-dimensional (2D) semiconducting materials like graphene, MoS2, WSe2, silicene, germanene etc. have been produced and studied. Their semiconducting properties allow the development of 2D structures, whose electronic properties can be tuned. By fabricating gate electrodes on the 2D materials, field effect transistors have been demonstrated. Further exciting possibilities open up when these materials are stacked together to achieve the desired application. The first series of experiments are carried out with graphene nanoribbons (GNRs) deposited on functionalized Si/SiO2 substrate. Prior to the deposition, the Si/SiO2 substrate is patterned with Ni alignment marks, to locate and characterize GNRs by AFM and Raman spectroscopy. Au electrodes are then fabricated on selected GNRs using electron beam lithography to measure the electrical transport properties. In future, the aim will be to fabricate a heterostructure by stacking different 2D materials, whose different properties can complement each other to fabricate a high mobility transistor.

DS 53.12 Thu 16:00 Poster A

Magnetic-field dependent photoluminescence measurements of WS_2 monolayers — •Jan Kuhnert, Simon Schmitt, Arash Rahimi-Iman, Ajanth Velauthapillai, and Wolfram Heimbrodt — Faculty of Physics and Materials Sciences Center, Philipps-Universität Marburg, Renthof 5, D-35032 Marburg, Germany

Layered transition-metal dichalcogenides have attracted great interest in the last few years. Thinned down to monolayers they exhibit outstanding optical properties caused by the direct band gap. Here we present photoluminescence measurements of tungsten disulfide monolayers at low temperatures (2 K) in the presence of an external magnetic field in Faraday geometry. In the monolayer limit the inversion symmetry is broken and spin and valley are coupled. The degeneracy between the two equivalent K and K' valleys is broken by applying external magnetic fields. This causes a Zeeman shift which has already been shown in similar layered transition-metal dichalcogenides (eg. MoSe2: 0,25 meV/T (1)). We show this field-dependent Zeeman splitting in tungsten disulfide at low temperatures (2 K) and find a surprisingly large splitting of 0,8 meV/T.

(1) Nature Physics 11, 141147 (2015)

DS 53.13 Thu 16:00 Poster A

Hydrogenation of Epitaxial Silicene Studied by *in situ* Raman Spectroscopy — •Dmytro Solonenko[1], Patrick Vogt[2], Ovidiu D. Gordan[1], and Dietrich R.T. Zahn[1] — [1]Semiconductor Physics, Technische Universität Chemnitz, D-09107 Chemnitz, Germany — [2]Institut für Festkörperphysik, Technische Universität Berlin, D-10623 Berlin, Germany

As silicene can be only grown epitaxially on a substrate like Ag(111) single crystals, the influence of the substrate on the 2D silicene properties have been extensively discussed in literature. It was shown that the

electronic properties of epitaxial silicene are altered due to the significant interaction with the substrate but it still keeps a clear semimetallic character[1], as expected for ideal freestanding silicene. On the other hand, an electronic bandgap could be opened by applying an electric field perpendicular to the sheet, or via functionalization, *e.g.* by H-adsorption. In the latter case, controlled hydrogenation of freestanding silicene might open a bandgap up to the UV edge of the visible spectral region[2]. In order to examine if the silicene structure is preserved upon hydrogenation, we grew silicene monolayer sheets on Ag(111) substrate and hydrogenated them by supplying activated atomic H. *In situ* Raman spectroscopy study was carried out in order to follow structural changes of the silicene layer upon H-adsorption. We find that the silicene hydrogenation is reversible by heating the sample, at temperatures expected to be sufficient for breaking the H-Si bonds. [1] Johnson, N. W. *et al.*, *Adv. Func. Mat.* **24**, 5253-5259 (2014). [2] Osborn, T. H. *et al.*, *Chem. Phys. Lett.* **511**, 101 (2011).

DS 53.14 Thu 16:00 Poster A

Electrical properties of CVD Molybdenum disulfide — •Wajid Awan[1], Tommy Schönherr[1], Artur Erbe[1], Stefan Facsko[1], and Xinliang Feng[2] — [1]Helmholtz-Zentrum Dresden-Rossendorf — [2]Technische Universität Dresden

Two dimensional materials are attractive for the use in next-generation nanoelectronic devices as compared to one dimensional material because it is relatively easy to fabricate complex structures from them. Recently the layered 2D semiconducting Transition metal dichalcogenides came into the picture and got a place in a wide range of novel applications as well as in basic research. Strikingly, MoS_2 receives significant attention since it undergoes transition from indirect bandgap (bulk form) to a direct bandgap (1.2eV) semiconductor if thinned out to a single atomic layer. The bandgap is an essential property for tunable 2-D nanodevices. We performed electrical transport measurements at room temperature for CVD grown MoS_2 on SiO_2/Si substrate. Standard Electron beam lithography (EBL) was used to pattern Gold (Au) metal contacts on MoS_2 flakes. For the purpose of sample characterization, we performed the Atomic Force Microscopy (AFM) and Raman Spectroscopy techniques, respectively, which confirm that the thickness of the CVD grown MoS_2 triangular flakes corresponds to single layers. Low temperature characterization of the electrical properties of the layers elucidates the exact mechanisms of charge transport in the 2d-layers. This knowledge will be used to modify the electrical properties in a controlled way, for example by ion irradiation.

DS 53.15 Thu 16:00 Poster A

Molecular beam epitaxy growth and in situ analysis of transition metal dichalcogenides — •Avanindra Kumar Pandeya, Amilcar Bedoya Pinto, Ilya Kostanovskiy, Kai Chaang, and Stuart Parkin — Max Plank Institute for Microstructure Physics, Halle, Germany

Atomically thin transition metal dichalcogenides (TMDCs), layered materials which have captured great attention due to their tunable electronic properties [1], are commonly fabricated via exfoliation of high-quality bulk crystals. Although there has been tremendous progress in fabricating devices out of exfoliated heterostructures [2], there are other effects, such as spin transfer, that need atomically clean interfaces for an optimum harvesting. Our approach is to grow TMDCs layers by molecular beam epitaxy and assess the layer and interface quality using in-situ characterization (RHEED, LEED, XPS, AES and STM). The fabrication of high-quality TMDCs heterostructures by UHV methods opens new prospects for the design of interface-sensitive electronic and spintronic devices.

1. J. Kang, et al. Applied Physics Letters, 102, 012111 (2013)
2. C. Lee, et. al. Nature Nanotechnology 9, 676-681, (2014)

DS 53.16 Thu 16:00 Poster A

Si(553)-Au surface functionalized by small molecules — •Svetlana Suchkova[1], Eugen Speiser[1], Sandhya Chandola[1], Conor Hogan[2], Friedhelm Bechstedt[3], and Norbert Esser[1] — [1]Leibnitz-Institut für Analytische Wissenschaften - ISAS - e.V., Department Berlin, Schwarzschildstr. 8-10, 12489 Berlin, Germany — [2]Universita di Roma Tor Vergata, Via della Ricerca Scientifica 1, 00133 Roma, Italy — [3]Friedrich-Schiller-University Jena, Institut für Festkörpertheorie und optik, Helmholtzweg 3, 07743 Jena

We discuss the adsorption of toluene-3,4-dithiol molecules on the Si(553)-Au surface. In contrast to the highly reactive clean Si surface, Au-passivated surfaces offer the potential for a more selective adsorption, eventually yielding molecular layers that are essentially self-ordered on the underlying silicon substrate. The calculations of Potential Energy Surface (PES) by Density Functional Theory (DFT) in combination with reflectance anisotropy spectroscopy (RAS) provide us with the information on molecular orientation on the surface.

DS 53.17 Thu 16:00 Poster A

Preparation-dependent viscoelastic properties of ultra-thin glass-forming polymer films. — •Pierre Chapuis[1,2], Anne Rubin[2], Freddy Anstotz[3], Paul Montgomery[3], and Günter Reiter[1] — [1]Physikalisches Institut, Albert-Ludwigs-Universität Freiburg, Germany — [2]Institut Charles Sadron, Strasbourg, France — [3]ICube/IPP, Strasbourg, France

Properties of ultra-thin glassy polymers films differ from bulk behavior. Many studies stated that it is a consequence of confinement and/or interfacial physics. Another possible explanation is suggested: the preparation process of the film by spin-coating entails an out-of-equilibrium state of the chains [1].

To give insight on this phenomenon we explore the influence of the preparation process of ultra-thin glassy freestanding polymer films on their viscoelastic response. Ultra-thin polymer films are obtained by spin-coating technique and transferred onto a silicone substrate containing an array of 5 μm. Using the nanobubble inflation method [2], a static pressure was applied and the resulting deformation was probed with time by 4D interferometric microscopy which is a non-contact method (3D + real time) developed at ICube.

We discuss the results of creep compliance measurements on poly(vinyl acetate) (PVAc) films of thicknesses below 100 nm for different molecular weights.

[1] M.Chowdhury et al., PRL 109, 136102 (2012) [2] P.A. O Connell et al., Science 18, 1750 (2005).

DS 53.18 Thu 16:00 Poster A

Transparent white AC/DC OLEDs — •Felix Fries, Markus Fröbel, Simone Lenk, and Sebastian Reineke — Institut für Angewandte Photophysik, Technische Universität Dresden, Germany

Future lighting applications will strongly benefit from transparent luminescent devices. In this contribution, we demonstrate transparent organic light-emitting diodes (OLEDs), which allow for flexible adjustment of the emission color. We extend the AC/DC concept, that was only recently presented for bottom-OLEDs, to transparent devices. Since two units are stacked on each other and the cathode of one is connected to the anode of the other, they can be addressed independently via an AC-signal. Comprising blue and yellow emission units leads to the possibility to tune the color between deep blue over cold and warm white to yellow emission.

Based on optical simulation, we build OLEDs that show an overall transparency of 62% when switched off and emit warm white light to both sides (top, bottom) with an overall power efficacy of 11.8 lm/W at a brightness of 1000 cd/m^2 when switched on. Moreover, devices without indium-tin oxide (ITO) are presented, which exclusively rely on highly transparent ultra-thin metal electrodes. These ITO-free devices achieve a power efficacy of 18.4 lm/W at 1000 cd/m^2 for warm white emission and 56% transmission.

Using an emitter combination providing red, green, and blue emission, we were also able to achieve a high color-rendering index (CRI) of 84, which further expands the range of possible applications for this promising device concept.

DS 53.19 Thu 16:00 Poster A

Influence of temperature on the interaction of excitons with electron-hole pairs in organic bulk heterojunction structures — •Jędrzej Szmytkowski — Faculty of Applied Physics and Mathematics, Gdańsk University of Technology, Gdańsk, Poland

Nowadays, a great attention is focused on organic photovoltaics. Bulk heterojunction structures based on donor-acceptor materials are treated as very promising systems to obtain high efficiencies of organic solar cells. The main effect which causes a loss of photocurrent is a recombination of charge carriers. Recently, it has been shown that an order of recombination depends on temperature. The aim of this work is to describe this process in the case when it occurs at a donor-acceptor interface due to excitons annihilation on electron-hole Langevin pairs. Additionally, a theoretical consideration based on the role of disorder is also presented.

DS 53.20 Thu 16:00 Poster A

Polarization-dependent Differential Reflectance Spectroscopy for real-time monitoring of organic thin film growth

— •Andrea Navarro-Quezada, Markus Aiglinger, Ebrahim Ghanbari, Thorsten Wagner, and Peter Zeppenfeld — Institute of Experimental Physics, Johannes Kepler University, Altenbergerstr. 69, 4040 Linz, Austria

Optical spectroscopy is a powerful tool to study physical processes occurring in molecular thin films and at their interfaces with inorganic materials. In particular, differential reflectance spectroscopy (DRS) records the change in the reflectance of a surface upon physical or chemical modification. Therefore, it allows real-time monitoring of the deposition of organic thin films. In this work, we present an extended DRS setup that allows the simultaneous detection of both linear polarization states (s and p) of the reflected light [1]. The setup exhibits a signal to noise ratio better than 1000:1 as well as high signal stability, thus we detect changes in the reflectance in the order of 10^{-3}. As a proof of principle, we have implemented polarization-dependent DRS to monitor the growth of perfluoropentacene thin films on a Ag(110) single crystal in combination with photoelectron emission spectroscopy. From the analysis of the different DRS transients for s and p polarized light, we follow the alignment of the molecules on the Ag(110) surface during growth.

[1] A. Navarro-Quezada, M. Aiglinger, E. Ghanbari, Th. Wagner, and P. Zeppenfeld, *Rev. Sci. Inst.* 86, 113108 (2015)

DS 53.21 Thu 16:00 Poster A

Improved color stability of white OLEDs with tandem structure and new host material — •Yuan Liu[1,2], Zuo-Quan Jiang[1], and Liang-Sheng Liao[1] — [1]Institute of Functional Nano & Soft Materials, Soochow University, 215123 Suzhou, China; — [2]Institut für Angewandte Photophysik, Technische Universität Dresden, 01062 Dresden, Germany;

Tandem structures can improve the efficiency and lifetime of organic light-emitting diodes (OLEDs) simultaneously. More importantly, this is also an effective strategy to reduce the color shift with increasing current density in white OLEDs. High performance tandem OLEDs require highly efficient emitting units along with an efficient charge generation layer. To improve the performance of single emitting unit, two novel host materials SF2BCz and SF3BCz which combine spirobifluorene and carbazole units via meta- and para-bonding are designed for phosphorescent OLEDs (PhOLEDs). The meta-linkage of spirobifluorene enables SF3BCz to possess high triplet energy, suitable energy levels, and good thermal stability. Blue PhOLEDs featuring SF3BCz as a host show high performance and low efficiency roll-off, with an efficiency of 41.4 cd/A (18.0%, 39.8 lm/W) at 100 cd/m2 and 39.7 cd/A (17.2%, 29.8 lm/W) at 1000 cd/m2. In addition, SF3BCz is adopted as a universal host for tandem white OLEDs, achieving an external quantum efficiency of 40% and a color stable emission spectrum.[1]

References: [1] Y. Liu, L. Cui, X. Shi, Q. Li, Z. Jiang and L. Liao, J. Mater. Chem. C, 2014, 2, 8736.

DS 53.22 Thu 16:00 Poster A

Controlling Nanostructures by Templated Templates: Inheriting Molecular Orientation in Binary Heterostructures — •Tobias Breuer and Gregor Witte — AG Molekulare Festkörperphysik, Philipps-Universität Marburg

Precise preparation strategies are required to fabricate nanostructures of specific arrangement. In bottom-up approaches, where nanostructures are gradually formed by piecing together individual parts to the final structure, the self-ordering mechanisms of the involved structures are utilized. In order to achieve the desired structures regarding morphology, grain size and orientation of the individual moieties, templates can be applied, which influence the formation process of subsequent structures. However, this strategy is of limited use for complex architectures, as the templates only influence the structure formation at the interface between the template and the first compound. Here, we discuss the implementation of so-called templated templates and analyze, in which extent orientations of initial layers are inherited in top layers of another compound to enable structural control in binary heterostructures. To that purpose we have prepared crystalline templates of the organic semiconductors pentacene and perfluoropentacene in different exclusive orientations. We observe that for templates of both individual materials the molecular orientation is inherited in the top layers of the respective counterpart.

[1] T. Breuer & G. Witte ACS Applied Materials & Interfaces 7 (36), 20485-20492 (2015)

DS 53.23 Thu 16:00 Poster A

Preparation and Characterization of Mixed Organic Thin Films Containing Sexithiophene and Perfluorinated Sexithiophene — •Berthold Reisz, Simon Weimer, Rupak Banerjee, Christopher Lorch, Johannes Dieterle, Giuliano Duva, Alexander Hinderhofer, Alexander Gerlach, and Frank Schreiber — Universität, Tübingen, Deutschland

We study molecular mixed thin films of α-Sexithiophene (6T), a well known organic p-type semiconductor with high hole mobility, together with its perfluorinated counterpart, the so far rarely studied n-type tetradecafluoro-α-sexithiophene (PF6T). Thin films of this donor-acceptor system with various mixing ratios have been grown on several substrates in ultrahigh vacuum by coevaporation. The films have been examined with x-ray and ultraviolet photoelectron spectroscopy (XPS/UPS), atomic force microscopy (AFM), x-ray diffraction (XRD), absorption measurements and variable angle spectroscopic ellipsometry (VASE). Connections between mixing ratio, morphology, crystalline structure and optical properties are discussed, following previous studies [1].

[1] A. Hinderhofer, F. Schreiber. Organic-Organic Heterostructures: Concepts and Applications. ChemPhysChem, 13(3):628-643, 2012.

DS 53.24 Thu 16:00 Poster A

Surface morphology of vapor deposited chitosan thin films — •Maria Jose Retamal[1,3], Tomas Corrales[2], Marcelo Cisternas[3,6], Nicolas Moraga[3,6], Sebastian Gutierrez[4], Tomas Perez-Acle[4], Patrick Huber[5], and Ulrich Volkmann[3,6] — [1]Facultad de Química, PUC, Santiago, Chile — [2]IAI Universidad de Tarapacá, Arica, Chile — [3]CIEN-UC, Santiago, Chile — [4]DLab, Fundación Ciencia y Vida, Santiago, Chile — [5]Hamburg U. of Technology, D-21073 Hamburg, Germany. — [6]Instituto de Física, PUC, Santiago,Chile

Chitosan is a useful biopolymer with several industrial and biological applications. In spite of the many applications of chitosan, there is a lack of studies regarding the morphology and growth mechanisms of thin films of this biopolymer. We present a study of thin chitosan films prepared using PVD with in-situ ellipsometric monitoring. The prepared films are studied using AFM in order to correlate surface morphology with evaporation parameters. We find that the surface morphology of our final thin films depends both on the ellipsometric optical thickness as well as the evaporation rate. We find the correct evaporation parameters in order to obtain homogeneous thin films of chitosan, which are relevant for future chitosan based nano-devices. AFM images on samples prepared as a function of film thickness at constant evaporation rate, as well as AFM topographies of samples prepared as a function of evaporation rate for reaching identical film thickness show both very strong similarities to images reported as spinodal dewetting of thin metal and polymer films as a function of temperature.

DS 53.25 Thu 16:00 Poster A

XPS study of Tetraphenylporphyrin layers on Au(111) — •Peter Roese[1,2], Philipp Espeter[1,2], Christoph Keutner[1,2], Dominique Krull[1,2], Ulf Berges[1,2], and Carsten Westphal[1,2] — [1]Experimentelle Physik I, TU Dortmund, Otto-Hahn-Straße 4a, 44221 Dortmund, Germany — [2]DELTA, Technische Universität Dortmund, Maria-Goeppert-Mayer-Straße 2, 44221 Dortmund, Germany

Porphyrins are important building blocks of life. Furthermore, the interest in applying porphyrins as technical devices increased in recent years. Applications such as organic solar cells [1], organic LED's [2] or the usage of porphyrins as a photosensibilisator in cancer treatment [3] utilize the strong absorption properties of porphyrins in the visible spectrum. Here, we present the investigation of multilayers of metal-free meso-tetraphenylporphyrin (2HTPP) on an Au(111) surface using x-ray photoelectron spectroscopy (XPS) at the U55 beamline 11 at DELTA. In this study we report on a possible bonding between the molecules in the first interface layer to the Au(111) substrate while the upper molecule layers are deposited in their original form without bonding. References: [1] J. P. Collman et al., Chemical Reviews 104, 561 (2004). [2] J. M. Olson, Biochimica et Biophysica Acta (BBA) - Reviews on Bioenergetics 594, 33 (1980). [3] W. M. Campbell et al., The Journal of Physical Chemistry C 111, 11760 (2007).

DS 53.26 Thu 16:00 Poster A

Interface Analysis of PTCDI-C1 thin films on polycrystalline silver surfaces — •Guangcheng Huang, Carolin C. Jacobi, Julia Rittich, Cathy Jodocy, and Matthias Wuttig — I. Institute of Physics (IA), RWTH Aachen University, Aachen, Germany

Electronic devices based on organic thin films, such as organic solar cells (OSCs) and organic thin film transistors (OTFTs), have been greatly improved in the last decade. Understanding the interface effects between organic thin films and metal surfaces is one of the crucial steps to further improve these devices. The organic material N,N'-Dimethyl-3,4,9,10-perylenetetracarboxylic diimide (PTCDI-C1) is a promising n-type semiconductor for the application in OSCs and OTFTs. In this work, thin films of PTCDI-C1 are deposited by organic molecular beam deposition (OMBD) with varying film thicknesses onto polycrystalline silver surfaces. The energy level alignment and binding state between the metal surface and the organic molecule are determined in-situ by photoelectron spectroscopy (PES) and inverse photoelectron spectroscopy (IPES). In addition, the morphology of the organic thin films is investigated by atomic force microscopy (AFM) and the structure by X-ray diffraction (XRD).

DS 53.27 Thu 16:00 Poster A

Optical and Structural Properties of Thin Films of Difluoro-anthradithiophene — •Timo Storzer[1], Alexander Hinderhofer[1], Giuliano Duva[1], Alexander Gerlach[1], John E. Anthony[2], and Frank Schreiber[1] — [1]Universität Tübingen, Institut für Angewandte Physik, Auf der Morgenstelle 10, 72076 Tübingen — [2]Department of Chemistry, University of Kentucky, Lexington, Kentucky, 40506, USA

We report on the optical and structural properties of the novel functionalized anthradithiophene derivative difluoro-anthradithiophene (diF-ADT). Anthradithiophene (ADT) is isoelectronic with pentacene, which is one of the most studied organic semiconductors. A fluorinated anthradithiophene derivative with (triethylsilyl)ethynyl side groups (diF-TES-ADT) has been studied in recent years and showed high charge carrier mobilities in solution-cast thin-film transistors [1]. We present a study of thin films of diF-ADT prepared by organic molecular beam deposition (OMBD). We show how the growth conditions (e.g. substrate temperature, deposition rate) influence the optical and structural properties based on UV-Vis absorption, spectroscopic ellipsometry, photoluminescence (PL), X-ray reflectivity (XRR) and AFM measurements.

[1] Gundlach, D. J.; Anthony, J. E. et al., Nat. Mater. 2008, 7, 216.

DS 53.28 Thu 16:00 Poster A

Nanomechanical investigation of a thin-film multi-layered electroceramic/metal-organic framework optical device — •James P Best[1], Engelbert Redel[2], Hartmut Gliemann[2], Christof Wöll[2], and Johann Michler[1] — [1]EMPA, Thun, Switzerland — [2]KIT-IFG, Karlsruhe, Germany

Thin-film multilayer stacks of mechanically hard magnetron sputtered indium tin oxide (ITO) and mechanically soft highly porous surface anchored metal-organic framework (SURMOF) HKUST-1 were studied using nanoindentation. Crystalline, continuous, and monolithic surface anchored MOF thin films were fabricated using a liquid-phase epitaxial growth method. Control over respective fabrication processes allowed for tuning of the thickness of the thin film systems with a high degree of precision. It was found that the mechanical indentation of such thin films is significantly affected by the substrate properties; however, elastic parameters were able to be decoupled for constituent thin-film materials. For indentation of multilayer stacks, it was found that as the layer thicknesses were increased, while holding the relative thickness of ITO and HKUST-1 constant, the resistance to deformation was significantly altered. Such an observation is likely due to small, albeit significant, changes in film texture, interfacial roughness, size effects, and controlling deformation mechanism as a result of increasing material deposition during processing. Such effects may have consequences regarding the rational mechanical design and utilization of MOF-based hybrid thin-film devices.

DS 53.29 Thu 16:00 Poster A

Adsorption study of terephthalic and benzoic acids on HOPG with Metastable Induced Electron Spectroscopy (MIES) — •Marcel Marschewski[1], Harun Tas[2], Christian F. Otto[2], Wolfgang Maus-Friedrichs[1], Andreas Schmidt[2], and Oliver Höfft[3] — [1]Institut für Energieforschung und Physikalische Technologien, Technische Universität Clausthal, Deutschland — [2]Institut für Organische Chemie, Technische Universität Clausthal, Deutschland — [3]Institut für Elektrochemie, Technische Universität Clausthal, Deutschland

The adsorption behavior of benzoic acids on conducting interfaces like HOPG is of high interest for the understanding of the building mechanism of 2D and 3D frameworks on surfaces. Thus, the knowledge about the molecular orientation and the molecule-substrate interaction is of great importance. Here we present our results on the adsorption of 4-substituted benzoic acids (R = hydroxy-, methoxy-, propoxy-, pentyloxy- and decyloxy-chains) and terephthalic acid (TPA) on HOPG. The molecular films were studied with Metastable Induced Electron Spectroscopy (MIES) and Ultraviolet Photoelectron Spectroscopy (UPS(HeI)). For the TPA monolayer we find hints for a more planar orientation of the molecules. The benzoic acid molecules show a similar adsorption behavior on HOPG. For the 4-(decyloxy) benzoic acid we assume a possible reorientation of the alkyl chains after the first monolayer.

DS 53.30 Thu 16:00 Poster A

The study of interaction, nonlinear and dissipation effects in nanomembranes by investigating the dispersion relations of bending waves — •Fan Yang, Elke Scheer, and Reimar Waitz — Universitaetsstrasse.10 Fach 681, 78457 Konstanz, Germany

Deciphering the mode shapes of vibrations of nanopatterned membranes is paving the way for applications of nanoscale membrane which rely on particular properties of vibrational excitations. The mode shape of bending waves in thin silicon, silicon carbide, silicon nitride and ultrathin carbon nanomembranes is measured as a function of space and time, using a phase-shift interferometer with continuous and stroboscopic light [1,2]. We develop a method to obtain the contribution of the membrane itself, the eigen-frequencies and the Q factor of the membrane. The contributions of a superposition of the mode corresponding to the excitation frequency and several higher harmonics can be separated and be imaged up to the eighth harmonic of the excitation frequency. We can determine the dispersion relation of membrane oscillations in a frequency range from ground mode up to 12 MHz. The study of the temperature-dependent vibration behavior reveals an unexpected temperature dependence of the mechanical properties of a prestressed nanomembrane. At variance to expectations based on classical continuum mechanics we observe that Young's modulus increases with increasing temperature.

[1] R. Waitz, et al., Phys. Rev. B 86, 039904 (2012).
[2] X. H. Zhang, et al., Appl. Phys. Lett. 2015, 106(6): 063107.

DS 53.31 Thu 16:00 Poster A

Growth of pinholes in metal electrodes of organic photovoltaic cells — •Daniel Fluhr[1], Burhan Muhsin[1], Rolf Öttking[1], Roland Rösch[1], Marco Seeland[2], and Harald Hoppe[1] — [1]Center for Energy and Environmental Chemistry Jena (CEEC Jena) & Laboratory of Organic and Macromolecular Chemistry (IOMC), Friedrich Schiller University Jena, 07743 Jena, Germany — [2]Technische Universität Ilmenau, 98693 Ilmenau, Germany

Lifetime is still a major problem of organic photovoltaic (OPV) cells. There are many reasons for solar cell degradation varying from shunts induced by impurities or electromigration over photoinduced oxidation of active layer materials to corrosion and delamination of the metal contact both induced by oxygen or water ingress. One issue concerns so-called pinholes through the metal back electrode of the device. These pinholes offer pathways for ingress of water and oxygen which may attack the metal-organic interface by introducing delamination through formation of insulating metal oxides or hydrogen evolution. As charge injection and extraction is suppressed at delaminated areas, the active area taking part in power conversion - and hence the overall efficiency - becomes reduced. We investigated the influence of different environmental conditions on the reduction of the active area of the OPV cell. Spatially resolved measurements give information on location and size of insulated areas induced by pinholes in the metal back contact. Time resolved measurements during degradation of the devices revealed the dynamics and rate of growth of these individual defects.

DS 53.32 Thu 16:00 Poster A

Formation of noble metal thin films on P(VDF-TrFE) during DC-magnetron sputtering — Alexander M. Hinz[1], •Oleksandr Polonskyi[1], Franziska C. Löhrer[2], Volker Körstgens[2], Matthias Schwartzkopf[3], Stephan V. Roth[3], Peter Müller-Buschbaum[2], Thomas Strunskus[1], and Franz Faupel[1] — [1]CAU zu Kiel, Institut für Materialwissenschaft, LS Materialverbunde, 24143 Kiel, Germany — [2]TU München, Physik-Department, LS Funktionelle Materialien, 85748 Garching, Germany — [3]Deutsches Elektronensynchrotron DESY, 22607 Hamburg, Germany

In most devices using organic thin films as functional layers, e.g. organic solar cells, OLEDs or MEMS sensors, it is necessary to have an electrical contact with well-defined properties on these layers. This is often accomplished by depositing metallic electrodes onto the organic layers by physical vapour deposition (PVD) techniques. In order to control and predict the properties of the electrical contacts it is necessary to understand the interplay between the deposition process and the formation of the metallic electrodes. In this contribution we present the in-situ morphological characterization of Au thin film growth during the deposition by DC-magnetron sputtering onto P(VDF-TrFE). P(VDF-TrFE) is a versatile ferroelectric polymer used in many applications including transducers, actuators and sensors. The morphological information is obtained by grazing incidence small angle x-ray scattering (GISAXS). The in-situ information is compared with ex-situ information obtained by SEM.

DS 53.33 Thu 16:00 Poster A

Molecular order in dihexylsexithiophene thin film OFETs — Nina Zeilmann[1], Hans-Georg Steinrück[2,3], Manuel Johnson[1], Andreas Magerl[2], and •Rainer Fink[1] — [1]FAU Erlangen-Nürnberg, Physical Chemistry 2, Erlangen, Germany — [2]FAU Erlangen-Nürnberg, LS Kristallografie, Erlangen, Germany — [3]present address: SSRL, Menlo Park, USA

The end-functionalized sexithiophene Hex6THex represents a benchmark molecule for organic electronic applications such as OFETs due to its high charge carrier mobility. The latter is mainly related to the high degree of molecular ordering and π-π-stacking within the films. We have employed several probes to investigate the morphologies, molecular order and orientations of such films (thicknesses around 10 layers) prepared by vacuum sublimation at various substrate temperatures on inert SiO2 or Si3N4 substrates. X-ray reflectivity (XRR) probes the vertical electron density distribution that provides information on the thickness and density of individual sublayers. In particular, XRR yields high quality data on the arrangements of both the hexyl functionalities and the thiophene backbone. It is found that the projected length of both film features critically depends on the substrate temperature during deposition. Based on the experimental results, a model proposing the molecular orientation of the Hex6THex molecules with respect to the substrate is derived. These results are in very good agreement with AFM and micro-NEXAFS studies. Some correlations to the electrical transport properties of the films are drawn.

DS 53.34 Thu 16:00 Poster A

Colloidal masking and ion-etched nanochannels on flexible thin foils — •Calvin Brett[1,2], Matthias Schwartzkopf[1], Stephan Roth[1], Michael A. Rübhausen[2], Patrick Kluth[3], Markus Bender[4], Daniel Severin[4], and Christina Trautmann[4] — [1]DESY, Notkestr. 85, 22607 Hamburg — [2]Universität Hamburg, Inst. f. Nanostruktur- und Festkörperforschung, CFEL, APOG, Univ. Hamburg, Luruper Chaussee 149, 22761 Hamburg — [3]Australian National University. Department of Electronic Materials Engineering, Research School of Physics and Engineering, The Australian National University, Canberra, ACT 2601 — [4]: GSI Helmholtzzentrum für Schwerionenforschung GmbH, Planckstraße 1, 64291 Darmstadt

The major issues in the fabrication of periodic nanostructure arrays are the high costs, low patterning speed, and small patterning area. Spray coating of polystyrene colloids (PS) and ion-etched nanochannels on a flexible, chemical resistance polymer (PDMS) thin foil, enable reusable soft masks for deposition and imprinting techniques. Spray coating leads to a self-assembled colloidal film, where every nanosphere can be used as lenses for lithographic fabrication methods. We prove the application principle and the morphology by scattering methods, contact angle analysis and spectroscopic imaging methods. This study offers a novel routine for cost effective nanofabrication which is wide applicable in nanoscale materials.

DS 53.35 Thu 16:00 Poster A

Organic thin film growth on exfoliated hexagonal boron nitride — •Jakob Alexander Genser[1], Markus Kratzer[1], Alexandar Matkovic[2], Rados Galic[2], and Christian Teichert[1] — [1]Institute of Physics, Montanuniversität Leoben, Austria — [2]Institute of Physics, University of Belgrade, Serbia

Hexagonal boron nitride (h-BN) is a two-dimensional insulator. Especially in conjunction with graphene as ultrathin flexible electrode in organic electronics h-BN has great potential as 2D dielectric. Therefore, it is essential to understand organic thin film growth on h-BN.

Here, we use the organic semiconductor molecule para-hexaphenyl (6P) to study the growth of small, linear, conjugated molecules on h-BN. As substrates, exfoliated h-BN flakes transferred onto a SiO2 support is used. Submonolayer 6P thin films are prepared by vapor deposition in a hot wall epitaxy (HWE) system. The resulting thin film morphologies are investigated as a function of substrate temperature using atomic force microscopy. First results indicate that 6P forms needle like structures consisting of molecules with their long axes oriented parallel to the h-BN plane. The needles show preferential growth directions corresponding to the substrate symmetry.

DS 53.36 Thu 16:00 Poster A

Tailoring Bragg-gratings for light outcoupling of red top-emitting organic light-emitting diodes — •Paul-Anton Will[1], Cornelius Fuchs[1], Frank Boldt[2], Reinhard Scholz[1], Simone Lenk[1], and Sebastian Reineke[1] — [1]Institut für Angewandte Photophysik, Technische Universität Dresden, Germany — [2]Institut für Physik, Technische Universität Chemnitz, Germany

Introducing Bragg-gratings into OLED structures is a promising approach to increase the overall device efficiency. Here, scattering effects lead to a redistribution of internal modes, i.e. wave guided and/or surface plasmon polariton modes, with the benefit of an increased out-coupled mode fraction [1]. The overall emission characteristics of a device depend on the OLED properties like emitter spectrum, device layout, and optical micro cavity order, and also strongly on the shape, period, and height of the incorporated grating structure. We present a detailed analysis of the influence of one dimensional gratings on the emission of various red top-emitting OLEDs by using optical thin film simulations quantifying the emission from periodically perturbated optical micro cavities. AFM measurements of nanoimprinted Bragg-gratings serve as input for the optical simulations. This facilitates the comparison with experimental results from manufactured devices leading to first hints for optimal grating periods in relation to the vertical aspect ratios of the grating structure. Once the optimal parameters are found, the use of Bragg-gratings pose a cheap and up-scalable method to improve the OLED efficiency.

[1] T. Schwab *et al.*, Opt. Express 22, 7524-37, (2014)

DS 53.37 Thu 16:00 Poster A

Growth morphologies of a polar pentacene derivative on SiO_2 and graphene — •Benjamin Kaufmann[1], Markus Kratzer[1], Tony Lelaidier[2], Olivier Siri[2], Aleksandar Matković[3], Radoš Gajić[3], Conrad Becker[2], and Christian Teichert[1] — [1]Institute of Physics, Montanuniversitaet Leoben, Franz Josef Straße 18, 8700 Leoben, Austria — [2]CINaM, Aix Marseille Université, Campus de Luminy Case 913, 13288 Marseille, France — [3]Institute of Physics, Department for Solid State Physics and New Materials, University of Belgrade, Pregrevica 118, 11080 Belgrade, Serbia

We investigated the growth morphologies of the polar organic molecule dihydrotetraazapentacene (DHTAP) on SiO_2 and exfoliated graphene. The morphology of ultra-thin films grown by hot wall epitaxy was analyzed using atomic force microscopy. The morphologies arising between 290K - 390K exhibit a strong temperature dependence and differ from those found for pentacene. Above substrate temperatures of 330K, the molecules tend to build curved, needle-like structures with lengths of 50nm - 1000nm and heights of a few nanometers. At lower growth temperatures, no needles are present as it is also the case for pentacene growth on SiO_2. On graphene, the islands are reduced in height compared to those grown on SiO_2. Also here, needle-like structures were found.