

O 59: Nanostructures at surfaces: 1D and 2D structures and networks I

Time: Wednesday 10:30–13:00

Location: MA 141

O 59.1 Wed 10:30 MA 141

Physical Vapor Deposition at Oblique Angles — ●CHRISTOPH GRÜNER, SUSANN LIEDTKE, and BERND RAUSCHENBACH — Leibniz Institute of Surface Engineering (IOM), Permoserstraße 15, D-04318 Leipzig, Germany

Physical vapor deposition at oblique angles is an often found circumstance in applied thin film deposition. Besides the geometric relation between material source and the substrate, the topography of the substrate as well as its curvature, shape and roughness locally lead to oblique deposition. Thin films deposited at oblique angles can show significant morphological differences compared to the vertically deposited counterparts. The formation of porous films, consisting of a large number of tilted columns is typically observed under non-normal deposition conditions. Deposition at highly oblique angles is also utilized to create separated nanostructures on surfaces. Techniques referring to this are known as oblique angle deposition (OAD) and glancing angle deposition (GLAD). Although these techniques have been used since the 1950s, a model that is able to adequately predict the properties of the obliquely grown films has not been found yet. In this contribution, a model is proposed, which allows predicting the density, growth speed and columnar tilt angle of obliquely deposited thin films for different materials over the complete angle of incidence range.

O 59.2 Wed 10:45 MA 141

Texture, morphology and microstructure of nanostructured Ti thin films grown by oblique angle deposition — ●SUSANN LIEDTKE, CHRISTOPH GRÜNER, JÜRGEN W. GERLACH, ANDRIY LOTNYK, and BERND RAUSCHENBACH — Leibniz Institute of Surface Engineering (IOM), Permoserstraße 15, D-04318 Leipzig, Germany

Highly porous, sculptured metallic thin films are interesting for numerous applications such as electrodes in fuel cells and Li-ion batteries as well as for surface enhanced Raman sensors. Combining electron beam evaporation and oblique angle deposition (OAD) represents a powerful method to sculpture such thin films consisting of separated, tilted nano-sized columns. Tailoring the properties of the thin films requires the ability to control the shape of the nano-sized columns precisely. Although considerable research has been performed on insulating and semi-conducting OAD-structures, the growth of metallic OAD-structures still remains only fragmentarily understood. However, it is known that the angle of the incoming particle flux θ and the substrate temperature T influence the growth of such columns significantly. The experimental setup allows covering a substrate temperature range between $77\text{ K} < T < 1000\text{ K}$, while the angle of the incoming particle flux can be varied between $0^\circ < \theta < 90^\circ$. The presentation focuses on the texture, morphology and microstructure of Ti porous thin films depending on these parameters. The samples were deposited on natively and thermally oxidized Si(100) substrates. Analysis was carried out using X-ray diffraction in-plane pole figure measurements, scanning electron microscopy and transmission electron microscopy.

O 59.3 Wed 11:00 MA 141

Cobalt silicide nanostructures on planar and vicinal Si(111) surfaces — ●LARS FRETER, MARTIN FRANZ, STEPHAN APPELFELLER, and MARIO DÄHNE — Institut für Festkörperphysik, Technische Universität Berlin, Hardenbergstraße 36, 10623 Berlin

The growth of transition metal silicides on Si(111) surfaces is interesting since they form various different nanostructures. Using Co is especially promising because Co silicide nanostructures range from small ring clusters over two-dimensional reconstructions, like the $\text{Si}(111)\sqrt{7} \times \sqrt{7}\text{R}19.1^\circ\text{-Co}$ and the $\text{Si}(111)\sqrt{13} \times \sqrt{13}\text{R}13.9^\circ\text{-Co}$, to three-dimensional islands and nanowires consisting of bulk silicides.

Here, the properties of these structures were investigated using scanning tunneling microscopy and spectroscopy as well as low energy electron diffraction. The samples were prepared using Co coverages between submonolayers and some monolayers and temperatures between 500°C and 900°C .

In order to force the formation of Co silicide nanowires instead of planar films, the vicinal Si(557) and Si(553) surfaces were also employed. Here, the formation of elongated, nanowire-like silicide islands is observed.

O 59.4 Wed 11:15 MA 141

Pressure-induced melting of confined ice — ●KAI SOTTHEWES^{1,2}, PANTELIS BAMPOULIS^{1,3}, HAROLD ZANDVLIET¹, DETLEF LOHSE³, and BENE POELSEMA¹ — ¹Physics of Interfaces and Nanomaterials, Mesa+ Institute of Nanotechnology, University of Twente, P.O. Box 217, 7500AE Enschede, The Netherlands — ²II. Institute of Physics B and JARA-FIT, RWTH Aachen University, D-52074 Aachen, Germany — ³Physics of Fluids Group and Max Planck Center Twente, University of Twente, P.O. Box 217, 7500AE Enschede, The Netherlands

The states of aggregation of confined water are highly important and of great fundamental interest in surface chemistry, life and environmental sciences. Due to limited experimental access, a coherent understanding of the phase behavior and the occurring phase transitions of interfacial ice is still lacking. Using scanning probe techniques, we studied the fully reversible ice-liquid water transition for water confined between graphene and muscovite mica. A transition from two-dimensional (2D) ice into a quasi-liquid phase is observed by applying a pressure exerted by an atomic force microscopy (AFM) tip. At room temperature the critical pressure amounts to about 6 GPa. The transition is completely reversible: refreezing occurs when the applied force is lifted. The critical pressure to melt the 2D ice decreases with temperature and the latent heat of fusion is 0.15 eV/molecule, being twice as large as for bulk ice. Our findings form a paradigm of the classic phenomenon of regelation decoupled from environmental thermal effects.

O 59.5 Wed 11:30 MA 141

Topological states and nearly flat electron band in engineered atomic lattices — ●ROBERT DROST^{1,2}, ARI HARJU¹, TEEMU OJANEN¹, and PETER LILJEROTH¹ — ¹Aalto University School of Science, Espoo, Finland — ²Max-Planck-Institut für Solid State Research, Stuttgart, Germany

Topological materials exhibit protected edge modes that have been proposed for applications in spintronics and quantum computation. Although a number of such systems exist, it would be desirable to be able to test theoretical proposals in an artificial system that allows precise control over key parameters of the model. The essential physics of several topological systems can be captured by low-dimensional tight-binding models which can also be implemented in artificial lattices. Here, we apply this method using a vacancy lattice in a chlorine monolayer on Cu(100). We use low-temperature scanning tunnelling microscopy to fabricate such lattices with atomic precision and probe the resulting local density of states. We implement of two tight-binding models of fundamental importance: the polyacetylene (dimer) chain with topological domain-wall states, and the Lieb lattice with a flat electron band. These results provide an important step forward in the ongoing effort to realize designer quantum materials with tailored properties.

O 59.6 Wed 11:45 MA 141

Exchanging the central metal atoms in adsorbed macrocycles — ●ALEXANDRA RIEGER¹, STEPHAN SCHNIDRIG², BENJAMIN PROBST², KARL-HEINZ ERNST¹, and CHRISTIAN WÄCKERLIN¹ — ¹Swiss Federal Laboratories for Material Science and Technology, Dübendorf, Switzerland — ²University of Zurich, Switzerland

Surface adsorbed macrocycles exhibit a number of interesting physical and chemical properties, many of them are determined by their transition metal centers. We report on the substitution of the transition metals in surface-adsorbed porphyrin (P), a porphyrin-related macrocycle. Using scanning tunneling microscopy (STM) and X-ray photoelectron spectroscopy (XPS), we demonstrate a defined hierarchy in this replacement process, that is: Ni substitutes Cu, Fe substitutes Cu and Fe substitutes Ni, although less efficiently. The Cu to Ni and Cu to Fe atom replacement reactions are surprisingly efficient and proceed completely at 423 K. These results open up new possibilities to study coordination chemistry in solvent free environment. Furthermore, we show that the atomic hydrogen produced by on-surface metalation can lead to the scission of the cyano groups on the rim of the macrocycle which desorb as hydrogen cyanide. This result implies that atomic hydrogen, which is produced in numerous on-surface reactions, can induce interesting reactions.

O 59.7 Wed 12:00 MA 141

Identification and Nanoengineering of Hot Electron-Induced Tautomerization — ●JENS KÜGEL¹, MARKUS LEISEGANG¹, MARKUS BÖHME¹, ANDREAS KRÖNLEIN¹, AIMEE SIXTA², and MATTHIAS BODE^{1,3} — ¹Physikalisches Institut, Experimentelle Physik II, Universität Würzburg, Am Hubland, 97074 Würzburg, Germany — ²University of Texas at Austin, Austin, Texas 78712, United States — ³Wilhelm Conrad Röntgen Center of Complex Material Systems (RCCM), Universität Würzburg, Am Hubland, 97074 Würzburg

The tautomerization of molecules, that is, the bistable position of hydrogen protons within an organic frame, has recently been discussed as a potential avenue toward nanoscale switches. Whereas consensus exists that STM-induced local switching is caused by inelastic electrons that excite vibrational molecular modes [1], the detailed process responsible for nonlocal switching and methods to control this process are largely unknown. Here, we demonstrate for dehydrogenated H₂Pc molecules on Ag(111) how to controllably decrease or increase the probability of nonlocal, hot electron-induced tautomerization by Ag nanostructures [2]. We will show that Ag atom walls act as potential barriers that exponentially damp the hot electron current between the injection point and the molecule. Furthermore, by using elliptical nanostructures, we could coherently focus hot electrons onto the molecule, resulting in an almost tripled switching probability.

[1] T. Kumagai *et al.*, Phys. Lett. **111**, 246101 (2013)

[2] J. Kügel *et al.*, Nano Lett. **17**, 5106 (2017)

O 59.8 Wed 12:15 MA 141

Below 2D: Design and characterization of electronic fractals — ●MARLOU SLOT¹, SANDER KEMPKE², SAOIRSE FREENEY¹, STEPHAN ZEVENHUIZEN¹, DANIEL VANMAEKELBERGH¹, INGMAR SWART², and CRISTIANE MORAIS SMITH¹ — ¹Debye Institute for Nanomaterials Science, Utrecht University, Netherlands — ²Institute for Theoretical Physics, Utrecht University, Netherlands

The dimensionality and geometry of a quantum system are decisive factors for its electronic properties. So far, research has focused on systems with integer dimensions, ranging from 0D to 3D. However, very little is known about the properties of electrons in fractional dimensions. This is because geometric fractals, although pervasive in our everyday life, remain elusive in the quantum world. One possible route to create electronic quantum fractals is by confining the surface state electrons of Cu(111) by accurate positioning of adsorbed CO molecules [1,2]. Here, we realize and characterize an electronic Sierpiński triangle fractal with dimension 1.58. Using scanning tunneling spectroscopy and wave-function mapping, we observe single-electron wave functions with a fractal dimension derived from the Sierpiński geometry. These results bear importance for the understanding of the transport properties of and charge storage in fractal-like structures, opening the path to fractal-dimension electronics in a systematic and controlled manner.

1. K.K. Gomes *et al.*, Nature 483, 306-310 (2012)

2. M.R. Slot *et al.*, Nature Physics 13, 672-676 (2017)

O 59.9 Wed 12:30 MA 141

Regulation of Organic Structures by Cations and Anions from Salts — ●LEI XIE and WEI XU — Interdisciplinary Materials Research Center, Tongji-Aarhus Joint Research Center for Nanostructures and Functional Nanomaterials College of Materials Science and Engineering, Tongji University Shanghai 201804 (P.R. China)

From the combination of STM imaging and DFT calculations, we show that both cations and anions provided by salts can simultaneously interact with different sites of the target molecules resulting in structural formation in a synergistic way. In the first example, we choose the 9-ethylguanine molecule (9eG) and transition metal halides as model system, showing that metal-organic structures can further be stabilized by the electronic interactions between halogen anions and hydrogen-rich sites of molecules. In the second case, 1-methylcytosine (1mC) and alkali halide are chosen where both ions participating in structural formation. The elementary metal*organic motifs are connected by Cl in a variety of fashions demonstrating structural diversity. These findings provide a facile method of introducing both cations and anions at the same time for the regulation of organic structures.

References: [1] L. Xie, C. Zhang, Y. Ding, W. Xu*, Angew. Chem. Int. Ed. 56, 5077-5081, 2017 [2] L. Xie, C. Zhang, Y. Ding, W. E, W. Xu*, Chem. Commun. 53, 8767-8769, 2017

O 59.10 Wed 12:45 MA 141

Large area nanopatterns in elastomers by nanosphere mask replication — ●JULIUS BÜRGER¹, KATHARINA BRASSAT¹, THORSTEN MEYERS², ULRICH HILLERINGMANN², and JÖRG K. N. LINDNER¹ —

¹Paderborn University, Dept. of Physics, Paderborn, Germany — ²Paderborn University, Sensor Technology Dept., Paderborn, Germany

Soft lithography is a well-established low-cost surface patterning technique using structured elastomers for transferring large-scale patterns with nanometer-sized features. The biocompatible, optically transparent, highly flexible and isolating polydimethylsiloxane (PDMS) is a widely used elastomer which can be poured on a mold. After cross-linking it is released by a peel off, replicating the surface morphology of the mold. For the creation of a mold with nanoscale features, we exploit nanosphere lithography (NSL). In NSL a colloidal suspension forms a hexagonally close packed sphere mask on a substrate by self-organization. The sphere diameter can range from nanometers to several micrometers and post sphere deposition treatments of the masks such as plasma shrinking yield a huge diversity of possible masks. We use a monolayer of 618 nm polystyrene spheres on a silicon substrate as a mold to obtain stamps with replication of a hexagonal structure with elevated tips at initial interstices between the spheres. Aspect ratios of stamp features were optimized by adjusting the PDMS viscosity, by hydrophilisation of the substrate surface and by interlinking the spheres. We show a novel approach for tactile sensing with a transistor-based capacitive pressure sensor with promising characteristics for creation of an electronic skin.