

O 68: Nanostructures at Surfaces: 1D, 2D Structures and Networks

Time: Wednesday 18:15–20:30

Location: Poster A

O 68.1 Wed 18:15 Poster A

Electronic structure of semiconductor superlattices — ●MARLOU SLOT¹, JACO GEUCHIES¹, JOEP PETERS¹, EFTERPI KALESKI^{2,3}, CHRISTOPHE DELERUE³, INGMAR SWART¹, and DANIEL VANMAEKELBERGH¹ — ¹Condensed Matter and Interfaces, Utrecht University, Utrecht, the Netherlands — ²Physics and Materials Science Research Unit, University of Luxembourg, Luxembourg, Luxembourg — ³IEMN - Département ISEN, UMR CNRS 8520, Lille, France

In the search for materials for (opto-)electronic applications, two-dimensional metal chalcogenide semiconductors have emerged as high-potential candidates. In addition to the atomic structure, the nanoscale lattice of the material has a significant influence on the electronic band structure. Oriented attachment of colloidal nanocrystals results in atomically coherent semiconductor superlattices with a long-range square or honeycomb periodicity. [1] Tight-binding calculations predict a rich electronic structure that is determined by strong electronic coupling between the periodically arranged nanocrystals. [2,3] Using scanning tunneling spectroscopy, we studied the local density of states of the superlattices.

1. W.H. Evers et al., *Nano Lett.* 13, 2317 (2013).
2. E. Kalesaki et al., *Phys. Rev. B* 88, 115431 (2013).
3. E. Kalesaki et al., *Phys. Rev. X* 4, 011010 (2014).

O 68.2 Wed 18:15 Poster A

Structure of Cu(100)-c(2x2)N surfaces — ●JULIA ANDREWS, KARIMAN ELSHIMI, TORSTEN VELTUM, and MATHIAS GETZLAFF — Institut für angewandte Physik, Universität Düsseldorf, 40225 Düsseldorf

Nanostructured surfaces have become of significant interest in the field of surface science over recent years. The understanding of self-arranged structures is relevant for instance for the use as a pattern for nanoparticle deposition. We study the pattern that nitrogen forms when reacting with a Cu(100) surface.

Under ultra-high vacuum conditions, we first proceed to a standard cleaning of the copper crystal by sputtering with argon followed by annealing. To prepare the Cu(100)-c(2 × 2)N surface we sputter with activated nitrogen followed again by annealing.

We examine the crystal structure by low energy electron diffraction (LEED). With a scanning tunnelling microscope (STM) we observe how the nitrogen arranges itself when forming Cu_xN.

O 68.3 Wed 18:15 Poster A

Sierpiński-triangle fractal crystals with the C_{3v} point group — ●DAOLIANG SONG¹ and YONGFENG WANG^{1,2} — ¹Key Laboratory for the Physics and Chemistry of Nanodevices, Peking University, Beijing 100871, China — ²Beida Information Research (BIR), Tianjin 300457, China

Self-similar fractals exist widely in nature, from the well-known snowflakes to the complicate Saturn's rings and are not only fundamentally important in both science and engineering, but also interesting in esthetics. Metal-organic Sierpiński triangles are particularly attractive for applications in gas separation, catalysis and sensing. Such fractals are constructed in this study by using 120°V-shaped 4,4'-dicyano-1,1':3',1"-terphenyl molecules and Fe atoms on Au(111), and studied in detail by low-temperature scanning tunneling microscopy. Density functional theory calculations are employed to rationalize the invisible Fe atoms in STM images. Monte Carlo simulations are performed to understand the formation mechanism of the surface-supported fractal crystals.

O 68.4 Wed 18:15 Poster A

Glancing angle deposition of metals — ●SUSANN LIEDTKE, CHRISTOPH GRÜNER, JÜRGEN W. GERLACH, and BERND RAUSCHENBACH — Leibniz-Institut für Oberflächenmodifizierung, Permoserstraße 15, 04318 Leipzig, Germany

Glancing angle deposition (GLAD) represents an ultrahigh vacuum physical vapor deposition process that utilizes self-shadowing of growing crystallites. Such self-shadowing effects occur if the substrate is strongly tilted with respect to the incoming particle flux. So far, the growth of metallic GLAD nanostructures remains poorly understood. For that reason, in this study GLAD of metals with different melting points is examined. Precisely, Ti and Al nanostructures are grown

on unstructured Si substrates. The growth of metal nanostructures is investigated depending on process parameters such as substrate temperature and the incidence angle of the particle beam. Finally, the resulting nanostructures are compared with each other.

O 68.5 Wed 18:15 Poster A

Electromigration to create nanoscale gaps for molecular electronics — ●ATASI CHATTERJEE, FREDERIK EDLER, CHRISTOPH TEGENKAMP, and HERBERT PFNÜR — Leibniz Universität Hannover, Institut für Festkörperphysik, 30167, Hannover, Germany

The fundamental size limitations of today's silicon based technologies can be solved by the bottom up approach, if stable and reproducible nanometer spaced electrodes can be generated, and single (organic) molecules can be reproducibly attached to them in well-defined geometries. Therefore, fabrication of reliable contacts in order to investigate the functionalities of the molecules is a primary challenge. Electromigration, which was earlier well known as a failure mechanism of integrated circuit metallizations subjected to high current densities, now serves as one of the most promising methods of fabricating metallic nanogaps. We create flat ultrathin silver nanocontacts at the centre via electro-migration of lithographically prepared silver nanowires on a silicon substrate. A thin adhesion layer of Cr is used for Ag contact pads to avoid contact problems with STM tips. Electromigration is performed in a 4-tip SEM/STM chamber where two tips are used to contact the structure and a software controlled process is used to reach the tunneling regime at a preset tunneling resistance. Ultrathin and laterally open contact structures allow direct access for the STM tips for local control, in-situ observation and characterization of the gap. By detailed investigations of the dependence on current density and temperature, we try to explore the underlying physical mechanisms that form electromigrated gaps.

O 68.6 Wed 18:15 Poster A

ARPES Studies of the Bi/InAs(100) Interface — OLIVIER HECKMANN^{1,2}, ●MARIA CHRISTINE RICHTER^{1,2}, UROS DJUKIC¹, WEIMING WANG³, IVANA VOBORNIK⁴, JEAN-MICHEL MARIOT⁵, JAN MINAR^{6,7}, JÜRGEN BRAUN⁶, HUBERT EBERT⁶, and KAROL HRICOVINI^{1,2} — ¹LPMS, Université de Cergy-Pontoise, Cergy-Pontoise, France — ²DSM/IRAMIS/SPEC, CEA Saclay, Gif-sur-Yvette, France — ³Tongji University, Shanghai 200092, China — ⁴APE beamline, Sincrotrone Trieste, Area Science Park, Basovizza, Italy — ⁵LCP-MR, Université P et M Curie/CNRS, Paris, France — ⁶LMU Munich, Munich, Germany — ⁷University of West Bohemia, Czech Republic

In this contribution we present ARPES studies of Bi/InAs(100) interface. Bismuth deposition followed by annealing of the surface results in the formation of one full Bi monolayer decorated by Bi-nanolines. We found that the building up of the interface does affect the electronic structure of the substrate. As a consequence of weak interaction, bismuth states are placed in the gaps of the electronic structure of InAs(100). We observe a strong resonance of the Bi electronic states close to the Fermi level; its intensity depends on the photon energy and the photon polarization. These states show nearly no dispersion when measured perpendicular to the nanolines, confirming their one-dimensionality. Interestingly, Bi atoms behave as donors, as their presence results in the appearance of an accumulation layer.

O 68.7 Wed 18:15 Poster A

Heat-induced formation of 1D and 2D coordination polymers on Au(111) — TUAN ANH PHAM¹, FEI SONG¹, MARIZA N. ALBERTI², MANH-THUONG NGUYEN³, CARLO THILGEN², FRANCOIS DIEDERICH², and ●MEIKE STÖHR¹ — ¹University of Groningen — ²ETH Zürich — ³International Centre for Theoretical Physics, Trieste

In the fast growing research field of on-surface molecular self-assembly, coordination bonding is considered as an important tool for the construction of low-dimensional molecular networks on metal surfaces. To date, most of the reported metal-ligand coordination units are based on the combination of organic ligands bearing pyridyl, cyano, hydroxyl or carboxyl endgroups and transition-metal atoms such as Cu, Fe, Co or Ni. However, the construction of such MOFs on Au surfaces with native Au atoms is hardly reported. Here, we show that MOFs comprising porphyrin derivatives can be formed on Au(111) upon anneal-

ing. Both a threefold and a fourfold coordination motif stabilizing the MOFs were found. These findings were compared to MOFs made from the same porphyrin derivatives and Co atoms. For this, Co atoms and porphyrin derivatives were deposited on Au(111).[1] In both cases, the same structures were observed what evidences that indeed a coordination bonding is formed between the cyano groups and gold atoms. Moreover, we also investigated the influence of the position of the substituents (cis- vs. trans-isomers) on the MOF formation on Au(111). We could successfully demonstrate that the dimensionality of the MOF can be tuned from 1D to 2D depending on the chosen isomer.

[1] T.A. Pham et al., Chem. Commun. 51 (2015) 14473

O 68.8 Wed 18:15 Poster A

Tuning the Interaction of Magnetic Molecules with a Metallic Substrate via an Insulating Film — DAVID SCHWICKERT¹, MACIEJ BAZARNIK¹, MICHA ELSEBACH¹, BERNHARD BUGENHAGEN², MARC H. PROSENC³, and ROLAND WIESENDANGER¹ — ¹Institute for Nanostructures and Solid State Physics, University of Hamburg, D-20355 Hamburg, Germany — ²Institute of Inorganic Chemistry, University of Hamburg, D-20146 University of Hamburg, Germany — ³Dept. of Chemistry, Technical University Kaiserslautern, Erwin-Schrödinger-Str. 52, D-67663 Kaiserslautern, Germany

Magnetic molecules are a promising approach towards spin-based information technology. We use Co-Salophene as a tailored building block for spintronic devices. The possibility to build self-assembled covalently bonded chains by tailored on-surface chemistry makes this molecule a perfect candidate for an all-spin based device.

However, it is necessary to eliminate Kondo screening of the magnetic centers of the molecules. We use ultrathin films of NaCl to decouple the molecules from the metallic surface. The Ullmann reaction requires a Au-crystal as catalyst. Therefore, we intercalate the presynthesized chains with NaCl.

In this presentation we show the dependence of the intercalation on the sample temperature during the deposition, as well as the deposition rate and time. For low coverages of NaCl, monolayer and double layer islands grow between the chains. With increasing coverage the chains are pushed ahead by the growing islands. When two islands grow together, a chain lying between them is lifted up.

O 68.9 Wed 18:15 Poster A

Self-assembly and stability of bridged triphenylamine derivatives on metal surfaces — CHRISTIAN STEINER¹, UTE MEINHARDT², BETTINA GLIEMANN², MARTIN GURRATH³, BERND MEYER³, MILAN KIVALA², and SABINE MAIER¹ — ¹Department of Physics, FAU Erlangen-Nürnberg, Germany — ²Department of Chemistry and Pharmacy, FAU Erlangen-Nürnberg, Germany — ³Computer-Chemie-Centrum, FAU Erlangen-Nürnberg, Germany

Molecular self-assembly is a key concept in supramolecular chemistry and nanoscience allowing for the construction of complex molecular architectures in a bottom-up approach through noncovalent interactions. The adsorption, chemical nature, and self-assembly of diaminotriazinyl- and carboxyl-substituted triphenylamines with dimethylmethylene bridges were studied on Au(111) and Cu(111) at submonolayer coverage by low-temperature scanning tunneling microscopy and density functional theory calculations.[1] While the self-assemblies on Au(111) are strongly directed by intermolecular hydrogen bond interactions, on Cu(111) both molecules aggregate in dense islands owing to the stronger molecule-surface interaction. The carboxyl substituents partially deprotonate at room temperature on Cu(111). The diaminotriazinyl-substituted triphenylamines adsorb mainly intact at room temperature and deprotonate gradually at increased adsorption temperatures changing the bonding mechanism from hydrogen bonding to metal-ligand interactions.

[1] C. Steiner et al. J. Phys. Chem. C, 119 (46), 25945-25955 (2015)

O 68.10 Wed 18:15 Poster A

Growth competition between Sierpiński triangle fractals and two-dimensional molecular crystals of H3PH on noble metal surfaces — XUE ZHANG¹ and YONGFENG WANG^{1,2} — ¹Key Laboratory for the Physics and Chemistry of Nanodevices, Department of Electronics, Peking University, Beijing, China — ²Beida Information Research (BIR), Tianjin, China

Recent studies demonstrate that simple functional molecules, which usually form 2D crystal structures when adsorbed on solid substrates, are also able to self-assemble into ordered openwork fractal aggregates. To direct and control growth of such fractal supramolecules it is necessary to explore the conditions under which both fractal and crystalline

patterns develop and coexist. In this contribution, we study the coexistence of Sierpiński triangle (ST) fractals and 2D molecular crystals which were obtained by adsorption of H3PH molecules on Au(111) in high vacuum. Growth competition between the STs and 2D crystals was realized by tuning surface coverage as well as by changing the substrate and functional groups of the molecular building block. To better understand the mechanisms of the fractal structure formation our experimental studies were accompanied by theoretical calculations with Density Functional Theory and Monte Carlo methods. The obtained results demonstrate the possibility of steering the self-assembly to create surface-supported fractal and non-fractal structures made up of the same material.

O 68.11 Wed 18:15 Poster A

Analysis of structural and mechanical properties of long chain self-assembled monolayer on Au(111) by STM and AFM — TORBEN MARX, DIRK DIETZEL und ANDRÉ SCHIRMMEISEN — Institut für Angewandte Physik, Justus-Liebig-Universität, Gießen

Self-assembled monolayers (SAMs) are considered potential building blocks for a variety of nanotechnology applications. They are employed in e.g. the fields of material protection, electrode modification in electrochemistry, lithography as well as biology and medicine. The specific structural and mechanical properties of SAMs are the result of a spontaneous formation of organized objects out of smaller units, i.e. molecules, and are typically of crucial importance for any application. An important parameter in this context is the chain length of the molecules. Short-chain alkanethiol SAM on Au(111) are well studied and it was found that at saturation coverage the monolayer is typically of complex structure. In this work we have analyzed a long-chain alkanethiol (hexadecanethiol), which have been rarely studied up to now due to their relatively high resistance in STM. We found distinct orientated domains with the typical $(\sqrt{3} \times \sqrt{3})R30^\circ$ structure to exist. The adsorbate was structured further into a $c(4 \times 2)$ superlattice, which splits up in five different phases [1]. Additionally we have used AFM to analyze the mechanical properties of SAM with respect to stability and self healing capabilities.

[1] Lüssem et. al., Langmuir, 21, 5256-5258 (2005)

O 68.12 Wed 18:15 Poster A

Metal-Peptide Coordination Complexes on Surfaces by Electro spray Ion Beam Deposition — ELISE DUQUESNE¹, SABINE ABB¹, LUDGER HARNAU¹, STEFAN RAUSCHENBACH¹, and KLAUS KERN^{1,2} — ¹Max Planck Institute for Solid State Research, Heisenbergstraße 1, 70569 Stuttgart, Germany — ²Ecole Polytechnique Fédérale de Lausanne, CH-1015 Lausanne, Switzerland

Peptides are flexible biopolymers of a unique sequence of amino acids, which defines intramolecular interactions. In metal-peptide coordination complexes, the type of metal and its specific interaction with the peptide influences the coordination site and thus has an impact on the conformation of the peptide. Generally biomolecules cannot be evaporated due to their thermal instability, however by adding a metal salt to an electrospray solution of peptides a beam of well-defined coordination complexes can be readily formed and mass-filtered to select the coordination complex of interest. The aim of our study is to investigate the structures of metal-peptide complexes deposited on an atomically defined surface in ultra-high vacuum and to compare them with pure peptide structures [1]. Our work paves the way towards rational design of surface supported coordination complexes that can be relevant for a great number of applications in particular biomimetic catalysis.

References : [1] S. Abb, L. Harnau, R. Gutzler, S. Rauschenbach, K. Kern, Two-dimensional honeycomb network through sequence-controlled selfassembly of oligopeptides, Nature Communication, Accepted.

O 68.13 Wed 18:15 Poster A

Pyrazine as a Directing Group in Control of Reactivity and Regioselectivity for On-Surface Dehydrogenative Aryl-Aryl Bond Formation — NEMANJA KOCIĆ¹, XUNSHAN LIU², SONGJIE CHEN², SILVIO DECURTINS², JASCHA REPP¹, and SHI-XIA LIU² — ¹Institute of Experimental and Applied Physics, University of Regensburg, 93053 Regensburg, Germany — ²Department of Chemistry and Biochemistry, University of Bern, 3012 Bern, Switzerland

Regioselectivity is of fundamental importance in chemical synthesis. While many concepts for site-selective reactions are well established for solution chemistry, for instance through introduction of electron donating or withdrawing directing groups, it is not a priori clear whether they can easily be transferred to reactions taking place on a metal

surface. Here we exploit a combined STM/AFM technique to demonstrate the on-surface formation of complex molecular architectures built up from a heteroaromatic precursor, the tetracyclic pyrazino[2,3-f][4,7]phenanthroline molecule. Selective intermolecular aryl-aryl coupling via dehydrogenative C-H activation occurs on Au(111) upon thermal annealing under UHV conditions. A full atomistic analysis of the different reaction products based on an unambiguous discrimination between pyrazine and pyridine moieties is presented. Our work not only elucidates that ortho-hydrogen atoms of the pyrazine rings are preferentially activated over their pyridine equivalents, but also sheds new light onto the participation of substrate atoms in metal-organic coordination bonding during covalent C-C bond formation.

O 68.14 Wed 18:15 Poster A

”Nunchakus”molecules at metallic surfaces investigated by scanning tunneling microscopy — ●LACHENG LIU^{1,2}, HONGYING GAO^{1,2}, PHILIPP HELD³, ARMIDO STUDER³, and HARALD FUCHS^{1,2} — ¹Center for Nanotechnology, Heisenbergstr. 11, 48149 Muenster, Germany — ²Physikalisches Institut, Westfälische Wilhelms-Universität,

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Scanning tunneling microscopy (STM) is demonstrated to be a useful tool to investigate the molecular conformation on metallic surfaces with atomic-scale resolution. In this work we study the adsorption conformations and self-assembly structures of four different ”Nunchakus” shaped molecules: Bis(2-naphthyl) peroxide, 2-Naphthoic anhydride, Bis(2-naphthyl)ethanedione and trans-1,2-Bis-(2-naphthyl)ethene. Different metal substrates Au(111), Ag(111) and Cu(111) were tested, to reveal the interaction between organic molecules and metal surfaces. For these nunchakus shaped molecules, different adsorption conformations even on the same metallic surface were identified. The center to center distances of 2-Naphthyl groups of one molecule were measured, which are shorter than the ones in gas phase due to the specific interaction between O atoms and metallic surface atoms which leads to the tortuosity of the molecules.