

## CPP 79: Nanostructured Surfaces and Thin Films I: 1D and 2D Networks (joint session O/CPP)

Time: Wednesday 15:00–17:30

Location: WIL B321

CPP 79.1 Wed 15:00 WIL B321

**Imaging the phase transition in thin film VO<sub>2</sub> microstructures** — ●JAN O. SCHUNCK<sup>1,2</sup>, FLORIAN DÖRING<sup>3</sup>, BENEDIKT RÖSNER<sup>3</sup>, JENS BUCK<sup>4</sup>, SANJOY MAHATHA<sup>1</sup>, MORITZ HOESCH<sup>1</sup>, CHRISTIAN SCHÜSSLER-LANGEHEINE<sup>5</sup>, ADRIAN PETRARU<sup>6</sup>, HERMANN KOHLSTEDT<sup>6</sup>, KAI ROSSNAGEL<sup>1,4</sup>, CHRISTIAN DAVID<sup>3</sup>, and MARTIN BEYE<sup>1,2</sup> — <sup>1</sup>Deutsches Elektronen-Synchrotron DESY, Hamburg — <sup>2</sup>Physics Department, Universität Hamburg — <sup>3</sup>Paul Scherrer Institut, Villigen-PSI, Switzerland — <sup>4</sup>Institut für Experimentelle und Angewandte Physik, CAU Kiel — <sup>5</sup>Helmholtz-Zentrum Berlin — <sup>6</sup>Nanoelektronik, Techn. Fakultät, CAU Kiel

Vanadium dioxide (VO<sub>2</sub>) is an intriguing compound, since upon heating it exhibits an insulator-to-metal transition (IMT) at a critical temperature  $T_c$  of around 340 K, which is characterised by a decrease in resistivity of several orders of magnitude. On a microscopic level, the phase transition is accompanied by a rearrangement of the crystal structure as well as electronic bands around the Fermi level and proceeds in a percolative manner, meaning that both phases coexist over a temperature range of several K around  $T_c$ .

Here, we present results of an experiment which combines X-ray spectroscopic methods for electronic structure analysis with imaging capabilities of a few micrometers spatial resolution. Studying electronic structure changes during the thermally driven IMT in a pulsed laser deposition-grown and microstructured VO<sub>2</sub> thin film, shows that  $T_c$  differs by around 2 K between the edges and centres of VO<sub>2</sub> squares with an edge length of 30  $\mu\text{m}$ .

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**investigation of Fe(CO)<sub>5</sub> as precursor for gas-assisted electron beam lithography techniques on cobalt oxide surfaces** — ●ELIF BILGILISOY<sup>1</sup>, CHRISTIAN PREISCHL<sup>1</sup>, RACHEL THORMAN<sup>2</sup>, HOWARD FAIRBROTHER<sup>2</sup>, and HUBERTUS MARBACH<sup>1</sup> — <sup>1</sup>Lehrstuhl für Physikalische Chemie II, Friedrich-Alexander Universität Erlangen-Nürnberg, Egerlandstr. 3, D-91058, Erlangen, Germany — <sup>2</sup>Department of Chemistry, Johns Hopkins University, Baltimore, Maryland/USA.

Electron Beam Induced Deposition (EBID) is a gas-assisted direct write electron-lithography fabrication technique in which structures from certain precursor molecules are deposited. A second technique is Electron Beam Induced Surface Activation (EBISA). In EBISA, a focused electron beam is used to locally modify the substrate such that it becomes active towards the decomposition of subsequently dosed precursor molecules [1]. Both approaches were conducted with Fe(CO)<sub>5</sub> on a Co<sub>3</sub>O<sub>4</sub>/Ir(100) surface. We will present first successful results on a clean Co<sub>3</sub>O<sub>4</sub> surface with Fe(CO)<sub>5</sub> for EBID and EBISA. To achieve a deeper understanding of the EBID process, corresponding surface science experiments were conducted, in which the dynamics and behavior upon low energetic electron[2] and ion beam irradiation of thin Fe(CO)<sub>5</sub> layers at liquid nitrogen temperatures were investigated using x-ray photoelectron spectroscopy (XPS) under UHV. We will compare the corresponding results and discuss the reaction mechanisms of Fe(CO)<sub>5</sub>. [1] H. Marbach, Appl. Phys. A 117 (2014) 987 [2] S. G. Rosenberg, et al., J. Phys. Chem. C, 117 (2013)16053

CPP 79.3 Wed 15:30 WIL B321

**Interaction of topological boundary states in graphene nanoribbon heterojunctions** — ●QIANG SUN<sup>1</sup>, OLIVER GRÖNING<sup>1</sup>, XUELIN YAO<sup>2</sup>, AKIMITSU NARITA<sup>2</sup>, KLAUS MÜLLEN<sup>2</sup>, PASCAL RUFFIEUX<sup>1</sup>, and ROMAN FASEL<sup>1</sup> — <sup>1</sup>Empa, Swiss Federal Laboratories for Materials Science and Technology, nanotech@surfaces Laboratory, 8600 Dübendorf, Switzerland — <sup>2</sup>Max Planck Institute for Polymer Research, Ackermannweg 10, 55128 Mainz, Germany

Graphene nanoribbons (GNRs), narrow stripes of graphene, are promising candidates for future electronic applications due to their widely adjustable electronic properties. The precise control of their atomic structure, including their termini, edges and width, allow for the realization of specific electronic quantum phases. For example, GNRs with chiral edges or cove edges have been predicted to host spin-polarized edge states. And recently, topological electronic quantum phases have been predicted and realized in the junctions between GNR segments belonging to different topological classes. Here, I will

show the synthesis and characterization of width-modulated GNRs that host topological junction states. By investigating such GNRs as a function of the number of periodically aligned junction states along the GNR axis, we follow the evolution of the new electronic bands formed by the finite overlap between the junction states. Furthermore, we investigate the interaction between boundary states in topological heterojunctions, revealing an interaction-induced energy splitting that decays exponentially with their relative separation.

CPP 79.4 Wed 15:45 WIL B321

**Determination of Carbon Nanomembrane Diffusion Coefficients via radioactive tracer experiments** — RAPHAEL DALPKE<sup>1</sup>, ANNA DREYER<sup>2</sup>, ●RIKO KORZETZ<sup>1</sup>, ANDRÉ BEYER<sup>1</sup>, KARL-JOSEF DIETZ<sup>2</sup>, and ARMIN GÖLZHÄUSER<sup>1</sup> — <sup>1</sup>Faculty of Physics, Bielefeld University — <sup>2</sup>Faculty of Biology, Bielefeld University

In recent years, 2D materials have gained a lot of attention as highly efficient filter materials. One class of materials are carbon nanomembranes (CNM), which are fabricated by self-assembly of organic precursors onto metal substrates and subsequent cross-linking by electron irradiation. They can be released from their original substrate and transferred onto arbitrary supports. Specifically, CNMs made from terphenylthiol (TPT) exhibit a very high selectivity towards water in combination with an outstanding permeance [1].

Here, we present new permeation measurements of TPT-CNMs utilizing radioactively marked water as well as carbonate and phosphate ions. We show that water and carbonate can pass through while phosphate ions are completely blocked by the CNM. The resulting diffusion coefficients in combination with recent findings indicate that the permeation across the membrane primarily occurs by transport of neutral species. This implies a fast transport of CO<sub>2</sub> in aqueous solution, while dry TPT-CNMs are not permeable to CO<sub>2</sub>, which suggests a facilitated transport in the presence of water.

[1] Yang *et al.*, *ACS Nano* **2018** 12(5), 4695-4701

CPP 79.5 Wed 16:00 WIL B321

**The electronic structure of atomically-precise graphene nano-ribbons investigated by photoemission tomography** — LUKAS REICHT<sup>1</sup>, XIAOSHENG YANG<sup>2,3</sup>, LARISSA EGGER<sup>1</sup>, PHILIPP HURDAX<sup>1</sup>, FRANCOIS C. BOCQUET<sup>2,3</sup>, GEORG KOLLER<sup>1</sup>, PETRA TEGEDER<sup>4</sup>, ALEXANDER GOTTFELD<sup>5</sup>, MATHIAS RICHTER<sup>5</sup>, MICHAEL G. RAMSEY<sup>1</sup>, F. STEFAN TAUTZ<sup>2,3</sup>, SERGUEI SOUBATCH<sup>2,3</sup>, and ●PETER PUSCHNIG<sup>1</sup> — <sup>1</sup>Institute of Physics, University of Graz, Austria — <sup>2</sup>Peter Grünberg Institut (PGI-3), Forschungszentrum Jülich, Germany. — <sup>3</sup>Jülich Aachen Research Alliance (JARA), Germany — <sup>4</sup>Physikalisch-Chemisches Institut, Universität Heidelberg, Germany. — <sup>5</sup>Physikalisch-Technische Bundesanstalt (PTB), Germany.

In this contribution we investigate the electronic structure of armchair graphene nanoribbons (AGNRs) by means of angle-resolved photoemission spectroscopy and density functional calculations. Specifically, using an orientated AGNRs with a width of 7 carbon atoms adsorbed on a stepped Au surface, we demonstrate how photoemission tomography can be used to shed light on the electronic structure of its frontier valence bands. We present a series of constant binding energy momentum maps which allow us to identify all relevant valence (sub)-bands of this graphene nanoribbon. By comparing theoretical results for free-standing and adsorbed ribbons, we investigate the degree of molecule-substrate hybridization and inter-ribbon interactions thereby demonstrating that photoemission tomography proves to be a powerful technique to study the electronic structure of such quantum confined 1D systems.

CPP 79.6 Wed 16:15 WIL B321

**Tuning electronic transport of 1D coordination polymers by the choice of the transition metal: Fe, Co and Ni** — ●ALEŠ CAHLÍK<sup>1</sup>, CHRISTIAN WÄCKERLIN<sup>1</sup>, SANTHINI VIJAI MEENA<sup>1</sup>, OLEKSANDER STETSOVYCH<sup>1</sup>, JESUS MENDIETA<sup>1</sup>, PINGO MUTOMBO<sup>1</sup>, SIMON PASCAL<sup>2</sup>, OLIVIER SIRI<sup>2</sup>, and PAVEL JELÍNEK<sup>1</sup> — <sup>1</sup>Institute of Physics, Czech Academy of Sciences, v.v.i., Czech Republic, — <sup>2</sup>Aix Marseille Université, CNRS, Marseille, France,

The choice of transition metal atom in organometallic complexes can significantly influence their electronic and spintronic properties. Here,

we study the electronic transport through 1D coordination polymers contacted by the tip of a scanning probe microscope (SPM). The polymers are synthesized in-situ by co-deposition of Fe, Co or Ni atoms and the quinonedimine (2,5-diamino-1,4-benzoquinone-diimine) ligand onto Au(111). The combination of STM and nc-AFM allows for simultaneous measurement of the current, conductance and force gradient as a function of bias voltage and lifting height. We observe a distinct bandgap opening behavior depending on the incorporated metal element. In addition, we show the possibility to modulate the conductance of these wires between highly conductive and non-conductive by increased bias voltage or upon light illumination.

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**Nitrogen Doped Carbon Nanofiber Composites as Anode for Sodium-Ion Batteries** — •MO SHA, LONG LIU, HUAPING ZHAO, and YONG LEI — Institut für Physik & IMN MacroNano (ZIK), Technische Universität Ilmenau, 98693, Ilmenau, Germany

Recently, sodium-ion batteries (SIBs) have attracted increasing attention as an important supplement or alternative to lithium ion batteries (LIBs) due to the abundance of sodium resources and its much lower cost. A critical issue and great challenge in current battery research for the extensive application of SIBs is the development of earth-abundant and high-performance electrode materials. In various studies of these electrode materials, carbon nanofibers have been identified as promising anodes for SIBs, because of the low cost and environment friendly features. In this study, nitrogen-doped carbon nanofiber (NCNFs) have been synthesized by an electrostatic spinning technique and used as anodes for SIBs. The corresponding specific capacity can reach about 175 mA h g<sup>-1</sup> at 0.1C after 100 cycles. The results demonstrate that this NCNFs composite is a promising anode material with good reversible capacity and cycling performance for SIBs.

CPP 79.8 Wed 16:45 WIL B321

**Ultra Large Lifting Installations (ULLIS) on HOPG** — •TRISTAN J. KELLER, GEORGIY POLUEKTOV, ANNA JOCHEMICH, ANNA KRÖNERT, STEFAN-SVEN JESTER, and SIGURD HÖGER — Kekulé-Institut für Organische Chemie und Biochemie, Bonn, Deutschland

Self-assembled monolayers at the solid/liquid interface on graphite (HOPG) are investigated by scanning tunneling microscopy (STM). Recently, we reported *i*-gonal arylene-alkynylene macrocycles (*i* = 3,4,5,6) that form tiling patterns that correspond to the macrocycle shapes and the interdigitation of adjunct -OC<sub>16</sub>H<sub>33</sub> side chains.<sup>[1]</sup>

Here, we present a novel approach for supramolecular surface patterning incorporating a tetraphenylmethane building block into a shape-persistent macrocycle in order to address the volume phase above the substrate. We observe monolayers with lattice constants in the range of 10 nm that are independent of the exact substitution of the pillar unit (e.g. propargylic alcohol, or fullerene). In addition, we present cocrystals of these triangular species and a molecular hexagon. The research aims at a detailed understanding on how functional groups that point into the third dimension can be incorporated in appropriate systems.

[1] S.-S. Jester, E. Sigmund, S. Höger, *J. Am. Chem. Soc.* **2011**, *133*, 29, 11062-11065.

CPP 79.9 Wed 17:00 WIL B321

**Atomic-scale mechanical evidence of surface-catalyzed gold-carbon covalent bonding** — •BENJAMIN LOWE, JACK HELLERST-EDT, DHANEESH KUMAR, and AGUSTIN SCHIFFRIN — School of Physics and Astronomy, Monash University, Clayton VIC 3800 Australia

Surface-confined self-assembly is a versatile method for creating and tuning the properties of low-dimensional nanostructures. Here we study the results of gold atoms and dicyanoanthracene (DCA) molecules deposited on Ag(111) in ultrahigh vacuum, characterized at 5K using combined scanning tunneling and non-contact atomic force microscopies (STM/nc-AFM). We found that the two-dimensional metal-organic self-assembly was composed of close-packed DCA-Au-DCA units, in which a single Au atom binds covalently to a carbon atom at the anthracene ends. This conclusion is based on submolecular resolution ncAFM imaging achieved with a CO-functionalized probe, as well as STM manipulation demonstrating the robustness of these DCA-Au-DCA units. Further experiments performed on an atomically thin insulator (hexagonal boron nitride) suggest the covalent DCA-Au-DCA bonding is catalyzed by the Ag surface. We expect these findings to inform the pursuit of metal-organic frameworks predicted to host topological electronic properties [1].

[1] Zhang, L. Z. et. al. *Nano Letters* (2016). 10.1021/acs.nanolett.6b00110.

CPP 79.10 Wed 17:15 WIL B321

**Methyl and Vinyl Functional Groups in On-Surface Synthesis** — •MARCO DI GIOVANNANTONIO<sup>1</sup>, JOSÉ I. URGEL<sup>1</sup>, SHANTANU MISHRA<sup>1</sup>, KRISTJAN EIMRE<sup>1</sup>, ALIAKSANDR V. YAKUTOVICH<sup>1</sup>, CARLO A. PIGNEDOLI<sup>1</sup>, PASCAL RUFFIEUX<sup>1</sup>, ULIANA BESER<sup>2</sup>, QIANG CHEN<sup>2</sup>, ZIJIE QIU<sup>2</sup>, AKIMITSU NARITA<sup>2</sup>, KLAUS MÜLLEN<sup>2</sup>, and ROMAN FASEL<sup>1,3</sup> — <sup>1</sup>Empa - Swiss Federal Laboratories for Materials Science and Technology, nanotech@surfaces Laboratory, 8600 Dübendorf, Switzerland — <sup>2</sup>Max Planck Institute for Polymer Research, 55128 Mainz, Germany — <sup>3</sup>Department of Chemistry and Biochemistry, University of Bern, 3012 Bern, Switzerland

On-surface synthesis has opened pathways to molecular nanostructures that have been inaccessible so far. Here, we demonstrate the successful use of methyl and vinyl groups to achieve one-dimensional (1D) polymers composed of repeat units with specific ring topologies.

Methyl groups are proven to undergo an oxidative cyclization to the neighboring phenyl, forming five-membered rings and affording unprotected indenofluorene isomers, some of which exhibit high radical character. Vinyl groups enable the formation of additional six-membered rings, affording benzo[k]tetrachene units after a stable intermediate with CH<sub>2</sub> groups protruding out of five-membered rings.

The structure and electronic properties of the obtained polymers have been characterized by STM, nc-AFM, and STS, and supported by theoretical calculations. The observed reaction steps and products extend the knowledge of on-surface reactions to fine tune architectures and functionalities.