O 7: Symposium: Atomic Wires at Surfaces I (Invited Speakers: Franz Himpsel, Hanno Weitering, Han Woong Yeom)

Time: Monday 11:15–13:45 Location: HE 101

Invited Talk O 7.1 Mon 11:15 HE 101

Low-Dimensional Electrons at Metallic Semiconductor Surfaces — •Franz Himpsel — Dept. Physics, University of Wisconsin, Madison, USA

In recent years, it has become possible to create well-ordered semiconductor surfaces with metallic surface states by using self-assembly of metal atoms. Since these states lie in the band gap of the semiconductor, they completely de-couple from the substrate. The surface structures can be tailored from two-dimensional triangular lattices to nearly one-dimensional atomic chains, which may be considered as the ultimate nanowires. The dimensionality can be varied systematically between 2D and 1D by using vicinal surfaces with variable step spacing. Angle-resolved photoemission and scanning tunneling spectroscopy reveal surprising features, such as a fractional band filling, nanoscale phase separation into doped and undoped chain segments, and a spin-splitting at a non-magnetic surface.

O 7.2 Mon 11:45 HE 101

Properties and origin of one-dimensional Au nanostructures on tungsten surface carbides — •Andrei Varykhalov, Oliver Rader, and Wolfgang Gudat — BESSY Berlin

We introduce a universal template for one-dimensional self-organization. The tungsten surface carbide W(110)/C-R(15×3) displays a large-scale reconstruction with interesting properties [1,2]. We recently showed that this structure which is rotated by 14° relative to W is able to order various atomic species ranging from C_{60} superclusters which show "magic" numbers to Au films which become patterned in a way that they in turn serve as templates for needle-shaped Ni clusters [3]. The Au reconstruction is uniaxial with corresponding one-dimensional $E(\mathbf{k})$ dispersion [3]. We will demonstrate the origin of the self-organization of Au comparing (15×12) and (15×3) templates by STM and LEED. Two principally different mechanisms are identified: At *room temperature*, regular Au clusters develop which are *1 monolayer high* when grown on the (15×12) structure and *2 monolayers high* on (15×3) but always aligned along the *physical potential* of the carbide nanomesh, i. e., off by 14°. *Annealing* rearranges the Au adatoms towards a nanowire-like reconstruction which has rotated back to the [001] of W. The *chemical* driving force for this is revealed in detail by photoemission spectra from the valence band and the W4f core level.

[1] M. Bode et al., Surf. Sci. 344, 185 (1995). [2] A. Varykhalov et al., Phys. Rev. B 72, 115440 (2005). [3] A. Varykhalov et al., Phys. Rev. B 73, 241404(R) (2006); 74, 95420 (2006); 72, 241404(R) (2005).

O 7.3 Mon 12:00 HE 101

Spatial Mapping of the Electronic States of a One-Dimensional System — Arie van Houselt, Bene Poelsema, and •Harold Zandvliet — University of Twente, Enschede, The Netherlands

Using low-temperature scanning tunneling microscopy and spectroscopy we have recorded spatial maps of confined electronic states in the troughs between self-organized Pt nanowires on Ge(001) that are spaced 2.4 nm apart. Two subbands are resolved, which correspond to the lowest energy levels of a quantum mechanical particle in a box. As expected, the spatial dI/dV maps exhibit a maximum and a minimum in the middle of the troughs for the n=1 and n=2 states, respectively.

O 7.4 Mon 12:15 HE 101

Electrons Confined to Atomic Nanowires of Au on Ge(001) — •Jörg Schäfer, Christian Blumenstein, Sebastian Meyer, Marc Wisniewski, and Ralph Claessen — Physikalisches Institut, Universität Würzburg, D-97074 Würzburg

Nanowires reach their lower size limit in metal-induced chains on semiconductors. In such quasi-one-dimensional (1D) systems, the Fermi surface may host a charge density wave (CDW) with concomitant energy gaps. Metallic chain reconstructions on Ge(001) can serve as model systems, such as Au nanowires on Ge(001). In using scanning tunneling microscopy, one finds that the wires are spaced by several Ge lattice constants, with their electron density being laterally strictly confined. In the related system Pt/Ge(001), our data show a conduction path of atomic dimensions [1], yet various dimer elements are detected. In contrast, in Au nanowires the charge density is spread out very evenly in chain direction, as seen for a large range of bias values. This reflects an unusually pronounced delocalization with metallic character at room temperature. Most significantly, at low temperature indication of a periodic superstructure along the chains of twice the unit cell is found. The electronic properties have also been explored with angle-resolved photoemission. These measurements reveal free-electron-like bands close to the Fermi level. Moreover, the observed Fermi level crossings are supportive of a CDW nesting condition. The talk will review the various aspects of this exceptional 1D electron liquid, and present a perspective regarding related systems.

[1] J. Schäfer *et al.*, Phys. Rev. B **74**, 041404(R) (2006).

Invited Talk O 7.5 Mon 12:30 HE 101

Electronic instabilities and fluctuations in quantum chains — •Hanno H. Weitering — Department of Physics and Astronomy, The University of Tennessee, Knoxville, TN 37931, USA — Materials Science and Technology Division, Oak Ridge National Laboratory, Oak Ridge, TN 37831, USA

One-dimensional (1D) quantum conductors have always captured the imagination of physicists. While a strictly 1D material remains a theoretical construct, a vast number of materials can be viewed as macroscopic ensembles of weakly-coupled quantum chains, making them interesting test cases for theoretical predictions. I will discuss the electronic and magnetic properties of some quasi 1D systems on Si and Ge surfaces. Highlights include the remarkable self-assembly of rare-earth metal atoms on Si into silicide nanowires. Large strain anisotropy in these wires can lead to extraordinary aspect ratios and uniformity. The thinnest wires exhibit electronic properties reminiscent of a multichannel 1D conductor. These include the stepwise increase of the tunnel current as a function of tip bias in scanning tunneling microscopy, and the appearance of a fluctuating charge density wave or Peierls instability at low temperature. Peierls instabilities are normally attributed to a collective screening response of the 1D electron gas, but in the present case there is no obvious connection to the classical Peierls picture. The remarkable assembly of yttrium atoms into long nanowires with built-in metal/semiconductor junctions is illustrative of how the finite-size- and temperature-scaling behavior of a collective phenomenon may one day be exploited in nano-architectures.

Invited Talk O 7.6 Mon 13:00 HE 101

Phase transitions and fluctuations of metallic atomic wires on silicon — •Han Woong Yeom — CAWL, Yonsei University, Seoul, Korea

Wire-type metals in nano scale are essential for nano/molecular electronics and their fundamental properties are challenging with various exotic ground states and fluctuations. As an unconventional form of such 1D metallic systems, we have investigated the self-organized metallic atomic wires on flat and vicinal Si surfaces such as In/Si(111) [1, 2, 3], Au/Si(111) [4], Au/Si(557) [5], and Au/Si(553) [6], and Pb/Si(557) [7]. For some of these systems, we observed Peierls-type phase transitions due to the 1D bands nested fully with electron fillings of 1/2 or 1/3 [1-3, 5, 6]. In the present talk, I will review the achievements so far and the present debates [8] on these phase transitions. A few issues related to the transitions will be introduced such as (i) the impurity control over the Tc, the band gap [4], and the solitonic dynamic fluctuation [9], and (ii) the atomic-scale characterization of the embryonic charge-density wave order [10]. I also raise the question of why some of these systems like Au/Si(111) and Pb/Si(557) are robust against Peierls instability down to fairly low temperature [7]. [1] H. W. Yeom et al., PRL 82, 4898 (1999); [2] J. R. Ahn et al., PRL 93, 106401 (2004); [3] S. J. Park et al., PRL 93, 106402 (2004); [4] W. H. Choi et al., PRL, submitted; [5] J. R. Ahn et al., PRL 91, 196403 (2003); [6] J. R. Ahn et al., PRL 95, 196402 (2005); [7] K. S. Kim et al., PRL, in press; [8] H. W. Yeom, PRL 97, 189701 (2006); [9] S. J. Park et al., PRL 95, 126102 (2005); [10] P. G. Kang et al., PRL, submitted.

O 7.7 Mon 13:30 HE 101

Peierls instability in platinum chains on Ge(001) — •Arie van Houselt, Daan Kockmann, Bene Poelsema, and Harold Zand-

VLIET — University of Twente, Enschede, The Netherlands

We have studied the structural and electronic properties of atomic Pt chains on a germanium (001) substrate. Using scanning tunneling microscopy we show that these Pt chains undergo a phase transition from a 2x periodicity at room temperature to a 4x periodicity at low temperatures. The coupling between the atomic chains turns out to be of essential importance, since isolated Pt chains and chains located at the edge of an array of chains maintain their 2x periodicity at temperatures as low as 4.7 K. The 2x to 4x transition is accompanied by an opening of an energy gap and can be interpreted as a Peierls instability.