O 14: Metal Substrates: Epitaxy and Growth

Time: Monday 14:15–17:45 Location: H39

O 14.1 Mon 14:15 H39

Determination of the <110> and <100> step edge Ehrlich Schwoebel barriers on Cu(001) — •Frank Everts, Frits Rabbering, Herbert Wormeester, and Bene Poelsema — Solid State Physics, MESA+ Institute for Nanotechnology, University of Twente, Enschede, The Netherlands

Paths available for interlayer mass transport determine the morphology evolution in multilayer growth. On Cu(001) the paths over the closed packed and open step edge compete. Their availability for interlayer diffusion is expressed by the so-called Ehrlich-Schwoebel barrier. Their height determines the layer distribution already in the early stages of growth as measured from the specular reflection of a thermal energy He atom beam. The value of the barriers for the two pathways is obtained from comparing the experimental roughness evolution with a Monte Carlo simulation incorporating both intra- and interlayer diffusions. A triangulation of experimental and simulated results at different temperatures and coverage enables an accurate determination of the two very different Ehrlich Schwoebel barriers.

O 14.2 Mon 14:30 H39

Shape anisotropy of adatom islands as a probe for long range dipolar forces — •Herbert Wormeester, Frits Rabbering, Teun Warnaar, and Bene Poelsema — Solid State Physics, MESA+ Institute for Nanotechnology, University of Twente, Enschede, The Netherlands

The observation of shape anisotropy of adatom, islands obtained after grazing incidence growth of Cu on Cu(001) was explained with the steering effect. This effect describes the local variation of incident flux due to attractive interaction between the incoming atoms and the surface. High-Resolution Low Energy Electron Diffraction was used to measure the shape anisotropy as a function of coverage from 0.3 to 0.6 ML. Simulations of the growth process including an evaluation of the steering effect also show the evolution of anisotropy. The strength of the long range attractive potential as a result of dipolar interactions is in the simulation varied between absent and stronger than expected on the basis of an analysis of the optical properties of both the atom and the half infinite substrate. We found counter-intuitively that a stronger long range interaction decreases the shape anisotropy. This can be explained by its influence on the flux distribution on adatom islands. Diffraction profiles evaluated for the simulated morphologies are used for comparison with experimental observations. This indicates that long range forces play a dominant role in the observed anisotropy and that their strength seems to be stronger than derived from optical properties.

O 14.3 Mon 14:45 H39

Surface state mediated atomic-string and superlattice — •Haifeng Ding[1,2], Chunlei Gao[1], Marta Waśniowska[1], Nikolay Negulyaev[1], Larissa Niebergall[1], Valeriy Stepanyuk[1], Patrick Bruno[1], and Jürgen Kirschner[1] — [1]Max-Planck-Institut für Mikrostrukturphysik, Weinberg 2, Halle, 06120, Germany — [2]National Laboratory of Solid State Microstructures and Department of Physics, Nanjing University, Nanjing, 210093, China

We present a joint experimental and theoretical study of Fe atoms alignment on a flat and a vicinal Cu(111) surface. A few percent monolayer of Fe atoms are deposited at around 5 K on a clean Cu(111)surface. Upon deposition, the Fe atoms are randomly distributed on the sample surface without apparent ordering. With annealing to 13 K, the Fe atoms form ordered structures on both flat and vicinal surfaces. On the flat surfaces, hexagonal superlattice with nearest neighbor distance of 1.2±0.1 nm is found. On the vicinal surfaces, we find the Fe atoms form a string like structure along the step edges. The Fe atoms also have the same nearest neighbor distance as the superlattice and they have a fixed separation of 0.8±0.1 nm away from the step edges. Together with the first principle calculation and Monte-Carlo simulations, our findings evidence that the surface state can mediate atom diffusion, resulting the formation of atomic string and superlattice.

O 14.4 Mon 15:00 H39

Initial growth of Co on Cu(100) by pulsed laser deposition — •Carsten Tröppner, Andreas Dobler, and Thomas Fauster — Lehrstuhl für Festkörperphysik, Universität Erlangen-Nürnberg, Staudtstr. 7, 91058 Erlangen

Pulsed laser deposition (PLD) provides an increase of the instantaneous particle flux by more than 4 orders of magnitude compared to thermal deposition (TD) and particle energies up to 100 eV. In order to better understand the improved layer-by-layer growth in epitaxy of thin metal films by PLD, we investigated the system Co/Cu(001) in the submonolayer regime by scanning tunneling microscopy. For this system, Co atoms may be incorporated into the top layer of the substrate by thermally activated exchange.

After deposition at 303 K, we recorded the resulting island and defect densities as well as island-size distributions as function of coverage and particle flux for PLD and TD. Defect nucleation at incorporated Co atoms dominates the initial growth so that identical defect densities measured for both methods lead to identical island densities for a wide range of parameters. Differences in the island-size distributions and in the island densities below 0.1 monolayers are found which can be assigned to the high flux at PLD. The high particle energies enhance the adatom mobility, which suppresses the second-layer growth, and cause some sputtering.

O 14.5 Mon 15:15 H39

Growth of Co nanoislands on Cu(111): theoretical and experimental study — •Nikolay Negulyaev[1], Valeriy Stepanyuk[2], Patrick Bruno[2], Lars Diekhöner[3], Peter Wahl[4], and Klaus Kern[4] — [1]Fachbereich Physik, Martin-Luther-Universität, Halle (Saale), Germany — [2]Max-Planck-Institut für Mikrostrukturphysik, Halle (Saale), Germany — [3]Institut for Fysik og Nanoteknologi, Aalborg Universitet, Denmark — [4]Max-Planck-Institut für Festkörperforschung, Stuttgart, Germany

We report on the theoretical and experimental study of the growth of Co nanoislands on Cu(111) at 80-300 K. The detailed molecular dynamics and kinetic Monte Carlo simulations are performed. Atomistic processes at edges, kinks, corners of islands and interlayer mass transport are studied. We reveal the effect of the strain in the substrate and nanoislands on the growth process. The temperature dependence of shape and structure of nanoislands is investigated. We report on the blocking effect: novel kinetic mechanism related to the interlayer mass transport and responsible for the growth of Co nanoislands of two monolayers height at room temperature. Results of the theoretical studies are compared with STM observations.

O 14.6 Mon 15:30 H39

Strain relief within thin films of Co and Ni on unreconstructed Ir(100) — •Wolfgang Meyer, Andreas Klein, Lutz Hammer, Stefan Müller, and Klaus Heinz — Lehrstuhl für Festkörperphysik, Universität Erlangen-Nürnberg, Staudtstr. 7, D-91058 Erlangen

As reported earlier, Co and Ni grows layerwise and pseudomorphically on the unreconstructed Ir(100) surface up to a thickness of at least five monolayers despite the large lattice misfit of about 8 % between Co/Ni and Ir. However, STM shows that the films are atomically flat only up to two monolayers, while thicker films show surface corrugations in the range 0.1 - 0.3 Å increasing in amplitude and frequency with film thickness. Moreover, LEED intensity analyses reveal large atomic displacements within the whole volume of the films much beyond usual thermal vibrations. Consistently, film layer spacings derived from LEED are somewhat larger than predicted from DFT calculations for ideal films. We interpret these displacements as the onset of a strain relief mechanism, a picture, which is also corroborated by surface stress measurements performed elsewhere [1]. The nature of this mechanism is discussed in detail on the basis of both the available experimental data as well as DFT model calculations.

[1] C. Tian, D. Sander, J. Kirschner, MPI Halle, unpublished.

O 14.7 Mon 15:45 H39

The growth of Co on Cr/W(110) investigated by STM and STS — •Torsten Methfessel and Hans Joachim Elmers — Johannes Gutenberg-Universität Mainz, Institut für Physik, Staudingerweg 7, D-55099 Mainz

Highly spinpolarised metals are of great interest e.g. for the application in spin-valves. Recently observed large tunneling magnetoresis-

tance effects indicate that the metastable bcc phase of Co provides a high spin-polarisation at the Fermi edge. Previous investigations of Co on Cr(110) with high-resolution low-energy electron diffraction (LEED) indicated pseudomorphic growth of bcc-Co on Cr(110) [1]. In order to prepare a Cr(110) substrate, we deposited a 8 ML Cr film on W(110) that was annealed to 500 K. The annealing results in high islands with a perfect Cr(110) surface, that serves as a substrate for Co. Using STM and STS we investigated local structural and electronic properties of the Co films. While the Co monolayer is pseudomorphic to the Cr(110) surface we oberserve significant variations of the local conductivity on thicker Co coverages indicating different electronic structures. The variation of the electronic structure results from different crystallographic structures of the Co. Comparing the tunneling spectra with previously measured spectra of pure Co films on W(110) [2] we conclude that the Co grows in a hcp and fcc structure. Areas with different stacking sequences are separated by dislocation lines similar to the growth of Co on W(110).

[1] S. Fölsch et al., Phys.Rev.B **57**, R4293 (1998).
[2] M. Pratzer et al Phys.Rev.B **72**, 035460 (2005).

O 14.8 Mon 16:00 H39

The initial growth of silver on Pt(111) revisited — •Esther van Vroonhoven and Bene Poelsema — Solid State Physics, MESA+ Institute for Nanotechnology, University of Twente, Enschede, The Netherlands

Ultrathin films of silver on Pt(111) are quite commonly considered as a model system for surface confined alloying: If deposited (or heated) at, or above, 550 K the first monolayer has been reported to initially form an alloy, followed by de-alloying towards monolayer completion [1].

New mesoscopic measurements, performed with LEEM, reveal evidence for yet unanticipated and highly complex behaviour. Various unanticipated and complex process, governed by different aspects of stress and strain, determine the evolution of the growing film. They include alloying, de-alloying, segregation, re-entrant partial alloying and gradual de-alloying.

As will be shown and discussed, the concept of a neatly behaving, simple model system for surface confined alloying need substantial revison.

[1] H. Roeder, R. Schuster, H. Brune and K. Kern, Phys. Rev. Lett. 71, 2086 (1994)

O 14.9 Mon 16:15 H39

Quantum-Well Wave-Function Localization and the Electron-Phonon Interaction in Thin Ag Nanofilms — •Stefan Mathias[1], Martin Wiesenmayer[1], Martin Aeschlimann[1], and Michael Bauer[2] — [1]Department of Physics, University of Kaiserslautern, 67663 Kaiserslautern, Germany — [2]Institut für Experimentelle und Angewandte Physik, Universität Kiel, 24098 Kiel, Germany

The electron-phonon interaction in thin Ag nanofilms epitaxially grown on Cu(111) is investigated by temperature-dependent and angle-resolved photoemission from silver quantum-well states. Clear oscillations in the electron-phonon coupling parameter as a function of the silver film thickness are observed [1]. Different from other thin film systems where quantum oscillations are related to the Fermi-level crossing of quantum-well states, we can identify a new mechanism behind these oscillations, based on the wavefunction localization of the quantum-well states in the film.

[1] S.Mathias, M. Wiesenmayer, M. Aeschlimann, M.Bauer, Phys. Rev. Lett. 97, 236809 (2006)

O 14.10 Mon 16:30 H39

Alloying and dealloying in pulsed laser deposited Pd on Cu(001) — •Holger Meyerheim, Elena Soyka, and Jürgen Kirschner — Max-Planck-Institut f. Mikrostrukturphysik, Weinberg 2, 06120 Halle

Using surface x-ray diffraction we have studied the geometric structure of ultra thin Pd films grown at room temperature on Cu(001) by pulsed laser deposition (PLD) in the coverage regime between 0.4 and 4 monolayers (ML). We find a complicated growth mechanism characterized by alloying, dealloying and Pd-agglomeration above an alloyed structure. The growth sequence is governed by the balance of the free surface energy, the strain energy and the activation energy for interlayer exchange. Up to about 2 ML, the interface formation is characterized by an alloying-dealloying mechanism, where Pd is incorporated into the Cu substrate for less than half filled layers, but expelled if the Pd coverage is close to a complete layer. In this case the top layer is composed of Pd. Above 2 ML, Pd agglomeration sets in characterized by Pd-rich alloy layers covered by Pd-layers. Interlayer spacings linearly depend on the Pd-concentration (x) in the Pd(x) Cu(1-x) alloy layers. Our study shows that the film structure is inhomogeneous with respect to both, layer composition and interlayer spacings. It thus provides new structure informations for the strain relief mechanism developed for PLD grown Pd/Cu(001). So far, layer-by-layer growth of a homogeneous non-alloyed Pd-film was assumed as concluded by reflection high electron diffraction and scanning tunneling microscopy [1]. [1] Y. Lu et al., PRL 94, 146105 (2005).

O 14.11 Mon 16:45 H39

Atomic distribution in 2D surface alloys - linking STM results with DFT studies via effective cluster interactions — •Andreas Bergbreiter[1], Harry E. Hoster[1], Yoshihiro Gohda[2], Axel Gross[2], and R. Jürgen Behm[1] — [1]Institut für Oberflächenchemie und Katalyse, Universität Ulm, 89069 Ulm — [2]Institut für Theoretische Chemie, Universität Ulm, 89069 Ulm

Surface alloys such as Pt_xRu_{1-x}/Ru(0001), Pd_xRu_{1-x}/Ru(0001), Cu_xPd_{1-x}/Ru(0001), or Au_xPt_{1-x}/Pt(111) are governed by a local equilibrium [1,2], i.e., intermixing is confined to the outermost layer, and the lateral atomic distributions depend on the intermetallic interactions. These can be described by an Ising type Hamiltonian based on effective cluster interactions (ECIs). From atomically resolved STM images of the distinct surface alloys we have derived ECIs by an Inverse Monte Carlo approach. Complementary, the respective parameters can also be derived from energies attained for ordered surface alloys of varying unit cell compositions and geometries via Density Functional Theory (DFT). This allows us to compare theoretically predicted with experimentally found atomic distributions of systems without long-range order.

[1] A.V. Ruban et al., in *Surface Alloys and Alloy Surfaces*, *Vol. 10*, (ed.: D. P. Woodruff), Elsevier; Amsterdam **2002**, pp. 1-29.
[2] H.E. Hoster, E. Filonenko, B. Richter, R.J. Behm, Phys. Rev. B 73 (2006) 165413.

O 14.12 Mon 17:00 H39

Adsorption geometry and electronic properties of Ag(111)-Cs studied by scanning tunnelling microscopy and spectroscopy — •Martin Ziegler, Jörg Kröger, and Richard Berndt — Institut für Experimentelle und Angewandte Physik der Universität Kiel

A scanning tunnelling microscope operated in ultra-high vacuum and at low temperatures is used to study superstructures of ultrathin Cs films on Ag(111) at various coverages. Hexagonally ordered adsorption domains which are rotated with respect to each other are observed. Mutual Cs atom distances are discussed in terms of surface state-mediated interactions. Electronic properties of the different Cs adsorption layers are investigated by tunnelling spectroscopy. Quantum well states as well as a modified Ag(111) surface state are present.

O 14.13 Mon 17:15 H39

Vanadium Oxide Superstructures and their Transitions on W(110) — •Benjamin Borkenhagen, Gerhard Lilienkamp, and Winfried Daum — Institut für Physik und Physikalische Technologien, TU Clausthal, Leibnizstr. 4, D-38678 Clausthal-Zellerfeld

Epitaxially grown ultrathin vanadium oxide films on a W(110) single crystal surface exhibit a wealth of superstructures, depending on growth conditions such as temperature and oxygen partial pressure. The thickness of the deposited vanadium oxide films was in the range from submonolayer to a few monolayers as determined by a quartz microbalance. The structure of the films and their composition was analysed by LEED and AES, respectively. The oxidation state of vanadium in the films was determined by AES. For atomically smooth films, low energy electron microscopy (LEEM) reveals flat terraces with widths up to 6 μm separated by monoatomic steps. Using dark-field imaging the domain structure of the films is resolved with high contrast. Depending on the preparation conditions (oxygen partial pressure, heating rate), a more granular or a more homogeneous domain structure is obtained. Structural transitions of the thin oxide films under oxidising or reducing conditions have been monitored by LEEM.

O 14.14 Mon 17:30 H39

Wachstum und Manipulation von Ferrocene Molekülen auf der Au(111) Oberfläche — •Kai-Felix Braun[1], Violeta Iancu[1], Natalya Pertaya[1], K.-H. Rieder[2] und S.-W. Hla[1] — [1]Department of Physics and Astronomy, Ohio University, Athens OH, USA —

[2]Institut für Experimentalphysik, Freie Universität Berlin, Arnimallee 14, D-14195 Berlin, Germany

Mit Hilfe von Rastertunnelmikroskopie wurde das Wachstum von Ferrocene Molekülen bei tiefen Temperaturen untersucht. Die Ferrocene Moleküle wachsen in einer inkommensuraten Struktur bestehend aus zwei Schichten. Laterale Manipulation ermöglicht die genaue Bestimmung der Höhen einzelner Fragmente. Zur Bestimmung der Fragmente wurden Rechnungen im Rahmen der Dichtefunktionaltheorie durchgeführt. Dabei ergeben sich in der ersten Schicht Eisen-Cyclopentadyenyl Einheiten mit einer dreizähligen Symmetrie und in der obersten Lage Cyclopentadienyl Einheiten mit einer vierzähligen Symmetrie. Die verschiedenen molekularen Wechselwirkungen, die zu dieser Struktur führen, werden diskutiert.