Wednesday Afternoon, November 15, 2006

Surface Science
Room 2002 - Session SS1-WeA

Growth Processes on Metal and Semiconductor Surfaces

Moderator: A.A. Baski, Virginia Commonwealth University

2:00pm SS1-WeA1 2D Ordered Nanocluster Arrays Growth via Threading Dislocation Pair Annihilation, *B. Diaconescu,* University of New Hampshire, US*; K. Pohl,* University of New Hampshire

The process of growing nanostructured ordered arrays of clusters on the misfit dislocation networks of strained metallic thin films@footnote 1,2@ requires a detailed understanding of the nucleation and film-adsorbate interaction at the atomic level. In the case of sulfur adsorption on submonolayer silver films on the 0001 surface of ruthenium, the Ag's short herring bone rectangular misfit dislocation unit cell of 54Å x 40Å (19x16 Ag atoms) reconstructs into a well-ordered triangular array of S filled vacancy islands 50Å apart. Atomically and time resolved measurements from our home-built variable-temperature scanning tunneling microscope reveal that the S cluster growth mechanism involves a local restructuring of the highly dynamic misfit dislocation network of Ag with the final structure free of threading dislocations. Adsorbed S atoms will preferably bind on the Ru substrate thus displacing Ag atoms and creating two-dimensional S filled Ag vacancy islands while the strain of the misfit dislocation network of Ag assures the long-range order of the vacancies. The new morphology and symmetry of the composed S/Ag/Ru(0001) system is obtained via a threading dislocation annihilation mechanism in which adjacent and opposite pairs of threading dislocations are replaced by the S filled Ag vacancy islands. The driving force of this process is the strain relaxation whose local character is shown by the conservation of the unit cell size area of 21.5nm@super2@. @FootnoteText@ @footnote 1@ K. Pohl et al., Nature 397, 238 (1999)@footnote 2@ K. Thürmer et al., Science 311, 1272 (2006)*Supported by NSF-CAREER-DMR-0134933 and ACS-PRF-37999-G5.

2:20pm SS1-WeA2 Diffusion and Clustering of Ag Atoms on a Si(111)7x7 Surface, *S. Suto,* J. Osiecki, K. Takusari, H. Kato, A. Kasuya, Tohoku University, Japan

We report here the measurements of the diffusion and clustering of silver atoms on a Si(111)7x7 surface at room temperature using scanning tunneling microscopy (STM). The 7x7 structure is made of relatively large unit cells, which consist of faulted and unfaulted triangular half unit cells (HUCs). There are intercell hopping and intracell motion of Ag atoms. Up to now, the atomistic intercell diffusion of single Ag atoms and formation process of dimers was already reported by Sobotik et al.@footnote 1@ We evaporated the Ag between 0.001ML and 0.088ML on the Si(111)7x7 surface and then observed the relaxation of deposited Ag atoms for 150 min. The intercell hopping and clustering inside the HUCs were observed. First, we discuss the hopping rates and atomistic formation process of dimer, trimer, tetramer and pentamer with the theoretical model proposed by Vasco et al.@footnote 2@ The intercell hopping rates are 1.6 x 10@super -4@ 1/s from unfaulted to faulted HUCs and 1.3 x 10@super -5@ 1/s vice versa. The cluster formation process indicates the cooperative diffusion growth; the hopping rates depend on the occupation numbers of target HUCs. Second, we present the intracell motion of dimers and trimers. Third, we discuss the initial stage of nucleation. The conformation of tetramer adjacent to monomer is very stable. The monomer doesn't jump to teteramer. The tetramer doesn't show the intracell motion and the motion may contribute clustering and stability. We discuss the significance of the intercell and intracell diffusion upon clustering and nucleation. @FootnoteText@ @footnote 1@P. Sobotik et al., Surf. Sci. Lett. 537, L442(2003).@footnote 2@E. Vasco et al., Phys. Rev. B 67, 2355412(2003).

2:40pm SS1-WeA3 Pb on Si(111)--from Magic Clusters, Nanowires to Thin Films*, *J.F. Jia,* The Chinese Academy of Sciences, China INVITED

Group IV metal Pb on Group IV semiconductor Si(111) substrate has been shown to be a very unique system in terms of epitaxy growth, in which various nanostructures such as islands with magic height and atomically flat films of novel properties have been reported.@footnote 1,2@ By controlling the Pb coverage and deposition conditions, we have achieved identical nanocluster array,@footnote 3@ nanowire array@footnote 4@ and ultra-thin films with atomic-scale uniformity.@footnote 5-7@ Our scanning tunneling microscopy and angle-resolved photoemission study reveals that quantum size effect (QSE) plays a crucial role in the formation of nanowires and thin films. In this talk, I will discuss how the QSE in this system modulates the density of states near the Fermi level and regulates the growth, and the correlation between electronic structure modulation and oscillating superconductivity transition temperature,@footnote 5@ surface stability,@footnote 6,7@ work function and chemical reactivity.@footnote 8@ @FootnoteText@ *In collaboration with Qikun Xue, Xucun Ma, Yan-Feng Zhang, Yang Guo, S. C. Li, S.B. Zhang, E. G. Wang, Q. Niu, Z. Q. Qiu and Zhong-Xian Zhao. Supported by the Natural Science Foundation of China and Ministry of Science and Technology of China.@footnote 1@ M. Hupalo and M. C. Tringides, Phys. Rev. B65 (2002) 115406@footnote 2@ M. H. Upton et al., Phys. Rev. Lett. 93 (2004) 026802@footnote 3@ S. C. Li et al., Phys Rev. Lett. 93 (2004) 116103@footnote 4@ L. L. Wang et al., submitted to Appl. Phys. Lett.@footnote 5@ Y. Guo et al., Science 306 (2004) 1915@footnote 6@ Y. F. Zhang et al., Phys Rev. Lett. 95 (2005) 096802@footnote 7@ Y. F. Zhang et al., Surf. Sci. 596 (2005) L331@footnote 8@ X. C. Ma et al., (unpublished).

3:20pm SS1-WeA5 LEEM Observations of Pb Growth on W(110), *D.B. Hoffman, S. Chiang,* University of California, Davis

Although surface energy considerations would suggest that Pb would grow layer-by-layer on W(110), an earlier study,@footnote 1@ using low energy electron diffraction (LEED), Auger spectroscopy, and thermal desorption spectroscopy, found Stranski-Krastanov growth. After the completion of the first monolayer, our low energy electron microscope (LEEM) observations of this system show the development of 3D Pb crystallites. For Pb deposition at substrate temperature of 200C, the islands grow together and form larger islands with quasi-hexagonal sides. After about 8ML growth, gradually raising the temperature to 325C, the Pb meltiing point, causes the crystals to melt. As they melt, the islands suddenly move to step bunches and become round. They also become smaller as the Pb desorbs from the surface. Finally, some round black islands remain, corresponding to a quasi-(4x1) LEED pattern. If the temperature is lowered below 325C, those remaining islands develop a hexagonal shape. At 425C, these desorb from the surface. For growth at 300C, there appears to be a maximum coverage, possibly resulting from the competition between Pb condensation from the vapor and desorption due to the temperature. The few observed islands typically grow on top of high density step bunches. The density of the crystallites depends on the substrate temperature. For growth at 200C, the island density is about 40 times higher than for growth at 300C, with only 3 islands apparent in a 10μm field of view at the higher temperature. @FootnoteText@ @footnote 1@ E. Bauer, H. Poppa, G. Todd, Thin Solid Films, 28, 19 (1975).

3:40pm SS1-WeA6 Exploring Complex "Wedding-Cake" Film Morphologies: Ag/Ag(111) Epitaxial Growth, *M. Li, P.-W. Chung, E. Cox, C.J. Jenks, P.A. Thiel, J.W. Evans,* Iowa State University

Ag/Ag(111) homoepitaxy constitutes a prototype for rough growth and the formation of wedding-cake morphologies due to the presence of a large Ehrlich-Schwoebel (ES) step-edge barrier inhibiting downward transport. However, systematic analysis of the temperature-dependence of these morphologies is lacking, and dispute persists regarding details of the ES barrier. Our study combines comprehensive VTSTM experiments and realistic atomistic modeling and kinetic Monte Carlo simulation of growth (neither of which was available in previous studies) in the regime of 120-200 K . We thereby selectively probe those features of the rich far-from-equilibrium film morphologies which provide the most insight into the atomistic diffusion processes and barriers controlling growth. Submonolayer island growth shapes around 180K, where the fractal growth instability is quenched but full shape equilibration is not yet achieved, already provide evidence of a non-uniform ES barrier. Detailed analysis of multilayer growth morphologies focusing on top-layer island sizes at the wedding-cake peaks provides the most sensitive assessment of the magnitude of the ES barrier. However, consistent analysis requires accounting for the effect of a transition from irreversible to reversible island formation which inhibits nucleation of top-layer islands.

4:00pm SS1-WeA7 Fundamental Limits in the Growth of Si Nanowires, *J.B. Hannon,* IBM T.J. Watson Research Center INVITED

Nanowires are promising candidates for nanoscale electronic devices, and controlling nanowire properties is a major focus of research in nanotechnology. While there have been tremendous advances in both the understanding and the engineering of nanowire properties, the mechanism by which nearly all nanowires are grown (the 'vapor-liquid-solid' or VLS mechanism) is less understood. This is all the more remarkable given the fact that VLS growth has been studied for more than 40 years. We have investigated the growth of Si nanowires under conditions in which all the critical growth parameters are strictly controlled, while growth is directly

observed using real-time in situ electron microscopy.@footnote 1@ We find that the migration of Au during nanowire growth places fundamental limits on the shape, length, and sidewall properties of the nanowires. Our results show that the conventional picture of VLS growth is insufficient when the growth takes place under conditions in which the substrate surface cleanliness, the deposition and formation of the Au-Si eutectic catalyst droplets, as well as the Si source gas purity and background contamination levels are rigorously monitored and controlled. Surprisingly, we find that under the cleanest growth conditions, VLS growth does not result in long wires of fixed diameter with clean sidewalls. Au from the catalyst droplets coats the nanowire sidewalls, terminating VLS growth when the catalyst is consumed. In addition migration of Au from one catalyst droplet to another during nanowire growth (catalyst droplet coarsening) determines the sidewall profile. In other words, the high surface diffusivity of Au, combined with the strong tendency of clean Si surfaces to getter Au atoms, together with the conventional VLS process, results in Au-coated nanowires of limited length and variable diameter. @FootnoteText@ @footnote 1@ J.B. Hannon, S. Kodambaka, F.M. Ross, and R.M. Tromp, Nature 440 (2006) 69.

4:40pm **SS1-WeA9 In-Situ Observation of Wet Oxidation Kinetics on Si(100) Surface Via Ambient Pressure X-ray Photoemission Spectroscopy**, *M. Rossi*, *B.S. Mun,* Lawrence Berkeley National Laboratory*; Y. Enta,* Hirosaki University, Japan*; C.S. Fadley, P.N. Ross, Z. Hussain,* Lawrence Berkeley National Lab. & UC Davis

The initial stages of silicon water-based oxidation kinetics have been investigated as a function of temperature in the hundred milli-torr pressure range using photoemission spectroscopy. The formation of chemically-shifted states of the Si 2p core level was monitored in real time while exposing the surface to water vapour. Measured oxide growth rates are compared to several theoretical models and confirm the existence of a threshold temperature above 400°C after which growth rates are significantly higher. In addition, the observed enhancement of the oxide thickness at temperature higher than 450°C is consistent with previous works reporting the hydrogen desorption on the Si surface.

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