

Public Abstract

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Graduation Term:SP 2016

Department:Physics

Degree:PhD

Title:IN-SITU X-RAY SCATTERING STUDIES OF AG NANO-STRUCTURES

When metals are synthesized on the nanoscale, new physics can arise in the growth process as quantum confinement of the conduction electrons, known as quantum size effects, can lead to preferred heights of metallic nanoscale islands. Despite a significant amount of prior research, there has been a poor understanding of the growth behavior of the simple noble metal, silver, on the silicon(111)7x7 substrate and researchers have been unable to connect its growth morphology to quantum size effects. This dissertation investigated the growth of Ag on Si(111)7x7, in situ and in ultra-high vacuum, using synchrotron x-ray scattering. Because of the unique ability of this technique to explore the structure of a buried interface on the atomic scale, these studies led to a clear understanding of the role of quantum size effects in the growth behavior of this system.

The studies address the epitaxial relationship between Ag and the substrate as well as the transition from the wetting layer to the growth of nanoscale islands. It is found that islands have a minimum thickness of three Ag atomic layers, which is in contrast to the bilayer on top of a wetting layer that has been reported in previous scanning tunneling microscopy studies. Ag islands are found to form after the completion of the Ag/Si(111)7x7 wetting layer and they convert the underlying wetting layer into the FCC structure of the island. The observed preference of the Ag islands is explained by the energy per area of the island, which derives from quantum confinement effects, and its two phase coexistence with the wetting layer. For thicker island heights, it is found that the distribution of island heights reflect the minimum thickness of three layers. The height fluctuations are observed to exhibit a Poisson-like distribution where only the low heights in the fluctuation spectrum deviate from a Poisson distribution. A model of the height distribution is presented.

Techniques for exploring buried nanoscale vacancy defects in metals using diffuse x-ray scattering were also explored in this dissertation. Strain fields due to nanoscale vacancy clusters located below a surface were explored through analytical modeling of elastic displacements as well from results of accelerated molecular dynamics simulations. A method for numerically calculating diffuse scattering from nanoscale vacancy clusters was also explored.

As new technologies continue to exploit thin-film metals on nanoscale dimensions, this investigation provides important new understanding about how metals grow on the nanoscale.