

Growth of Ag Overlayers on Ge(111)-c(2×8) at Low Temperature

L. Basile,^{1,2} H. Hong,² P. Czoschke,^{1,2} T.-C. Chiang^{1,2}

¹Department of Physics and

²Frederick Seitz Material Research Laboratory (MRL),
University of Illinois at Urbana-Champaign (UIUC), Urbana, IL, U.S.A.

Introduction

Ag overlayers grown on semiconductor or metal substrates by low temperature (LT) deposition followed by thermal annealing can be prepared in a variety of meta-stable states with intriguing properties [1, 2]. For example, Ag films on Fe(100) can be prepared atomically flat and uniform up to ~100 monolayers (MLs). Smooth Ag overlayers can be grown on Si(111) and GaAs(110) above a critical thickness of 6 ML [2, 3]. Below the critical thickness, Ag forms islands of uniform preferred height [4].

The stability and critical thickness found in these systems have been suggested to be a result of quantum size effects (QSEs) [1-5]. As the size of a film approaches quantum dimensions, QSE should play a role in film morphology. Electrons in a metal film can be confined between the vacuum and substrate barriers. This confinement leads to modifications to the electronic structure, which, in turn, affect the growth and morphology of the film [6].

This report discusses a study of the morphology of Ag films grown on Ge(111)-c(2×8). We observed films that are quite flat and uniform and that present small layer relaxations.

Method and Materials

The UNI-CAT beamline at APS has a dedicated surface/interface station. The ultrahigh vacuum (UHV) chamber is coupled to a six-circle diffractometer, has molecular beam epitaxy (MBE) capabilities, and is equipped with reflection high-energy electron diffraction (RHEED). X-rays with an energy of 19.9 keV were used throughout the study.

Surface cleanliness was achieved by repeated cycles of Ar⁺ ion sputtering (1 μA, 10 minutes at 700K) and annealing to 900K for 10 minutes. A sharp RHEED pattern was observed, and x-ray diffraction showed sharp c(2×8)-reconstruction spots. A chromel-alumel thermocouple was behind and in contact with the sample. The sample was cooled to 100K by flowing liquid nitrogen. The temperature was controlled, within a few degrees, through the current flow during annealing. The growth rate was monitored by a quartz thickness monitor.

A nominal amount of Ag was deposited at LT and then annealed to room temperature (RT). (One ML is defined as the surface density; for Ag, it is 1.5×10^{15}

atoms/cm²). Reflectivity scans were taken at LT after an annealing cycle. A new thickness was studied on a substrate regenerated by the cleaning procedure aforementioned. A conventional hexagonal Ge(111) unit cell was used, in which the lattice parameter perpendicular to the surface (L direction) is given by $\sqrt{3} * a_{\text{Ge}}$, where a_{Ge} is the cubic lattice constant for Ge (5.6578 Å).

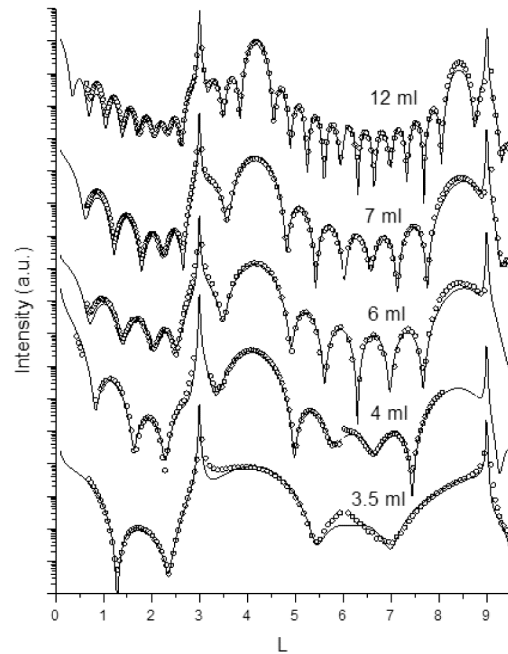


FIG. 1. Reflectivity profiles of Ag films deposited on Ge(111). Nominal thicknesses are indicated. Solid curves are best fits based on the model described in the text.

Results

Figure 1 shows reflectivity profiles taken at LT for each coverage after an annealing cycle. Offsets are included for display clarity. Each profile, background subtracted, has been fit to a model function. Fits are the solid lines also shown in Fig. 1. Our model is simple and describes the data well. The model assumes islands of flat tops and straight edges. Various thicknesses are allowed to be present in the film. Relaxation parameters are included for the N layers of the preferred island

present in the film, which is easily read out from the profiles. The model does not include adatoms that form the $c(2\times 8)$ reconstruction.

We found that films with a nominal thickness (N) of 6, 7, and 12 ML are formed of N - and $N-1$ -layer islands. N -layer islands account for roughly 80% of the film surface. For lower coverages, rougher films formed. Finally, relaxation fit parameters show quite small values: between 0.5% and 3.0% of the lattice layer spacing of Ag(111) ($d_{\text{Ag}} = 2.36 \text{ \AA}$). In summary, Ag films grown on Ge(111)- $c(2\times 8)$ can be prepared nearly atomically smooth and uniform.

Acknowledgments

This research is supported by the U.S. Department of Energy (DOE) under Grant No. DEFG02-91-ER45439. The UNI-CAT facility at the APS is supported by the UIUC MRL (DOE, State of Illinois Board of Higher Education, Higher Education Cooperation Act, and National Science Foundation); Oak Ridge National Laboratory (DOE under contract with UT-Battelle, LLC); National Institute of Standards and Technology (U.S. Department of

Commerce); and UOP LLC. Use of the APS was supported by the DOE Office of Science, Office of Basic Energy Sciences, under Contract No. W-31-109-ENG-38.

References

- [1] J.J. Paggel, T. Miller, and T.-C. Chiang, Phys. Rev. Lett. **81**, 5632 (1998); D.-A. Luh, T. Miller, J.J. Paggel, M.Y. Chou, and T.-C. Chiang, Science **292**, 1131 (2001).
- [2] A.R. Smith, K.-J. Chao, Q. Niu, and C.K. Shih, Science **273**, 226 (1996).
- [3] L. Huang, S.J. Chey, and J.H. Weaver, Surf. Sci. Lett. **416**, L1101 (1998).
- [4] L. Gavioli, K.R. Kimberlin, M.C. Tringides, J.F. Wendelken, and Z. Zhang, Phys. Rev. Lett. **82**, 129 (1999).
- [5] Z.Y. Zhang, Q. Niu, C.-K. Shih, Phys. Rev. Lett. **80**, 5381 (1998).
- [6] C.M. Wei and M.Y. Chou, Phys. Rev. B. **68**, 125406 (2003).