Observation of the Angular distribution of Core Level Photoelectrons during the Epitaxial Growth of Ag on Pd(111)

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X-Ray photoelectrons with a kinetic energy of some hundert electron volts exhibit enhanced intensity along the internuclear axes connecting the emitting atom with its neighbor atoms due to forward scattering [1]. Since XPS is an element specific method the observation of the angular distribution of the core level photoelectrons constitutes a probe of short range order around a particular element. Therefore this method is ideal for the investigation of the growth mode of thin films.

We have used a display-type electron spectrometer [2] to measure simultaneously the complete angular distribution of photoelectrons in a cone with 88° opening. Synchrotron radiation with an energy of 900 eV from the HE-TGM-1 beam line of the BESSY storage ring was employed to excite the 3d core levels of Ag and Pd. The angular distribution was measured at the core level peak and at the background which was subtracted. This intensity was normalized with respect to the spatial analyzer efficiency which was obtained by averaging pictures for thirteen azimuthal positions of the sample. The measurement time for thirteen pictures at two different energies was less than 10 minutes.

Figure a) shows the expected angular distribution of photoelectrons for a fcc(111) surface calculated with a simple forward scattering model. The area of the circles correspond roughly to the expected intensity. The numbers give the crystal directions between emitter and scatterer, and the atomic layer of the emitter (counted from the surface towards the crystal). The separation between the lines of the grid are 10° and 15° for the polar and azimuthal direction, respectively.

For clean Pd(111) (fig. b) we observe enhanced photoemission intensity in the directions expected from the simple forward scattering model (fig. a).

The angular distribution patterns of Ag on Pd(111) are shown in figs. c) - f). The silver coverage was measured with a quartz microbalance. For one monolayer of silver (fig. c) the angular distribution of the Ag 3d photoelectrons is uniform proving the growth of a single layer and the absence of islands or alloy formation.
Upon deposition of the second layer of silver (fig. d) enhanced intensity can be seen along the $<110>$ directions due to the forward scattering at the nearest neighbor atoms. These spots appear, however, reflected at the (112) plane relative to the corresponding spots of the clean surface. This proves unambiguously the different stacking of Ag relative to the Pd substrate. At three monolayers of silver (fig. e) additional forward scattering along the $<211>$ directions can be observed. Further deposition of silver shows the development of more spots due to other forward scattering directions from deeper layers. At a coverage of four monolayers (fig. f) the angular distribution of the photoelectrons is just the reflected image of the pattern of the clean Pd(111) surface.

This shows that Ag grows at room temperature epitaxially on Pd(111) in the layer-by-layer growth mode with a stacking fault at the interface. These results are in agreement with additional measurement by LEED and Auger electron spectroscopy.

Deposition of Ag onto the Pd(111) substrate at a temperature higher than 500 K leads to alloy formation without the occurrence of a stacking fault.

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References