Interfacial Strain Accommodation in Thin Metal Films Through Alloying

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We report a surface x-ray scattering study of surface alloying as a mechanism for interfacial strain accommodation at bimetallic interfaces. Specifically, thin Cu or Ag films grow strained on a Ru(0001) surface due to a lattice mismatch accompanying their epitaxy with a 5.8% tensile stress for Cu and a 6.3% compressive strain for Ag. Cu and Ag do not form bulk alloys but mix in a single layer on Ru(0001) which allows the lattice misfit to be compensated. We grew single layer films by co-depositing various Ag/Cu compositions at 690 K on Ru(0001). To monitor the strain relief at this interface during alloying, we studied the diffraction pattern of the Ag_xCu_{1-x} films. Figure 1 shows longitudinal scans along the [100] direction through the Ru(1,0,0.15) crystal truncation rod (CTR) for various alloy compositions. It becomes obvious from this figure that two phases coexist in the ad-layer film:

1. The strong peak on the left and the weaker satellite on the very right can be attributed to the formation of a Ag reconstruction. This reconstruction is observed for pure Ag films and is also present for submonolayer coverages. Its density increases slightly with a decrease of Ag content, which is indicated by a continuous Ag peak shift towards the Ru CTR in the middle.
2. For Cu contents of more than 15% an additional reflection appears between the Ag reconstruction and the Ru CTR peak. This reflection can be attributed to an alloyed phase with a lesser degree of structural order since the peak is four times broader than that of the Ag reconstruction. With increasing Cu coverage this peak shifts continuously towards the Ru position indicating the compensation of the lattice misfit.

To quantify this behavior, Figure 2 shows the wavevector positions of both phases as a function of alloy composition. The dashed line gives evidence that the interfacial misfit between the Cu/Ag alloy and the Ru substrate reduces as more Cu is added. For $Ag_{50}Cu_{50}$ mixtures the alloy reflection coincides with the Ru CTR suggesting that the two phases have the same lattice constant along [100]. It should be noted that this is not a surprising observation since the respective lattice misfit between Ag (-6.3%) and Ru and Cu (5.8%) and Ru compensate each other for this composition. The 'Ag rich' phase on the other hand adjusts its lattice constant close to the Ag bulk value as shown in Figure 2 by the solid line.

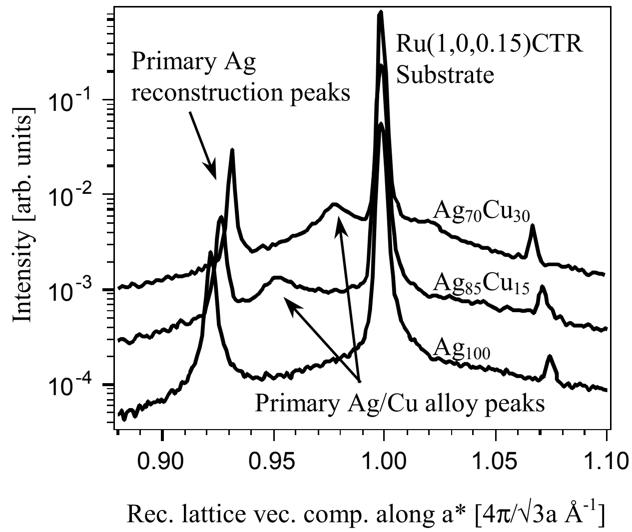

Figure 1. Longitudinal scan through the Ag_xCu_{1-x}/Ru(1,0,0.15) CTR for various Ag/Cu alloy compositions.

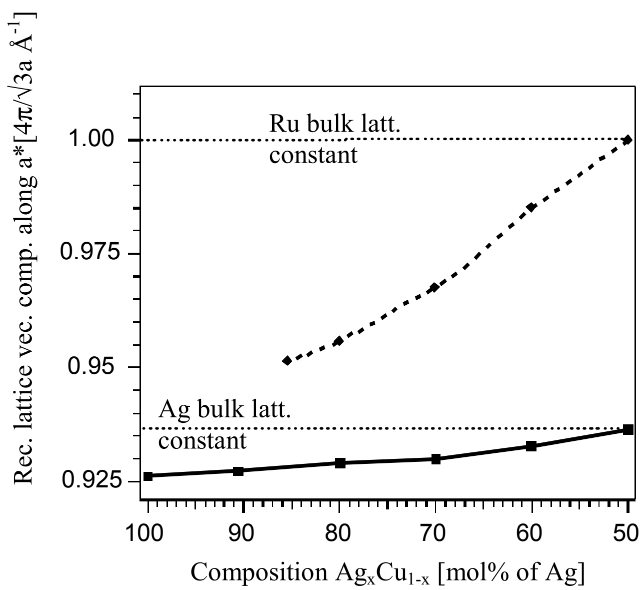

Figure 2. Wavevector as a function of Ag/Cu alloy composition for coexisting Ag and Ag/Cu phases on Ru(0001).

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