Ag on vicinal Cu(111): surface states and LEED

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Vicinal surfaces can be considered as model systems for lateral superlattices. In fact, due to the (dominant) repulsive step interaction, vicinal surfaces are expected to self-assemble forming regular arrays of linear, monoatomic steps. However in surfaces with small miscuts (<10º), the high step mobility at room temperature leads to a "terrace width distribution" that hampers the observation of superlattice effects. One can try different ways of overcoming this problem. The repulsive interaction between steps can be enhanced with the presence of foreign atoms attached to the step edges. The difference in the electron affinity leads to a local charge transfer and thereby to a strong dipole repulsion between steps. This is probably the case of stepped Cu(100) with minute amounts of Na [1]. Surfaces that display high order reconstructions are also interesting alternatives. As observed for Si(111) and Au (111) [2,3], the tendency of the terrace plane to reconstruct introduces additional elastic stress that favors terraces with an integer number of supercells. Thus only a few miscut angles result on extremely regular monoatomic step superlattices over very large areas. Away from this "magic" angles, the reconstruction appears to force the system into regular arrays of bunches with local high index planes (facetting), which is itself an interesting type of self-structuring.

Lately we are working out an intermediate approach, i.e. we deposit on the vicinal surface submonolayer amounts of adatoms that are known to wet the flat substrate forming a superestructured monolayer (ML). This is the case of Ag on Cu(111) and its approximately 9x9 (inconmensurate) monolayer. In general, with the Ag adlayer we try to force new lateral superstructures by introducing additional surface stress. In fact, our preliminary Scanning Tunneling Microscopy (STM) data indicate that submonolayer amounts of Ag induce a lateral pattern of one layer thick Ag stripes that alternate with clean Cu stepped areas [4]. For example at a coverage of ~0.35ML the silver stripes cover ~60Å wide facets with the [112] orientation, spaced by ~100Å wide clean stepped areas of the surface with a local miscut (here ~8°) that depends on the Ag coverage.

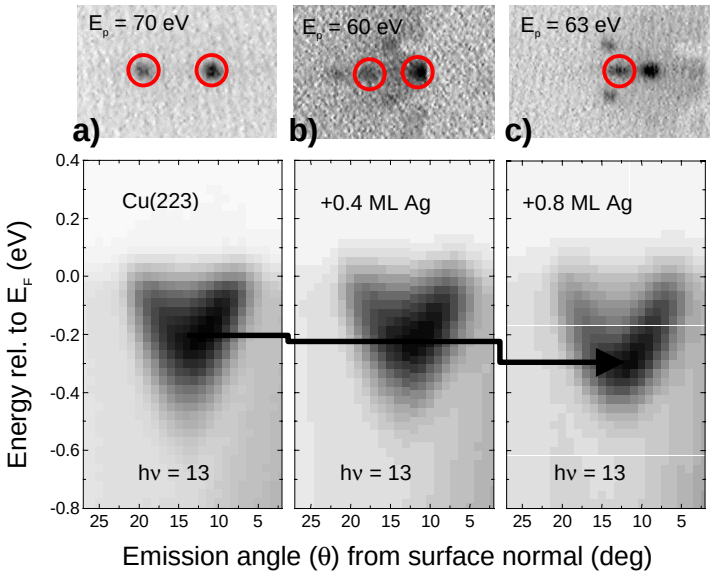

Fig. 1. Top, LEED structure around the (0,0)-spots (circled in red) for clean Cu(223) (Cu(111) with ~11º miscut and {100}-like steps) and the same surface covered with 0.4 and 0.8 monolayers of Ag. The Ag induces a c(10x2) reconstruction with respect to the primitive unit mesh of the [112] facet (visible outer spots in b) and c)). The spot splitting is preserved for 0.4 monolayers, wich is consistent with the presence of clean Cu stepped stripes. For 0.8 layers, the splitting disappears. Bottom, surface state dispersion for the same systems in the direction perpendicular to the steps. The photoemission intensity is shown in dark. The bottom of the band is shifted from –0.20 eV to -0.22 eV and –0.31 eV for clean, 0.4 and 0.8 Ag layer, respectively. Such a behavior is consistent with an increasing size of clean Cu terraces, which is actually required to compensate Ag covered (112)-facets.

At HASYLAB, we have studied the geometric (LEED) and the electronic structure (Photoemission) of 0.4 ML and 0.8 ML of Ag on Cu(223) (vicinal Cu(111) with ~11º miscut and {100}-like steps). The work was done at the F2.2 beamline using the Winkelemi setup. The results are shown in Fig. 1. The clean surface is characterized by the p_z-like surface band in photoemission, with the minimum at 0.20 eV below E_F, and by the spot splitting in LEED. With 0.4 ML the LEED results are consistent with the STM experiments [4], i.e we observe both the Ag-induced superstructure and the Cu splitting. The low intensity, extra spots corresponds to the c(10x2) reconstruction of Ag/Cu(112) areas. This superstructure displays the energy-dependent "travelling" of the spots with respect to the (0,0) beam, typical for facetting. On the other hand the splitting is smaller than the clean surface one indicating that clean stepped Cu stripes have wider terraces. Consistently, the surface band minimum shifts to E_F–0.22 eV, as observed for vicinal Cu(111) with smaller miscuts [5]. Indeed the Ag-covered (112)-facets require stepped Cu(111) stripes with a small local miscut to compensate the macroscopic (223) orientation. With a coverage of 0.8 ML the splitting dissappears and the c(10x2) is sharper. The band minimum shifts down to E_F-0.31 eV. Such a large shift and the single (0,0) spot in LEED are consistent with the presence of very wide Cu(111) terraces in this case.

Is there any specific emission from the Ag covered facets? It is known that stressed Ag(111) layers shift their surface state slightly above E_F [6]. We investigated this possibility in our photoemission data. Fig. 2 shows the Fermi energy region in the spectra corresponding to one side of the parabola of Fig. 1. In the case of the 0.4 ML covered surface we notice the presence of a peak, which is cut off at E_F. This peak is not as intense for 1 ML and it is absent in the clean surface. Thus it could be the Ag surface state tailing across E_F. At this point further characterization by means of inverse photoemission or Scanning Tunneling Spectroscopy is necessary.

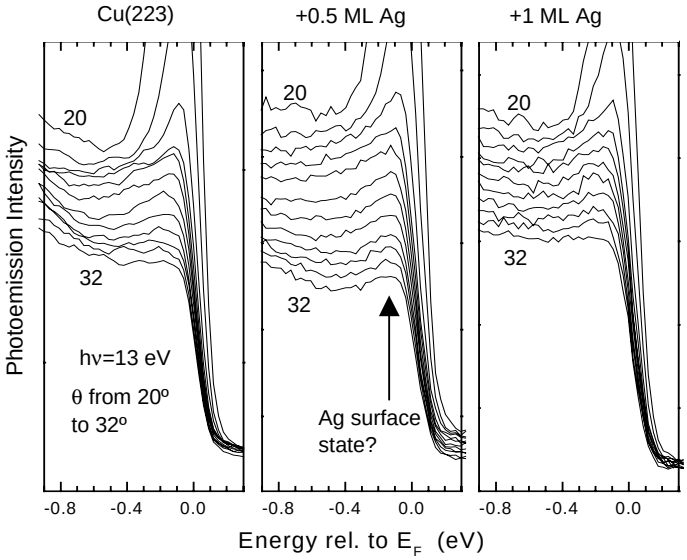

Fig. 2. Photoemission spectra near the Fermi level for clean Cu(223) and 0.4 and 0.8 Ag layers. The emission angle increases by 1º and corresponds to the left side region of the parabolas shown in Fig. 1. There is some residual intensity near E_F for 0.4 layers after the surface band has crossed the Fermi level at 21º. Such an intensity, which is absent in the clean surface could be the signature of the Ag surface state that tails from above E_F.

The work at HASYLAB was supported by the IHP Programme "Access to Research Infrastructures" of the European Commission (Contract HPRI-CT-1999-00040).

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