Surface State Engineering in Stepped Noble Metal Surfaces

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Noble metal surfaces are excellent playgrounds for testing the basic electronic properties of lateral nanostructures. The strong scattering of surface state electrons at adatoms, defects and steps gives rise to interference patterns that can be readily studied e.g. by scanning tunneling microscopy (STM) [1]. In particular, vicinal surfaces with 1D arrays of monatomic steps are attractive to investigate electronic states of self-assembled 1D superlattices using angle-resolved photoemission [2]. Usually they self-assemble forming a 1D step superlattice due to strong step-step interaction. The terrace width d is the lattice constant, which is tuned macroscopically by changing the miscut angle of the surface with respect to the [111] direction. Furthermore, in noble metal surfaces it is possible to tailor surface states by simply changing d, thereby switching from 2D step superlattice bands for narrow terraces to 1D confinement and quantum well states in wide terraces, as shown in Figure 1 [2].

The analysis of such simple systems allowed the development of the basic framework to understand photoemission data in more complex 1D step structures. In fact, the equilibrium shape of the vicinal surface can be strongly affected by surface reconstructions and adatom adsorption. This provides ample room to further engineer surface states. We have searched into a large number of different systems by means of STM, like those shown in Figure 2, and then they have been studied with high resolution angle-resolved photoemission. Vicinal Au(111) surfaces display faceting, i.e., two-phase separation of wide terraces and step bunches, with a finite number of steps tuned by miscut angle. In photoemission we observe a split-off of the surface band into 1D and 2D surface states. Ag induces faceting of vicinal Cu (111), leading to stepped Cu nanostripes with a step density that depends on Ag coverage. This allows us to readily look into the 2D to 1D transition of infinite vicinal crystals. Thin Ag films grown on vicinal Cu(111) display stacking fault boundaries, which lead to lateral confinement of vertical quantum wells.

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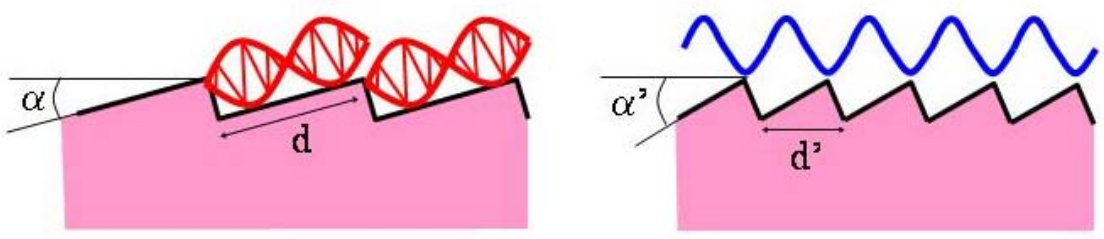

Fig.1: Surface states in 1D step superlattices change from 1D quantum wells in relatively wide terraces (left) to 2D resonant states in relatively narrow terraces (right).

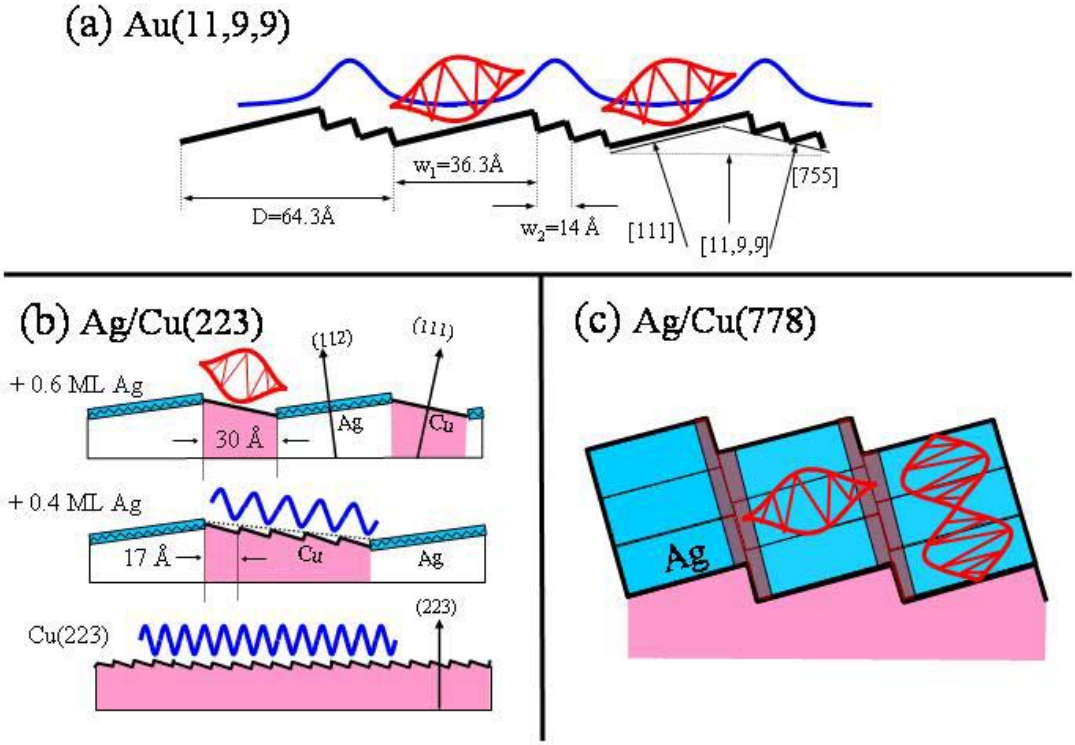

Fig. 2: (a) Surface states split-off into 1D (red) and 2D (blue) states in faceted Au(111). (b) Cu nanostripes are self-assembled by Ag adsorption on v-Cu(111). They smoothly switch from 2D to 1D character by increasing Ag coverage. (c) Vertical quantum wells of Ag films on v-Cu(111) are confined laterally by stacking fault boundaries.

References

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