Matching terrace size and Fermi Wavelength in Step Superlattices

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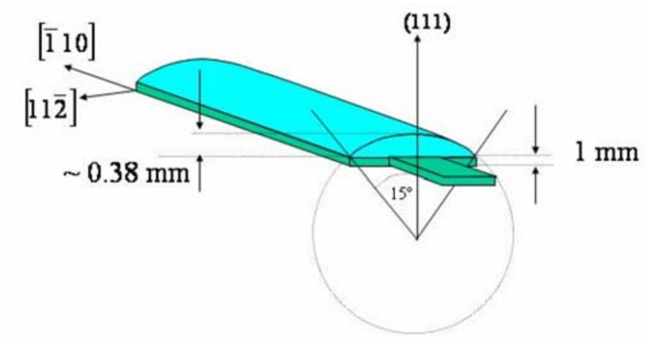
Free electrons of noble metal surfaces are known to scatter strongly at adatoms, defects and steps. In nano-object arrays, such scattering gives rise to periodically modulated density of states and superlattice bands. Moreover, the structure of the periodic system and the surface electronic states may eventually interact in order to make the Fermi wavelength $\lambda_F/2$ match the characteristic lattice constant d [1]. Therefore, structural instabilities, such as step lattice disorder in step arrays or subtle atomic density variations in dislocation networks, can be expected in nanostructure arrays with periodicity close to the critical value $d=\lambda_F/2$ [2].

In order to test the critical $d=\lambda_F/2$ matching in step arrays we have used curved metal surfaces. These allow one to smoothly vary the step distance d in a single sample. The figure describes the geometry of our crystal. The PGM/Scienta setup is particularly convenient for ARPES experiments in these surfaces. The polarization plane can be set parallel to the surface steps along the [-110] direction, allowing a straightforward scan (z-axis) of the light across the [11-2] direction. The spot size is reduced, via vertical slits, to 50 μm in the critical [11-2] direction, i.e., perpendicular to the step edges. This defines a local miscut uncertainty of <±0.5º.

Experiments have been done with Au and Cu surfaces. Both exhibited anomalies for $d=\lambda_F/2$ terrace sizes. The figure shows the photoemission intensity at the Fermi energy as a function of k_x perpendicular to the step edges (along the [11-2] direction), and across the Cu curved surface. The Fermi surface contains a single band (two spots) at the (111) surface, and umklapps (four spots) away from the (111) direction. At $d=\lambda_F/2$, the umklapp bands nest at the center of the figure. The yellow line marks the Fermi surface for one of the spots. It evolves smoothly from the flat surface, but showing a slight deviation around the $d=\lambda_F/2$ crossing (red circle, 8º miscut), suggesting the presence of electronic/structural instabilities.



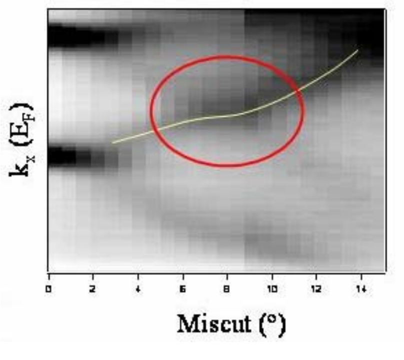


Figure 1: Left, curved Cu crystal. Right, Fermi level intensity measured as a function of k_x (along the [11-2] direction) and the local miscut in the curved surface. Umklapp bands split away from the (111) direction. They show a linear evolution, but also exhibit a smooth instability around the $d=\lambda_F/2$ crossing.

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References:

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