Application Note

Au(111) surface state - measured in less than a minute

The Deflection mode patent pending Scienta Omicron DA30-L analyser is demonstrated for the case of Au(111). The data presented is recorded in less than a minute at Elettra, BL 9.2 – APE.

The first generation ARPES analyser is situated on a goniometer and records one angle at the time, the second generation analyser is angular resolved along the slit. Au(111) is used here to illustrate the added capabilities of a third generation ARPES hemispherical analyser.

Figure 1 displays the surface state Fermi surface along with the bulk Fermi surface, originating from the gold sp bands. The surface state consists of two sub-bands with the shape of parabolas in E_k, k_x, k_y space, where E_k is kinetic energy and k_x and k_y are wave vectors in the plane of the crystal surface.

The split of the band can be seen in Figure 2. The minimum of the parabolas is located about 500 meV below the Fermi level at the Γ-point of the surface Brillouin zone and the parabolas crosses the Fermi level at about ± 0.2 $Å^{-1}$ (Nicolay et al. PRB 65 (2001) 033407). A second generation hemispherical ARPES analyser is capable of measuring a cut in E_k, $k_{||}$ space resulting in a spectrum as displayed in Figure 2.

In order to record the Fermi surface, as displayed in Figure 3, with such an analyser, the sample needs to be rotated. This leads to different portions of the Fermi surface being recorded in different experimental geometry.

A third generation hemispherical analyser on the other hand is capable of recording this whole E_k, k_x, k_y space without sample rotation (Figure 4). This feature significantly improves the performance and quality of the measurements, since the absence of sample rotation imply that the ... →

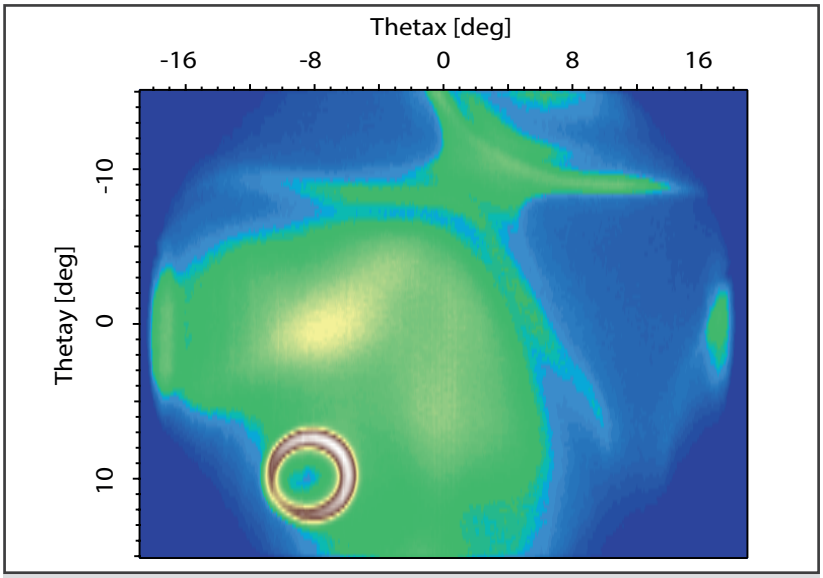

Figure 1: Fermi surface map of the Au(111) including the surface state (bottom left corner) and the bulk Fermi surface. Recorded in scan mode using angular mode 30.

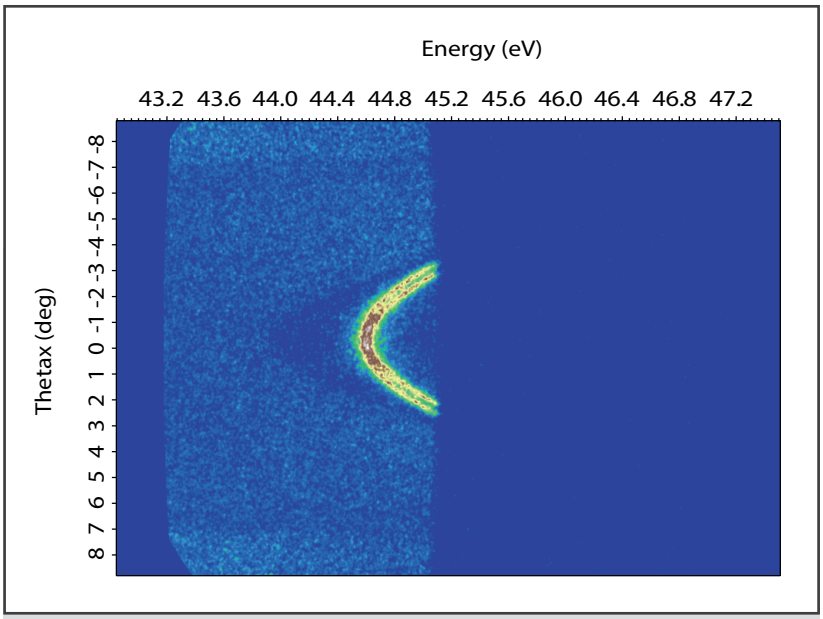

Figure 2: Figure 2: A typical second generation ARPES spectrum of the Au(111) surface state at the $\theta_{x'}$ =± 7, θ_y= 0 degrees position.

... → matrix elements are constant, the same sample spot is analysed for the full k-plane and the risk of misalignment of the crystal is minimised. Furthermore, electronic deflection is both faster and more accurate than most manipulator rotation motorisations. The Scienta Omicron DA30-L hemispherical analyser is a third generation ARPES analyser capable of measuring I,E_k,θ_x,θ_y for $\theta_x = \pm 15$ degrees and $\theta_y = \pm 12$ degrees, where I is intensity and θ_x,θ_y are angles along and perpendicular to the slit, with a high energy and angular resolution. Since θ is related to k the whole I,E_k,k_x,k_y space is measured without rotating the sample (Figure 5). The data is recorded at 77 K using angular mode DA 14, Fix mode, 50 eV pass energy, 0.3 mm slit and 50 eV excitation energy.
Angular DA 14 mode records ± 4 degrees in θx and pass energy 50 eV records a 4 eV energy window in parallel. Each spectrum in the deflection scan mode was recorded for 0.5 s. A region of ± 7 degrees in θy was covered using deflector scanning. The Δθy was set to 0.1 degrees and the total number of scanned spectra was 80. The whole surface state data set took less than a minute to record.

A viewer has been developed to display the data in the SES software. The viewer is an efficient tool during acquisition since it displays the spectrum during aqusition. The same viewer can also be used to display recorded data (several viewers can be open at the same time). The viewer offers the possibility to display data in 3D or as cuts in in Ek,θx, Ek, θy or θx,θy space. Figure 4 shows the viewer tool displaying the data in the form of a cut in Ek,θx space, similar to the traditional display of spectra using a second generation analyser. Figure 5 show the viewer displaying a 3D view of the data. The data can also be exported to third party analysis programs, e.g. Igor. The data and viewer can be seen on the our YouTube channel.

This application note was written in collaboration with Dr. Ivana Vobornik, CNR-IOM, TASC Laboratory, AREA Science Park, Trieste, Italy. The data were recorded at the APE (CNR-IOM) beamline at Elettra synchrotron in Triest /Italy. (http://www.elettra.trieste.it/elettra-beamlines/ape.html). For further questions please contact: ivana.vobornik@elettra.trieste.it.

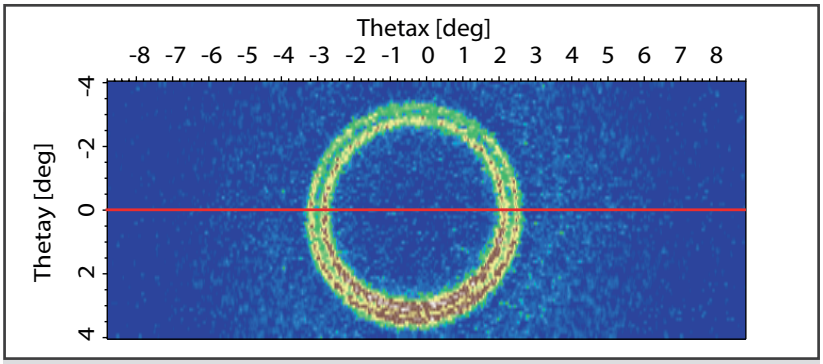

Figure 3: Fermi surface map of the Au(111) surface state recorded using a third generation ARPES analyser. The spectrum was recorded using the deflector mode and the sample was not moved during acquisition. The red line indicate the position of Figure 2.

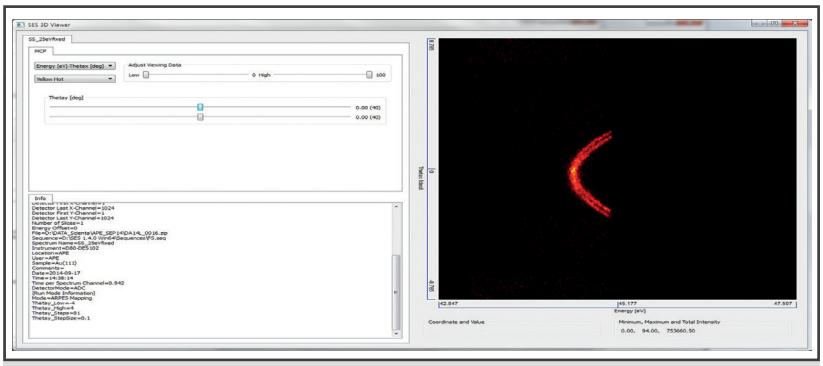

Figure 4: 2D representation of the surface state using the SES viewer.
The spectrum display the same cut as Figure 2.

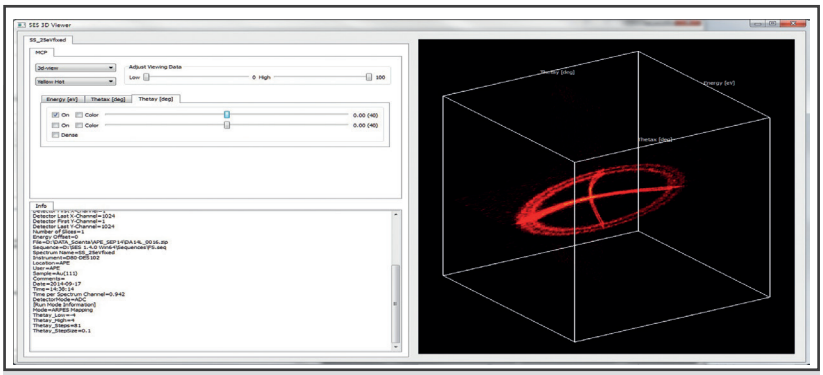

Figure 5: 3D representation of the surface state using the SES viewer where cuts in Ek, θx-, Ek, θy- or θx,θy space.