Polarization effects in high resolution photoemission of n=1 $Bi_2Sr_{2-x}La_xCuO_{6+\delta}$ - single crystals

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Angle-resolved photoemission spectroscopy (ARPES) has the potential to resolve some open questions about the electronic structure of the high temperature superconductors (HTSC's) since it is able to measure directly the momentum resolved spectrum of electronic excitations. From these ARPES measurements on the HTSC's (mostly BSCCO) one gets the knowledge of the Fermi surface (FS) topology, which has been accepted to be a hole like pocket centered around the Brillouin zone corners (X,Y-points) [1] (Figure 2, right panel). This so far accepted picture has recently been challenged by a new study [2] which finds a different Fermi surface for n=2 and also n=1 material with a large electron pocket centered around the Γ-point when measured with higher photon energies (32-33 eV). But there is also a newest study [3] performed with these higher photon energies predicting the "old" FS for Bi-n=2. One reason for the apparent discrepancies on the experimental side arises from the fact that the the near Fermi energy emissions in cuprates are strongly photon energy and polarization dependent, leading to a suppression or enhancement of emissions at certain values of the huge parameter space accessible with photoemision. Our aim in this contribution is to clearify some discrepancies resulting from polarization effects for the BSCCO material. We also intend to show that for a clear determination of the FS of the Bi-based cuprates polarization and photon energy dependence have to be taken into consideration. For our experiments we have chosen optimal doped n=1 material. The advantage of the Bi-n=1 material in comparison to n=2 is the simple fact that for both, the superconducting and the normal state properties are not affected by possible bilayer splitting. Furthermore the low T_c of Bi-n=1 makes it possible to detect the normal state properties with a much better resolution than for n=2, due to the lower thermal broadening. We present photoemission data from optimaly doped- (x=0.40,T_c=29K) $Bi_2Sr_{2-x}La_xCuO_{6+\delta}$ samples [4]. The samples were rectangular shaped with the long side along the crystallographic a-axis, as confirmed by Laue-diffraction and LEED (Figure 1), and have a typical size of 5×2 mm. The angle resolved-photoemission data were recorded with a hemispherical deflection analyzer operated in the energy distribution mode. We use the linearly polarized radiation of 18 eV emitted from the high resolution 3m normal incidence monochromator HONORMI at beamline W3.2.. Our measurements were performed with an overall energy resolution of 40 meV as measured from an Au Fermi edge. The spectra were taken with a total acceptance angle of 1°.

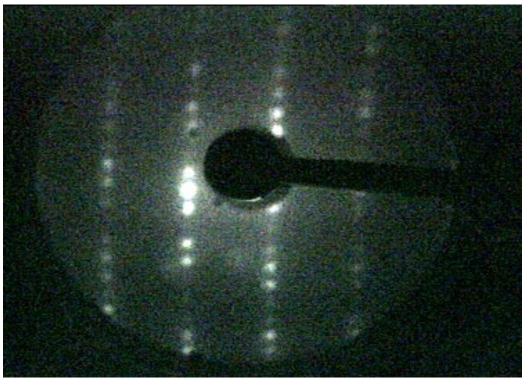

Figure 1: LEED pattern of an optimal doped $Bi_2Sr_{2-x}La_xCuO_{6+\delta}$.-single crystal. The sample is aligned in ΓX direction showing clear evidence for a superstructure in ΓY (perpendicular to ΓX).

A first polarization study on n=1 material [5] has not taken into account the discrepancies between ΓY and ΓX direction. Because of the superstructure in this material arising from a slight mismatch between BiO and CuO_2 planes, the ΓY and ΓX directions are not equivalent (Figure 1). We observed the two umklapp bands in the ΓY direction for n=1 material [6] (Figure 2e) already found for n=2 at different photon energies [1,3]. These umklapp emissions show up in photoemission either by the photoelectron being diffracted by the superlattice (SL) or by the BiO SL distortion affecting directly the electronic structure of the CuO_2 planes. So the data were taken for ΓY **and** ΓX directions around the Fermi surface crossing points at about 0.4ΓX and 0.4ΓY for both polarizations. This was achieved by taking the ΓY and ΓX cuts and then rotating the sample by 90° and retaking the cuts but with different polarizations. Figure 1(a-d) shows spectra near the Fermi surface crossing-point in ΓY (ΓX) direction in two polarization geometries of the electrical wave vector **E** with respect to the ΓX (ΓY) plane. For both ΓY and ΓX, there is less intensity if the electron emission is in the mirror plane defined by the surface normal and the polarization direction (Figure2, panels a+d). This effect is in good agreement to measurements of n=2 [7] and can be described by a simple model based on the symmetry of states (which predicts emission from a one-particle orbital with $d_{x^2-y^2}$ about a Cu-site) [6]. The polarization effects are significant for both directions but more pronounced for the ΓY direction (Figure2, panel c+d). Shen et al. [7] claimed that there is, in general, less intensity near the Fermi energy along ΓY than ΓX because of the superstructure. That is in contrast to our measurements (Figure1.b+c) Especially along ΓY the lineshape of the quasiparticle peak has a strong photon energy dependence resulting in a supression of states for some energies. We have observed this supression along ΓY for 34 eV (not shown) which is nearly the photon energy for the „new" FS study [2]. In the ΓX direction (Figure2, panel b) the Fermi surface crossing as observed for ΓY (Figure 2, panel c) is less pronounced. For this and the weaker polarization effect the shadow bands near the main band could be responsible in this direction ΓX. Therefore lineshape analysis of near Fermi energy structures should be made for quasiparticle dispersion along ΓY taken into account the matrix element changes with variation of photon energy and polarization geometry. Furthermore clear knowledge of effects arising from polarization geometry and photon energy dependence is necessary to determine the exact Fermi surface of Bi-based cuprates.

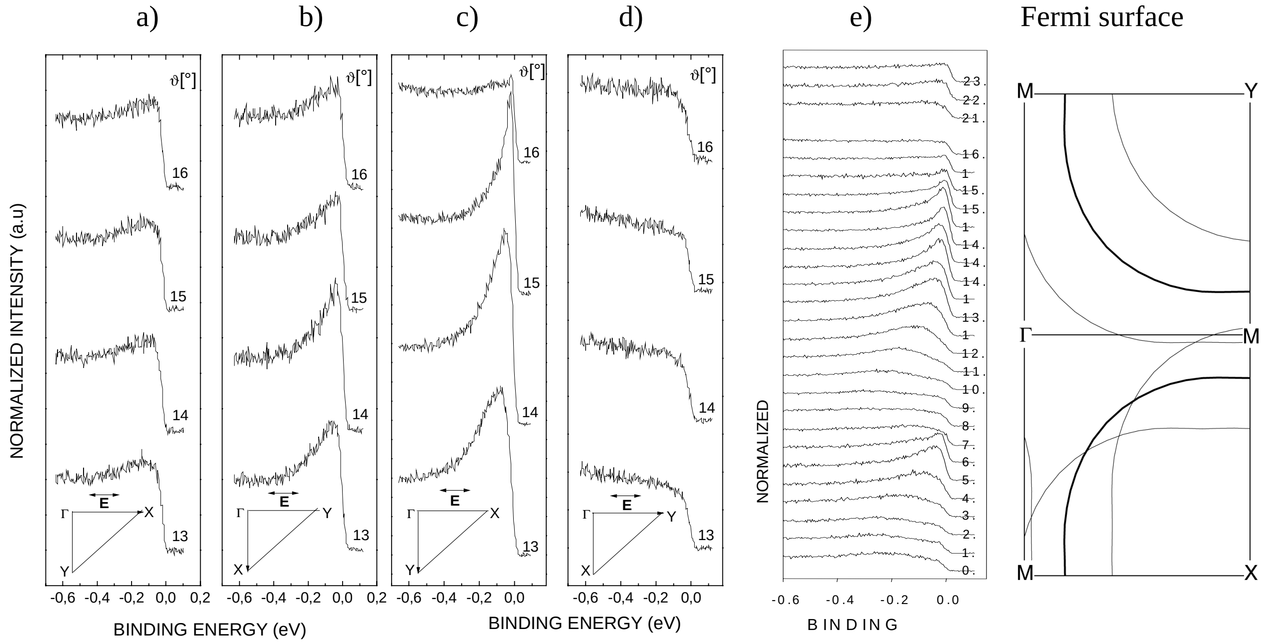

Figure 2: Normal state spectra from n=1 $Bi_2Sr_{2-x}La_xCuO_{6+\delta}$ along the directions ΓY and ΓX of the Brillouin zone for light polarized parallel and perpendicular to the emission direction given by the arrows in the insets taken with hν=18 eV at T=40 K (panel a-e). Panel e (polarization equal to panel c) shows the ΓY seria with crossing points with the umklapp bands near 0.21ΓY and 0.63ΓY. The right panel shows a theoretical Fermi Surface for n=2 taken from Ding et al. [1].

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