DIRECT ARPES AND T_C ENHANCEMENT IN COMPRESSIVELY STRAINED LSCO-214 FILMS

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Abstract: Direct ARPES studies on *in-situ* grown strained LSCO-214 films show striking strain effects on the electronic structure. The Fermi surface (FS) of LSCO-214 evolves with doping, yet changes even more significantly with strain. The compressive strain changes the Fermi surface topology from hole-like to electron-like and causes band dispersion along k_x and the Fermi level crossing before the Brillouin zone boundary, in sharp contrast to the 'usual' flat band remaining ≈30meV below E_F measured on unstrained samples. The associated reduction of the density of states does not diminish the superconductivity; rather, T_c is strongly enhanced (up to factor of two) in compressively strained thin films.

Key words: Cuprates, superconductivity, photoemission, films, strain, T_c, laser ablation

1. INTRODUCTION

In order to truly understand the mechanism of high-T_c superconductivity it is important to combine complementary studies like ARPES (surface) and transport (bulk) on in-house made (systematically monitored and characterized) single crystals and thin films. This was indeed our strategy in this complex field. In general, films of high-T_c oxides are *different* from single crystals even when they are of the highest quality [1-3]. Namely, it is often difficult to fully oxygenate single crystals, and there is always certain amount of growth induced strain (and also disorder) induced in films (at least up to ~25nm). Moreover, most of the crucial ARPES studies were performed on *cleaved* BSCCO-2212 single crystals or films [2] and there is still not sufficient systematic data of equal quality on numerous other

J. Ashkenazi et al. (eds.), New Challenges in Superconductivity: Experimental Advances and Emerging Theories, 9-14.

relevant phases. There are no reports on ARPES on thin oxide films (<30nm), or the role of strain and consequent changes of the electronic structure. The effect of strain in high-T_c cuprates was initially demonstrated by Sato and Naito et. al. (NTT-Tokyo) [4] and Locquet et al (IBM- Rüschlikon) [5] who have shown that in LSCO-214 films can enhance the T_c roughly by about 50%. Bozovic et al. have recently shown that it is important to 'fill' the films with oxygen: this, combined with the growth induced strain, can enhance T_c in LSCO-214 films up to 51K [6]. We were able to confirm the T_c enhancement due to compressive strain in thin LSCO-214 films, and in the first direct ARPES studies (without cleaving the samples) observed some striking effects on the electronic structure.

2. DIRECT PHOTOEMISSION ON HTSC FILMS

Since 1996 we have performed systematic photoemission studies (PES) on *in-situ* grown thin films of high-T_c and related oxides at the Synchrotron Radiation Center (SRC) in Wisconsin. We have successfully solved several non-trivial technical problems inherent in combining the epitaxial film growth by pulsed laser ablation (PLD), usually with 300mbar of oxygen pressure at substrate temperature of ~1030K, with photoemission measurements performed in an adjacent UHV chamber (10^{-10}-10^{-11} Torr) at low temperatures (300-6K). We have optimized an off-axis growth procedure (with deposition rate of only ~1Ås^{-1}) mostly on (100) $SrTiO_3$ substrates and on $SrLaAlO_3$ (SLAO) for strained LSCO films. The result is high epitaxial quality of c-axis oriented films with an in-plane crystal coherence of up to ~1μm [7-11]. We have studied thin cuprate films (down to ~1UC) and fabricated films of manganites and ruthenocuprates. We have mastered the transfer of *in-situ* grown films under vacuum to the adjacent PES chamber and systematically performed core level spectroscopy[11]. A summary of some of the most relevant results was given in a recent article [14,15].

In Figure 1 we schematically illustrate the changes of the Fermi surface (FS) topology with compressive strain: There is an evolution of the FS shape with strain, from the hole-like to the electron-like. This has been convincingly confirmed in our measurements on overdoped LSCO-214 films: while the measurements on the unstrained film give effectively the same ('flat band') spectra as reported by Ino et. al. on scraped single crystals [12], those on strained films unambigously show the band crossing. Therefore, we can confidently consider the data measured on unstrained films as equivalent to those on scraped single crystals. However, the fact that the saddle point near (π, 0) is no longer detected in the strained samples [13-15] is rather surprising since the associated sharp reduction of the DOS