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ENHANCED RESONANT SOFT X-RAY SCATTERING YBa2Cu3O7-x 50 nm THIN FILMS ON BYCRISTALLINE SUBSTRATES

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1. INTRODUCTION: $YBa_2Cu_3O_{7-x}$ GRAIN BOUNDARY JOSEPHSON JUNCTIONS

- *Josephson junction:* structure consisting of two superconductors called electrodes separated by a thin layer called barrier.

- The barrier coupling the two superconductors can be: insulator *(tunnel junctions)* or semiconductor, normal metal or alloy, or *another superconductor with reduced critical parameters (weak links).*

- The current across a high angle grain boundary in $YBa_2Cu_3O_{7-x}$ (YBCO) thin films is several orders of magnitude lower than that of an epitaxial film: behave as a *weak links or grain boundary Josephson junctions (GBJJs).* Fabrication of artificial GBJJs: deposition of the YBCO thin film on *bicrystalline substrates.*

- *Bicrystalline substrates:* two single crystals cut at different angles, polished and fused together. A tilt grain boundary is formed at the interface of the two single crystals. The grain boundary is transferred to the thin film deposited on the bicrystal substrate and *the grain boundary is the barrier of the junction.*

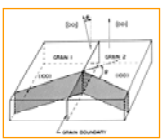


Figure 1. Bicrystalline substrate

2. MOTIVATION AND OBJECTIVE

- Experimental observations of the grain boundary in YBCO GBJJs: *the barrier is a very disordered region.*

- The strain fields of dislocations perturb the local structure, mainly in the YBCO oxygen sublattice in the barrier and in the adjacent regions even leading to non - superconducting zones.

- OBJECTIVE: *to obtain some compositional information, mainly related to the oxygen content, in different positions along the normal direction to the grain boundary.*

3. EXPERIMENTAL

3.1. Samples fabrication

- YBCO thin films are grown in a high pressure pure oxygen sputtering system at Applied Physics Department (Complutense University)

- The thickness of the samples fabricated is around 50 nm. The critical temperature for the films is in the range 89.5-91 K.

3.2. XAS measurements

X-Ray absorbance at $O_{K\text{-}edge}$, $Cu_{L3,2\text{-}edges}$ measured in the back scattering geometry by the enhancement of the YBCO [001] diffraction peak at station 6.3.1 of ALS (J. Kortright endstation)

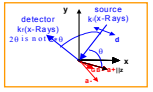


Figure 2. Experimental geometry. The enhanced scattering was measured at a value of θ_{Bragg} on the diffraction tail

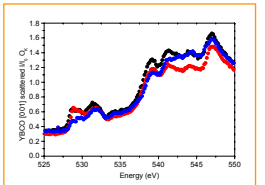
- Radiation: predominantly linearly polarized in the horizontal plane

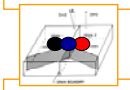
- Measurements: at different positions across the grain boundary

Figure 3. Samples on the probe for the experiment

4. RESULTS AND DISCUSSION

Figure 4. O spectra at three different positions.





The circle on the bicrystal is indicative of the region where the spectra shown have been collected.

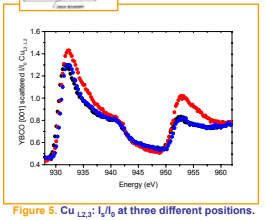


Figure 5. Cu $_{L2,3}$: I_s/I_0 at three different positions.

1) We have compared our Cu and O spectra to the previously data reported by other authors in YBCO single crystals for different x values:
N. Nücker et al, Phys. Rev. B 51,8534 (1995)
J. H. Guo et al, Phys. Rev. B 61, 9140 (2000)

2) We believe two phases with different x value (grain boundary and adjacent regions) are present in the YBCO thin film deposited on the bicrystalline substrate

3) We can obtain qualitative information of the contribution of these two phase along the normal direction to the grain boundary by fitting our spectra at the excitations Previously observed.
Oxygen spectra: the contribution of the full oxygenated phase is calculated by means of the area of the excitations indexed with 1 in Fig. 7 and 8. The contribution of the oxygen deficient phase is associated to the excitations indexed with 2.

4) From such analysis we can deduced:
- In all the regions contribution of both phases have been measured
- In the regions close to the grain boundary the oxygen deficient phase is the most important as previously envisaged by other kind of techniques
- Far from the grain boundary the higher contribution is coming from the full oxygenated phase as corresponds to a recuperation step by step of the YBCO good lattice, but the other phase does not disappear
- These results are corroborated for the fitting of the Cu spectra as well

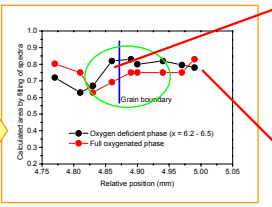


Figure 6. Estimation from the O spectra of the contribution of the two phases in different points along the normal direction to the grain boundary.

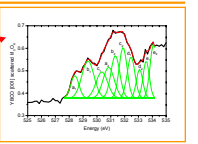


Figure 7. Fitting corresponding to at 4,83.

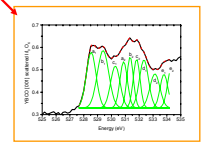


Figure 8. Fitting corresponding to at 4,99.

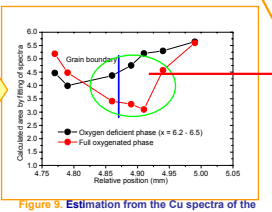


Figure 9. Estimation from the Cu spectra of the contribution of the two phases in different points along the normal direction to the grain boundary.

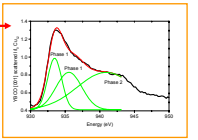
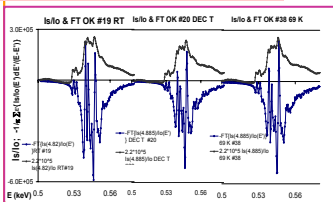
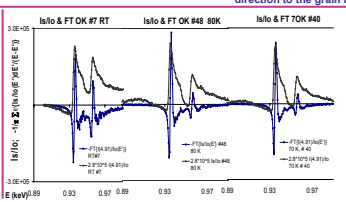


Figure 10. Fitting corresponding to at 4,86 .

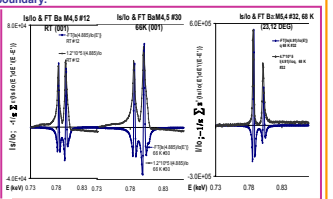
Fig. 11: Response I_s/I_0 and Fourier Transforms



➢Incident Radiation hν polarization, O:1s⇔ O:np by F gives l=1 symmetry scattered radiation polarization: $e_s = e_i$
➢Response at O_K edge: $e_s^* . F . e_i = (x^2 + y^2) < f_0' + f'' + i\ f'' >_{\pm 1}$
➢There is no mixing of f' into f''. The FT is symmetric.



➢ Incident radiation polarization, $Cu:2p_{3/2,1/2}$⇔ $Cu:nd_{5/2,3/2}$ by F gives l=2 symmetry scattered radiation polarization, $e_s \neq e_i$.
➢Response at $Cu_{L2,3}$ edge: $e_s^* . F . e_i$ mixes f' and f'' as shown by FT. A 10% asymmetry in FT is observed and I_s depends on θ and T.
➢ Shifts in I_{max} are due to mixture of f' and f''.



➢Incident radiation polarization, $Ba:3d_{5/2,3/2}$⇔ $Ba:nf_{7/2,5/2}$ by F gives l=3 symmetry scattered radiation polarization, $e_s \neq e_i$.
➢ f' and f'' mix, and I_s depends on θ and T.
➢Lines sharpen at (θ, 2θ)= (12, 23 DEG), FT have the same mix.
➢Signal enhancement and oscillations in FT are observed near T_c as in the $Ba_{L2,3}$edge XAS.

5. CONCLUSIONS

-Qualitative information of the composition of the YBCO deposited of a bi-crystalline substrate can be obtained from the analysis of the spectra collected in different regions along the grain boundary in the back scattering geometry by the enhancement of the YBCO [001] diffraction peak

-We have deduced that the crystallographic grain boundary is a region mainly deficient in oxygen but this affect to the adjacent regions as well

-Given the symmetry of the FT, the T and x dependence may be discussed for the O_K I_s/I_0 in absorption. This is not true for the $Cu_{L2,3}$ and $Ba_{M4,5}$ edges where the FT indicate mixture of the real and imaginary components of the scattering .