Polarization-Dependent X-ray Absorption Spectroscopy of In-plane Aligned (100) $YBa_2Cu_3O_{7-\delta}$ Thin Films

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Abstract

Polarization-dependent x-ray absorption spectra (XAS) on the O 1s edge has been measured on a highly in-plane aligned (100) a-axis $YBa_2Cu_3O_{7-\delta}$ (YBCO) thin films. The in-plane XAS, that is, the electric field E of the linearly-polarized synchrotron light parallels to b- or c-axes of YBCO films (E//b or E//c), were obtained in a normal-incidence alignment. Furthermore, the XAS for E//a was calculated from the oblique incidence to the sample with different angles. The present results are consistent with those obtained by using detwinned YBCO single crystals.

Key words: Polarization-dependent x-ray absorption spectroscopy; a-axis oriented $YBa_2Cu_3O_{7-\delta}$; XAS of E//a, E//b, and E//c

1. Introduction

It is well known that holes in cuprate superconductors are responsible for superconductivity. In addition, the cuprate superconductors exhibit strong anisotropic features due to their layered structure. These anisotropies are reflected in their electrical and superconducting properties. Therefore the determination of the position of the hole and its symmetry in the high-T_c superconductors has attracted significant attention in order to understand the origin of superconductivity. For many years, the electronic structure of CuO_2 planes and CuO_3 chains and the distribution of holes on all oxygen and copper sites in single crystals of YBCO have been investigated as a function of oxygen stoichiometry using polarization-dependent x-ray absorption spectra (XAS) in the O 1s and Cu 2p edges [1]-[4]. Since it is difficult to handle a single crystal because of its small size, it is interesting to use epitaxial YBCO thin films for such investigations.

However, a problem is encountered when using (001) YBCO film instead of single crystal. It is difficult to prepare a film with pure in-plane orientation (i.e., ensuring a- and b-axes of the film are distinguishable). Therefore, only average XAS for the electric field E of the polarized light parallels to the ab plane of the (001) films (E//ab) is obtained [5].

Here we report the recent results of polarization-dependent x-ray absorption experiments using a highly in-plane aligned a-axis YBCO thin film. The in-plane XAS (E//a and E//b) were obtained in a normal-incidence alignment. Furthermore, the XAS for E//a was calculated from the oblique incidence to the sample with different angles. Therefore, the XAS for the three polarizations E//a, E//b, and E//c are distinguishable.

2. Experimental

Highly in-plane aligned (100) oriented YBCO thin films have been deposited on (100) $LaSrGaO_4$ sub-

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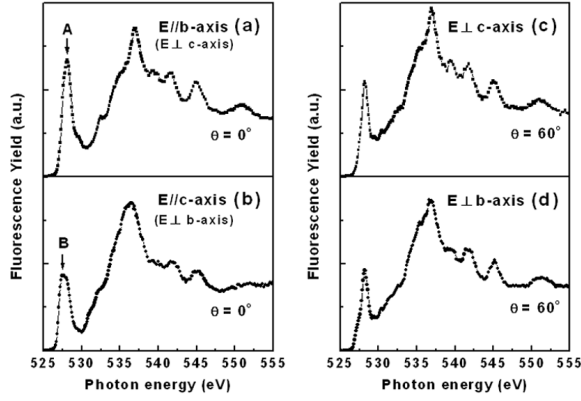[1] Corresponding author E-mail:khwu@cc.nctu.edu.tw

Fig. 1. E perpendicular (a), (c) c- and (b), (d) b-axes absorption spectra of (100) oriented YBCO thin films for various incident angles.
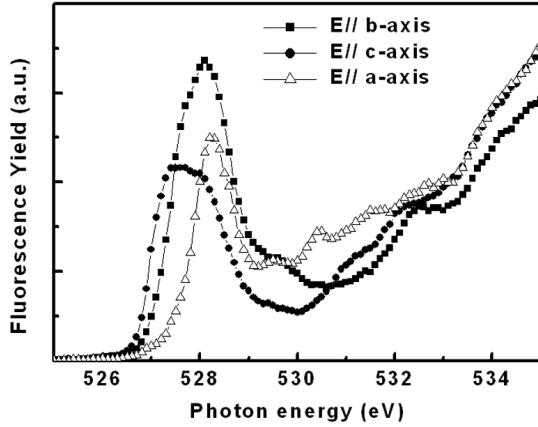

Fig. 2. Comparison of the O 1s absorption spectra of (100) oriented YBCO thin films for polarization E//a-, E//b- and E//c-axes.

3. Results and discussion

For normal incidence case ($\theta = 0^o$), that is, the electric field E of the linear polarized synchrotron light parallels to the bc plane of the thin films, the E//b or E//c absorption spectra can be obtained by rotating the (100) YBCO films such that b- or c-axes of the film is parallel to E. The O 1s in-plane XAS for E//b and E//c are shown in Fig. 1(a) and (b) respectively. The near-edge absorption peak in E//b absorption spectra is peak A (photon energy = 528.4 eV). However, the peak A was superseded by peak B (photon energy = 527.8 eV) in E//c absorption spectra.

In addition, the absorption spectra for oblique incidence at $\theta = 60^o$ were obtained by rotating the sample along the c- (Fig.1 (c)) or b-axes (Fig.1 (d)). Consequently, the O 1s x-ray near-edge absorption spectra along a-axis could be calculated from $I_\theta = I_0 \cos^2(\theta) + I_{90} \sin^2(\theta)$, where I_0, I_{90}, I_θ are the fluorescence yield at the incident angles $\theta = 0^o$ (E//b or E//c), $\theta = 90^o$ (E//a) and $\theta = 60^o$ respectively. Therefore, the XAS for the three polarizations E//a, E//b, and E//c are distinguishable and are shown in Figure 2. The present results are consistent with those obtained by using twin-free YBCO single crystals reported by M. Merz et al. [3].

Acknowledgements

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strates by pulsed laser deposition. A 230 nm-thick $PrBa_2 Cu_3 O_{7-\delta}$ (PBCO) thin film was used as a buffer layer between YBCO and LSGO. The crystallinity of the films was analyzed by measuring the X-ray diffraction (XRD) pattern, the full-width at half maximum (FWHM) of the rocking curve of the (200) peak. The percentage of in-plane alignment, larger than 95%, was obtained by the X-ray ϕ scanning. The transition temperature, 88.7 K, was measured by a standard four-probe method. The polarization-dependent XAS were measured using synchrotron radiation from a 6 m high-energy spherical monochromatic (HSGM) beam line at Synchrotron Radiation Research Center (SRRC), Taiwan, R.O.C. [6]. The samples were mounted on a holder by which they could be rotated around a vertical axis and horizontal axis. The detail experimental arrangement and results will be reported elsewhere.