

Epitaxial $Y_1Ba_2Cu_3O_{7-\delta}$ thin films with (103)/(110)- and (100)/(010)-orientation on $NdGaO_3$ and $SrTiO_3$ substrates grown by ion-beam sputter deposition

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A fully oxygen-compatible ion-beam sputter deposition process (IBS) has been implemented for investigation of four film/substrate couples: (103)/(110)YBCO on (110) $SrTiO_3$ (STO) and on (100) $NdGaO_3$ (NGO), and (100)/(010)YBCO on (110)NGO and on (100)STO. For comparison, some (103)/(110)YBCO films have also been prepared by off-axis rf-magnetron sputtering. Below about 600 °C semiconducting, sub-nm flat, and perfectly single-crystalline YBCO films crystallize on these substrates with a crystallographic unit cell of about 1/3 of the Cu–O subcell of YBCO and perfect registration with the Ti^{4+} –O and Ga^{3+} –O sublattice of STO and NGO, respectively. At higher temperature superconducting YBCO films grow coherently epitaxially in the first ~100 nm thickness; in thicker films the lattice-misfit strain relaxes to the “free” lattice constants. Above ~680 °C a faceted (103)YBCO orientation grows on (110)STO and (100)NGO substrates with uniform in-plane orientation of the [010]YBCO direction parallel to [001]STO and [001]NGO. Along [010]YBCO the (103)YBCO films exhibit high crystalline perfection and intrinsic superconducting properties approaching those of (001)YBCO films in the plane; i.e., $T_{c,0} > 88$ K, $\Delta T_{c,0} < 0.6$ K, $R_{300}/R_{100} > 2.9$, $\rho_{100} > 250 \mu\Omega\text{cm}$, and j_c (77 K) $\geq 10^6$ A/cm². Practical use of (103)YBCO films is hampered by the large surface roughness. Above ~680 °C a mixed (100)/(010)YBCO orientation grows on (110)NGO substrates, exhibiting a very smooth surface but less attractive superconducting properties; typically, $T_{c,0} \leq 80$ K, $\Delta T_{c,0} \sim 1$ K, $R_{300}/R_{100} \sim 1.2$, $\rho_{100} > 3$ m Ωcm , and j_c (77 K) $\leq 10^5$ A/cm². On (100)STO substrates the YBCO film orientation varies from pure (100)YBCO between ~580 and ~630 °C and mixed (100)/(010)YBCO below ~660 °C to pure (001) YBCO above ~670 °C. With rising temperature the surface roughness increases from <2 to ~6 nm-rms, while the other parameters continuously improve to state-of-the-art values for c_{\perp} -oriented films. Specifically, mixed (100)/(010)YBCO films reach $T_{c,0} > 86$ K, $\Delta T_{c,0} \sim 1$ K, $R_{300}/R_{100} > 2.8$, $\rho_{100} < 3$ m Ωcm , and j_c (77 K) $> 10^5$ A/cm². (100)/(010)YBCO films on (100)STO are a promising candidate for sandwich-type SIS-JJ.

Keywords: Electrical properties; Superconductors; Thin film

Materials: $YBa_2Cu_3O_{7-x}/NdGaO_3$