Electrochemical Modulation of Superconducting Properties in $YBa_2Cu_3O_{7-\delta}$ Films

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Introduction $YBa_2Cu_3O_{7-\delta}$ (YBCO) is a well-known high-temperature superconductor and its superconducting transition temperature (T_c) is highly dependent on the oxygen deficiency, δ; When δ is zero, the T_c is ~90 K and when δ is ~0.6, the T_c is almost zero kelvin. Generally, the oxygen content is fixed during the synthesis and it is traditionally tuned by annealing YBCO at 400−600 °C in an oxygen atmosphere. Such a process is very likely to cause detrimental changes in structures by interdiffusion, particularly for thin-film devices. In recent years, it is reported that an electric field can induce O^{2-} ions to migrate from the electrode and finally be removed from the CuO chains, introducing oxygen vacancies in the cuprate superconductor films.[1] In this study, we directly added or removed oxide ions in YBCO films using Yttria-Stabilized Zirconia (YSZ) substrate as the solid electrolyte. Here we show the T_c of YBCO film can be modulated by the electrochemical redox reaction using YSZ as the solid electrolyte.

Experimental YBCO films (~65 nm) were grown by pulsed laser deposition technique on (001) YSZ substrates with 10%-Gd-doped CeO_2 as the buffer layer.[2] A silver paste was coated on the back side of the YSZ substrate, and the film was then placed on an Au foil for the redox reaction at 300 °C in air (**Fig. a**).

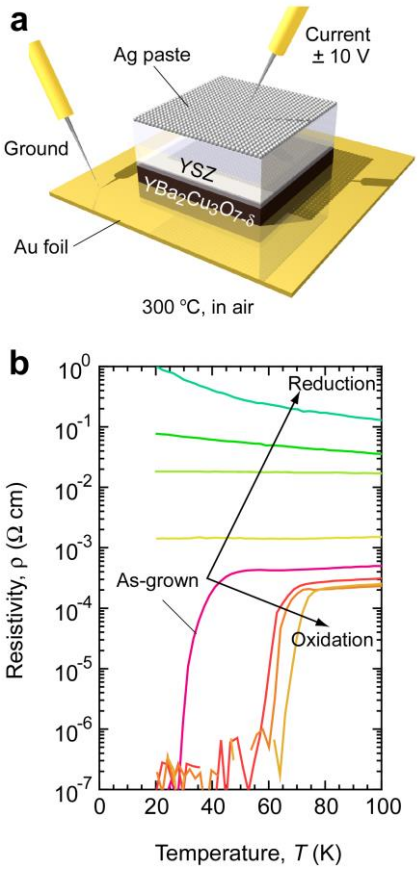

Figure (a) Schematic diagram of the electrochemical redox treatment of a YBCO film. (b) Temperature dependence of resistivity for YBCO films at the as-grown state and after electrochemical redox reaction.

Results The as-grown film shows a T_c of ~46 K and it increases with the oxidation of films. When a negative voltage is applied to the film, the T_c increases to ~76 K (**Fig. b**), resulting from the intercalation of oxide ions in the film. On the other hand, the positive voltages can efficiently remove oxygen from YBCO films and successfully modulate the electrical conductivity of YBCO films from superconductor to insulator (**Fig. b**). The electrochemical redox reaction induced crystal structural changes were also investigated by XRD. Obvious increase of *c*-axis lattice parameters was observed after applying a positive voltage, clarifying the effect of oxygen vacancies on YBCO crystal structure. This study provides an efficient approach to manipulate the superconductivity of cuprates in mild conditions.

References

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