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Optical investigation of high critical-current $Gd_{1+x}Ba_{2-x}Cu_3O_7$ coated conductors

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***Abstract*-- $Gd_{1+x}Ba_{2-x}Cu_3O_7$ (GdBCO) coated conductors on IBAD-MgO templates have grown by pulsed laser deposition. Critical current of the films were measured as about 90 A/cm by a four-probe method. The optical response of the films was investigated by Raman scattering spectroscopy. According to the Raman scattering spectra, the peaks at 328 cm^{-1}, 451 cm^{-1}, 504 cm^{-1} were found and assigned to one B_{1g} mode and two A_{1g} modes, respectively. The high critical-current carrying behaviors of the GdBCO coated conductors are ascribed to their 123-structure without exchange of cation and incorporation of oxygen into the cuprates.**

1. INTRODUCTION

The $ReBa_2Cu_3O_{7-\delta}$ (ReBCO, Re = rare earth element) materials have been attracted much attention due to their large critical current in the high magnetic field region. In particular, the critical current density (Jc) of $Nd_{1+x}Ba_{2-x}Cu_3O_7$ (NdBCO) materials is higher than $YBa_2Cu_3O_{7-\delta}$ (YBCO) materials in magnetic fields [1]. Superconducting properties of YBCO depend on oxygen content; for $\delta \leq 0.2$, it has an orthorhombic structure (ortho-I), for $\delta = 0.3$, it has an orthorhombic structure (ortho-II) as well, and then it becomes superconductor below Tc $\leq$ 60K. On the other hand, for $\delta \geq 0.6$ it has a tetragonal structure [2, 3]. ReBCO have a B_{1g} phonon in the D_{4h} point group symmetry-tetragonal structure, and an A_{1g} phonon in the orthorhombic D_{2h} symmetry. The B_{1g} phonon which is consisted of mainly the O2-O3 out-of-phase plane-oxygen vibrations, softens by up to 8 cm^{-1} below Tc. Simultaneously, the A_{1g} phonon (O2-O3, in-phase plane-oxygen phonon) becomes hardened by 4 $^{cm-1}$ [4].

This paper reports the results of Raman spectra of high critical-current $Gd_{1+x}Ba_{2-x}Cu_3O_7$ (GdBCO) coated conductors. Raman spectroscopy is a powerful method providing the information for charactering high Tc oxide superconductor such as vibratory, electronic and magnetic properties [5].

2. EXPERIMENTS

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GdBCO coated conductors were prepared by a pulsed KrF excimer laser (LPX220i with wavelength of 248 nm from Lambda Physik) on hastelloy tapes with ion-beam assisted to grow MgO layers. The GdBCO layers were grown at 810 °C of the substrate temperature (Ts), 300 and 500 mTorr of deposition pressure with pure O_2 gas, respectively. Repetition rate and energy of the pulsed laser beam were fixed at 10 Hz and 100 mJ, respectively. The deposition time is 20 minutes. The thickness will be measured later but presumably is about 0.5 □ m. The calculated laser energy density on the target from the focused spot area (5 x 1 mm^2) was 2 J/cm^2. The distance of substrate-to-target was fixed to 6.5 cm. Prior to the deposition, the chamber was evacuated to a base pressure of 5 x 10^{-6} Torr. Transports properties (Jc) of the samples were measured using a standard four-probe method. Raman scattering spectra were taken in a quasi-backscattering geometry using 30 mW of the 514.5 nm wavelength of an Ar ion laser, focused on a line with a cylindrical lens, as the excitation source [6].

We measured Raman spectra in order to investigate the crystal orientation of the coated conductors. Light, which is scattered by Raman spectroscopy, is frequency-shifted with respect to the excitation frequency, but the magnitude of the shift is independence from the excitation frequency. Therefore, this Raman shift is therefore an intrinsic property of the samples [5].

The direction of the film growth is not known before the Raman measurements, and the coated conductors can grow in either c- or a-axis perpendicular to the substrate. By comparing the relative intensities of the oxygen plane B_{1g} mode and the apical oxygen A_{1g} mode in various scattering geometries, the direction of the film growth can be determined [6]. Polarization-dependent measurements of the Raman spectra indicate that the films are well-grown as biaxially oriented with c-axis normal to the substrate. In addition, x-ray diffraction of the films also confirms the texture of the films.

3. RESULTS AND DISCUSSION

Figures 1 and 2 show current-voltage characteristics of the GdBCO samples which suddenly increase at the point of 35 and 32 A, which is corresponding to critical-current /width (Ic) of 90.5 and 89.6 A/cm, respectively.

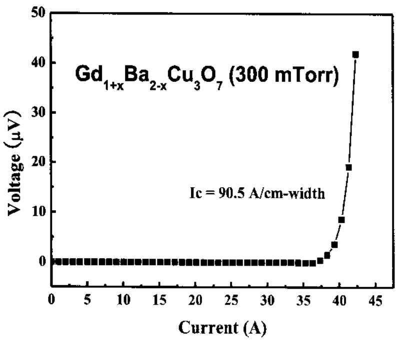

Fig. 1. Current-voltage characteristics of the GdBCO coated conductor (300 mTorr). The critical currents were measured at 77 K and self-field.

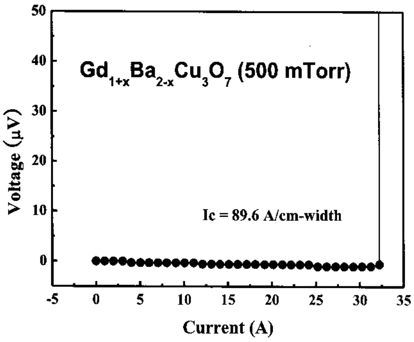

Fig. 2. Current-voltage characteristics of the GdBCO coated conductor (500 mTorr). The critical currents were measured at 77 K and self-field.

The critical current was measured at 77 K without external magnetic field. The difference of two samples is deposition pressure which is 300 and 500 mTorr with pure O_2 gas, respectively. S. Lee et al. [7] reported that the high critical current with uniform spatial distribution cannot be obtained in the Ba-poor composition. $Gd_1Ba_{1.9}Cu_3O_7$ thin film has 2.20 MA/cm^2 but as x increases, $Gd_{1.05}Ba_{1.95}Cu_3O_7$ thin film has 2.85 MA/cm^2. In our $Gd_{1+x}Ba_{2-x}Cu_3O_7$ samples, the critical current (Ic) was changed from 90.5 to 89.6 A/cm. It indicates that two samples have slightly different x concentration. The chemical composition of rare-earth base cuprates is known to be very sensitive to the deposition pressure [6].

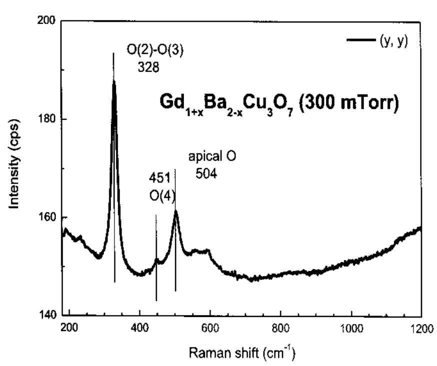

Fig. 3. Raman spectra of the GdBCO coated conductor (300 mTorr).

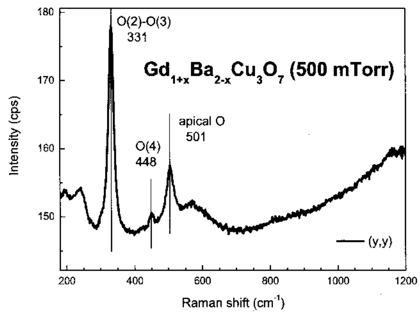

Fig. 4. Raman spectra of the GdBCO coated conductor (500 mTorr).

Raman spectra taken at room temperature of the samples are shown in Figs. 3 and 4. Most of the scattering occurs without change of energy. Some of the scattering involve the excitation of the molecule to a higher vibrational energy. A finite Raman shift corresponds to excitation energy of the sample. The obtained spectral features are quite similar to those of other cuprates like YBCO. In the sample has grown at 300 mTorr, and Raman peaks are observed at around 328 cm^{-1}, 451 cm^{-1}, and 504 cm^{-1} as had shown in Fig. 3. There are two A_{1g} modes at 451 (O4) and at 504 cm^{-1} (apical), and one B_{1g} mode at 328 cm^{-1}(O2-O3 out-of-phase plane-oxygen). Moreover, recently two lines at 248 and 596 cm^{-1} were unambiguously assigned to A_{1g} mode is stretching out of vibrations of copper and oxygen atoms, respectively [7]. These behaviors are similar to those of other ReBCO compounds, where four modes A_{1g} and one mode B_{1g} are observed [6]. Several groups reported that the frequency of the 500 cm^{-1} band is sensitive to the oxygen content for YBCO. It is rational to suppose that the frequency of the 500 cm^{-1} band may also changes with the oxygen content [8].

On the other hand, the two coated conductors measured in the XY polarization geometry do not show the B_{1g} mode. It means that the coated conductors are grown in the *c*-axis orientation [6]. Similarly, we assigned to the peak in Fig. 4. The peaks from one B_{1g} mode and two A_{1g} modes peak are shifted by +3 and -3 cm^{-1}, respectively. The shift can be interpreted as a small change of composition in the materials. Basically, the materials have the same 123-structure, so that we assume the deposition gas pressure might be changed the lattice constant and x concentration. From the Raman spectra, the well-formed phonon structure is confirmed without any other severe second phases or signs of cation exchange. In addition, the oxygen peaks are predominant factor, which are also an important factor for high quality coated conductors.

4. SUMMARY

Measurements of critical-current (Ic) and Raman scattering spectroscopy for GdBCO coated conductors are performed. Even though the materials have significant dependence on deposition pressure, large critical-current of the coated conductors are ascribed to c-axis orientation, well-formed 123 phase. It is important to control oxygen partial pressure during the deposition to optimize the large critical currents of GdBCO coated conductors.

ACKNOWLEDGEMENTS

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