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Novel Methods of Laser Ablation of $YBa_2Cu_3O_y$

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We have improved the characteristics of superconducting thin films by novel methods, which consist of a second laser irradiation method and a pulsed supersonic oxygen fluid shutter method. These novel methods were introduced on the basis of dynamics of the laser ablation and deposition process.

Introduction

The pulsed laser ablation and deposition method have many advantages for thin film fabrication of compound such as oxide superconductor[1-3] and semiconductor[4]. The most profitable feature of the laser ablation and deposition method is that the composition of the thin films is very close to that of target materials.[5]

As reported in a previous paper[6], the ablated fragments consist of four groups of different velocities. Hereafter, they are named as the first, second, third, and fourth components according to their average velocities of $5x10^6$, $1x10^6$, $2x10^5$, and $2x10^4$ cm/sec, respectively. When the thin film was fabricated from all the components, electrical properties were not good, as our expectation. The second laser excitation for third component was found to be effective to improve electrical properties as reported elsewhere.[7,8] Moreover, the second laser excitation for fourth component was also effective to improve electrical properties.

The fourth component can be separated from the others because of the lowest velocity. We succeeded in excluding the fourth component by a new pulsed supersonic oxygen fluid shutter method which was very effective to get good electrical properties of the thin films.

We propose the combination of these methods is a novel method of laser ablation/deposition of $YBa_2Cu_3O_y$.

Results and Discussion

Relation between probe-target distance and the time between the laser pulse and the transmittance dip[6] is shown in Fig. 1. Irradiation of second laser pulses just only for the third component and also the fourth component can be performed when the second laser pulse is delayed 300 nsec and 7 μsec from the first laser pulse, respectively. Time of laser irradiation is indicated in Fig. 1. In this duration, fragments of only purely third component or fourth component can be irradiated with the second laser, leading to excitation and decomposition on these nonradiative components. Second laser irradiation for fourth component was effective to improve the electric properties similar as that for third component. Change of T_c with second laser irradiation for the fourth component is shown in Fig. 2.

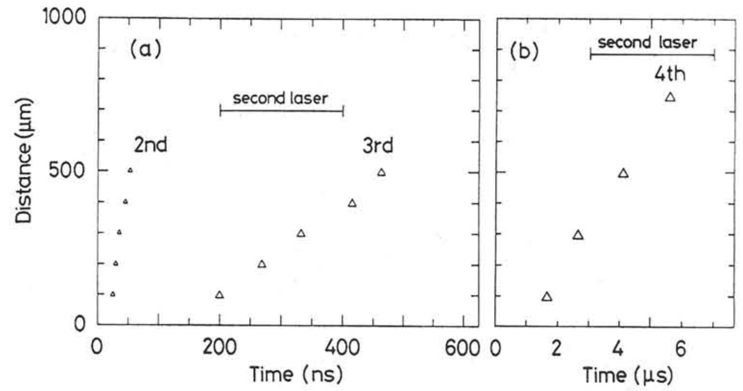

Fig. 1 The relation between probe-target distance and the time between the laser pulse and the transmittance dip.

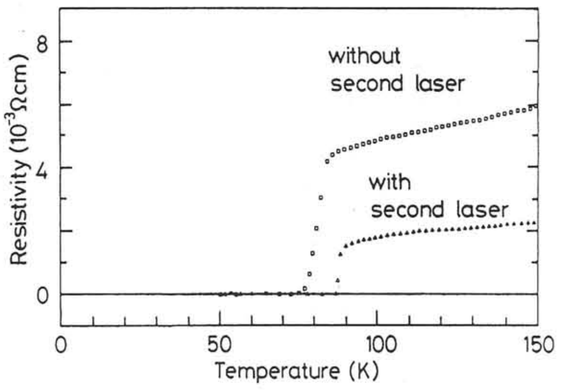

Fig. 2 Resistivity vs temperature for filmed by (a)without second laser and (b)with second laser.

We can prove again the previous report that excitation and/or decomposition of fragments are very effective to improve electric properties of laser ablated film. The average velocity of the fourth component is extremely slower than the other components, so that we have been able to exclude the fourth component by means of the fluid shutter method.

Figure 3 shows a schematic diagram of the experimental set up. Pulsed supersonic valve (PSV) was used as a fluid shutter. The PSV rise time for opening is about 1 μs and gas flow duration is 150 μs. The direction of supersonic oxygen fluid are perpendicular to the flight direction of ablated fragments. The ablated fragments fly through a 2 mm slit of a guide pipe. The supersonic oxygen fluid had already flowed into the guide pipe before the fourth component reached the slit of the guide pipe. The flow direction of the fourth component is changed downward by collisions with high pressure oxygen molecules, and then the fourth component is not able to reach to the substrate.

Scanning electron micrographs of two films (a) without fluid shutter and (b) with fluid shutter which were deposited by the 0.532 μm laser wavelength are shown in Fig. 4. The

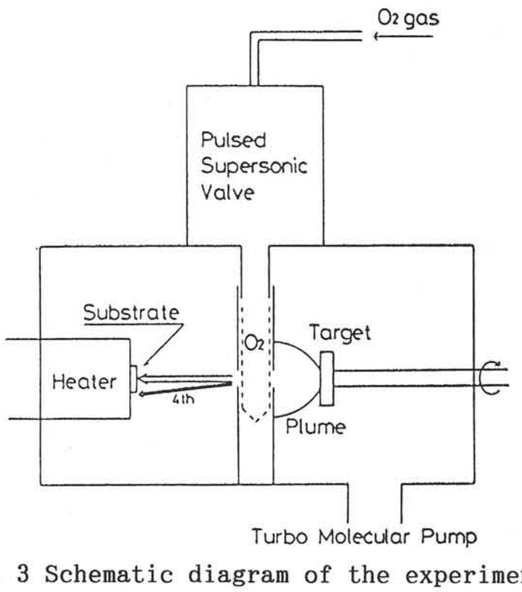

Fig. 3 Schematic diagram of the experimental set up of pulsed supersonic oxygen fluid shutter method.

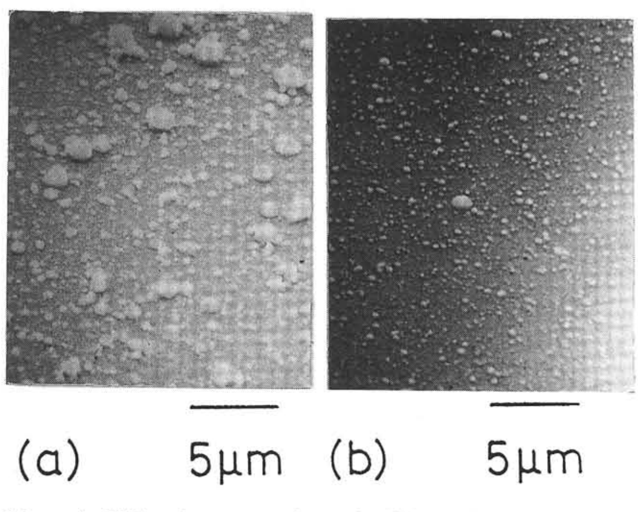

Fig. 4 SEM micrographs of films deposited (a)without PSV shutter and (b) with PSV shutter.

pulsed laser and PSV operate at 10 Hz, and laser energy density was 3 J/cm^2. Deposition experiments were done with an ambient oxygen pressure of 100 mTorr, during operation of the PSV. Many micron order particulates exist on the film as shown in Fig. 4(a), but they almost disappear on the film formed by using the fluid shutter, as shown in Fig. 4(b). Therefore we lead to a conclusion that the fourth component is the origin of micron order particulates. The biggest problem[9] of laser ablation and deposition method will be solved by this method.

Without the fluid shutter, the film shows a T_c of 60 K as shown in Fig. 5(a). On the other hand, with the fluid shutter, the T_c increased to 74 K and the resistivity at the normal state become 1/40 as shown in Fig. 5(b). The pulsed supersonic oxygen fluid shutter method is very useful for fabrication of good superconducting films.

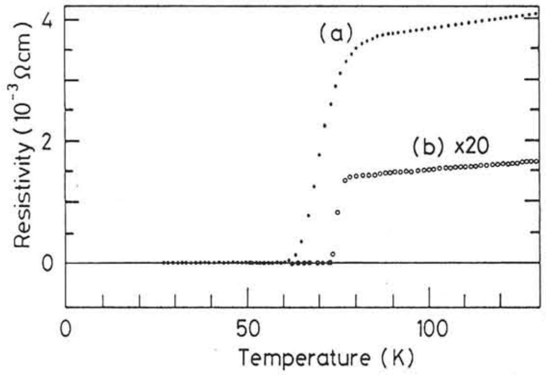

Fig. 5 Resistivity vs temperature for filmed by (a)without PSV shutter and (b) with PSV shutter.

Conclusions

Second laser irradiation for the third and fourth components was very effective to improve electrical properties of laser ablated films.

Exclusion of the fourth component by the pulsed supersonic oxygen fluid shutter method during thin film fabrication results in exclusion of large-size fragments. This is also very effective to improve electrical properties of laser ablated films.

The combination of the second laser irradiation method and the pulsed supersonic oxygen fluid shutter method is expected to be an excellent novel method to fabricate higher quality films.

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