EFFECT OF Nb_2O_5 AND V_2O_5 ADDITION ON THE SUPERCONDUCTING PROPERTIES OF $YBa_2Cu_3O_Y$ THIN FILMS

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ABSTRACT

The effect of Nb_2O_5 and V_2O_5 addition on the superconducting properties and microstructure of $YBa_2Cu_3O_y$ has been studied in thin films. Polycrystalline targets for laser ablation were prepared by mixing high purity V_2O_5 or Nb_2O_5 powders with a well characterized $YBa_2Cu_3O_y$ powder in the range 0 to 4 wt% by solid state reaction method. Thin films (≈1500 A thickness) of the above targets were grown on <100> $SrTiO_3$ (STO) and <100> $LaAlO_3$ (LAO) substrates at 700°C temperature by Pulsed Laser Deposition (PLD) technique. In the case of Nb_2O_5 addition we have noticed an increase in J_c upto 0.5 wt% and higher additive concentration (greater than 0.5 wt%) have degraded the superconducting properties. However, in the case of V_2O_5 addition, there is an improvement in current density and microstructural properties up to 1 wt% and the superconducting properties degrade for concentrations greater than 1 wt%. The best J_c for 0.5 wt% of Nb_2O_5 added YBCO thin film is $1.6x10^6$ A/cm^2 and for that of V_2O_5 added sample is $3.4x10^6$ A/cm^2 at 77K as compared to the pure $YBa_2Cu_3O_y$ (YBCO) film J_c ($1.2x10^6$ A/cm^2) observed on STO substates. The reason for improvement in J_c and microstructural properties in the case of V_2O_5 addition could be due to the low melting of V_2O_5 (690°C) which can act as a very good surfactant during deposition. Over all, we have realized that Nb_2O_5 addition or V_2O_5 addition to YBCO have shown significant improvement over the undoped $YBa_2Cu_3O_{7-x}$ films grown under identical conditions

1. INTRODUCTION

Research in high temperature superconductivity (HTSC) has made significant progress towards improving the microstructural and crystallographic quality of thin films during the last four years [1-3]. Effect of addition or substitution of transition metal elements in YBCO compound has been investigated and it is well established that superconducting properties will be suppressed by substitution at the Copper site by elements like Al, Ag, V, Nb, Ta and more severely suppressed by the substitution of Fe, Co, Ni & Zn [4,5,9]. Also, addition of transition metal elements to YBCO has resulted in similar effects above a certain concentration of additive [6]. Evidences confirm that Nb_2O_5 addition upto 0.5% has resulted in improvement of mechanical, microstructural and superconducting properties of YBCO compound in bulk form [7-8]. It has been stated that Silver plays an important role in improving the microstructural and transport properties [10-11] due to dissociation of Ag_2O on the substrate and the increased mobility of Ag atoms segregating out of the YBCO grains is responsible for the enlargement and alignment of grains in Ag-doped YBCO films. This result has motivated us to study the doping of some oxides which can melt on the substrate at low temperatures to aid the grain growth. In the present study we report the addition effect of V_2O_5 and Nb_2O_5 to YBCO on its superconducting properties.

2. EXPERIMENTAL

Targets for the Laser deposition were prepared by mixing 3N pure V_2O_5 and Nb_2O_5 powders with a well characterized $YBa_2Cu_3O_y$ (YBCO, 99.99% pure) in the concentration range of 0.0 to 4 wt% by solid state reaction method. Thin films of above samples were made using an excimer laser (Lambda Physik 301:KrF,248 nm and 300mm focal length quartz lens for laser beam focussing) [12]. The substrate to target distance was 4.5cm and growth pressure was

200 mTorr oxygen at 700°C substrate temperature and films were deposited in the thickness range 1500-2000 Angstroms. Structural characterization was done using JEOL 8030 XRD powder diffractometer and surface morphology of the films were studied by JEOL 840 scanning electron microscopy (SEM). DC electrical resistivity was measured by using standard linear four probe technique. Critical current density measurements were carried out using laser patterned 40-20 μm wide and 1mm long microbridges. The standard voltage criterion of 1μV/mm was used for determining J_c.

3. RESULTS AND DISCUSSION

a) V_2O_5 DOPED YBCO THIN FILMS :

XRD data has shown c-axis oriented films for 0.5 to 1 wt% V_2O_5 added YBCO thin films. An addition 4 wt% of V_2O_5 has yielded poor quality superconducting thin films (fig. 3) compared to undoped YBCO thin film. Undoped YBCO thin film made under identical conditions has relatively lower T_c(≈89K) and J_c (≈$1.2x10^6 A/cm^2$ at 77K) values. The best results for V_2O_5 doped YBCO thin films were observed for 0.5 wt% addition ($T_{c,o}$ ≈ 89.5K and J_c≈ $3.6x10^6 A/cm^2$ at 77K). Such high Jc values in the case of undoped YBCO thin films could be realized, only at higher deposition temparatures (800°C) on STO<100> substrate [9]. The V_2O_5 doped YBCO thin films deposited on LAO substrate have yielded relatively inferior quality superconducting flims when compared to that deposited on $SiTiO_3$ <100> substrate. The reason for this could be a good lattice match of $SiTiO_3$ with YBCO. We couldn't get any information from scanning electron micrographs as they are featureless which may be due to perfect orientation of grains. It is evident from fig. 3, the slope of the T_c-T vs $\sqrt{J_c}$ plot of V_2O_5 doped films is larger compared to that of undoped YBCO film, indicating grain enlargement and reduction of weak links.

b) Nb_2O_5 DOPED YBCO THIN FILMS :

Our results show that Nb_2O_5 addition upto 0.5 wt% in bulk has improved the superconducting properties of YBCO compound, however, no substantial improvement in the case of thin films deposited even on $SrTiO_3$<100> substrates has been noticed. X-ray diffraction patterns have showed (fig. 1) that films are c- axis oriented YBCO along with growth of <hoo> oriented a secondary phase YBa_2NbO_6 with the increase of $Nb_2O_5 \geq 1$wt%. However, the $T_c \approx 89.1$ and $J_c = 1.6 \times 10^6$ A/cm^2 for Nb = 0.5 wt% doped YBCO thin films have been recorded, degradation of superconducting properties has been noticed with increase in Nb_2O_5 concentration ($\geq$ 1wt%). The slope of $T_c - T$ vs $\sqrt{J_c}$ plot is slightly larger than the undoped YBCO film but smaller than V_2O_5 doped YBCO thin film which indicates that the grain size has not substantially improved when compared with that of V_2O_5 added film.

c) POSSIBLE EXPLANATION :

From the above results it is clear that V_2O_5 addition has improved the quality of YBCO superconducting thin films compared to that of Nb_2O_5 added YBCO thin films on $SrTiO_3$ substrate. Films deposited on $LaAlO_3$ substrates have resulted in poor quality due to the lattice mismatch between substrate and film. However, there is an improvement in J_c of 0.5 wt % V_2O_5 added film compared to that of Nb_2O_5 added and undoped YBCO film. Due to its low melting point, V_2O_5 during growth process may act as a surfactant and aids in better coalition of the individual grain which leads to increase in grain size of YBCO, where as in the case of Nb_2O_5 addition since the melting point is very high such a process does not take place. This is clearly evidenced in the improvement in J_c in the former case. De Gennes [13] and Clarke [14] have predicted a mechanism that near T_c the critical current density of S-N-S junctions can be expressed as

$$J_c(T) \alpha \ (T_c - T)^2 \exp(-d/\xi_n)$$

Where d is the thickness of the the grain boundary layer and ξ_n is the coherence length. From this equation the nature of grain boundaries in doped and undoped YBCO thin films can be studied by plotting $T_c - T$ vs $\sqrt{J_c}$ and the slope of this plot will decide the grain boundary domain thickness which in turn reflects on the nature of weak links. We have plotted T_c-T vs $\sqrt{J_c}$ values upto 77K for the sake of comparison in the cases of 0.5 wt % added V_2O_5 and Nb_2O_5 and undoped YBCO film. From fig.2, it is evident that V_2O_5 addition yields a larger slope value compared to Nb_2O_5 doped and undoped YBCO thin films, which is indicative of improvement in grain structure.

CONCLUSIONS

The effect of V_2O_5 and Nb_2O_5 addition on the superconducting properties of YBCO thin films is studied. It has been realized that V_2O_5 can act as a very good surfactant than Nb_2O_5 because of its low melting point. Also, it is found that there is an improvement in the J_c of the 0.5 wt% V_2O_5 doped YBCO thin film compared to that of Nb_2O_5 (0.5 wt %) doped and undoped YBCO thin films. This could be due to the surfactant effect of V_2O_5 which melts at relatively low temperature and improves the grain structure. On the other hand, the addition of Nb_2O_5 (which has high melting point) does not show such improvement.

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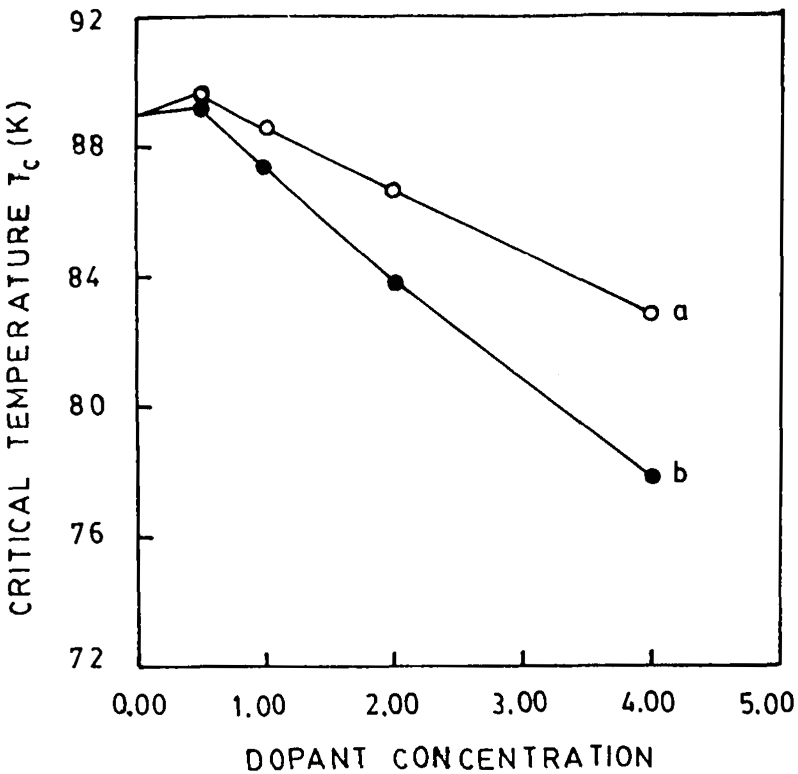


Fig.1. Dopant conc. vs. T_c plots for
(a) V_2O_5 doped YBCO thin film
(b) Nb_2O_5 doped YBCO thin film

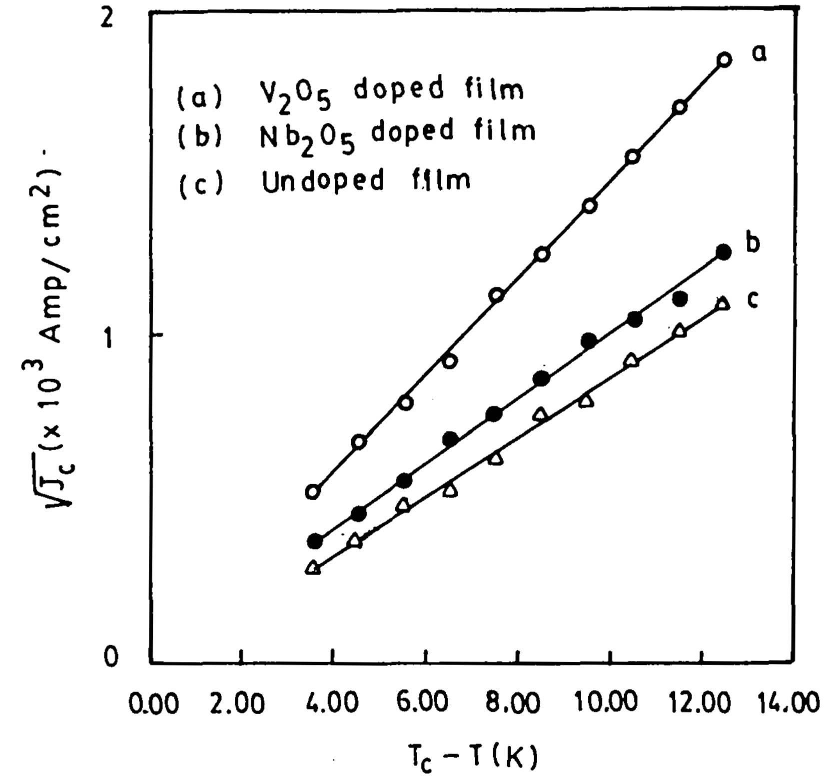


Fig.2. $\sqrt{J_c}$ vs (T_c-T) plots for undoped, V_2O_5 doped and Nb_2O_5 doped YBCO films grown at 700°C on $SrTiO_3$ <100> Substrate.

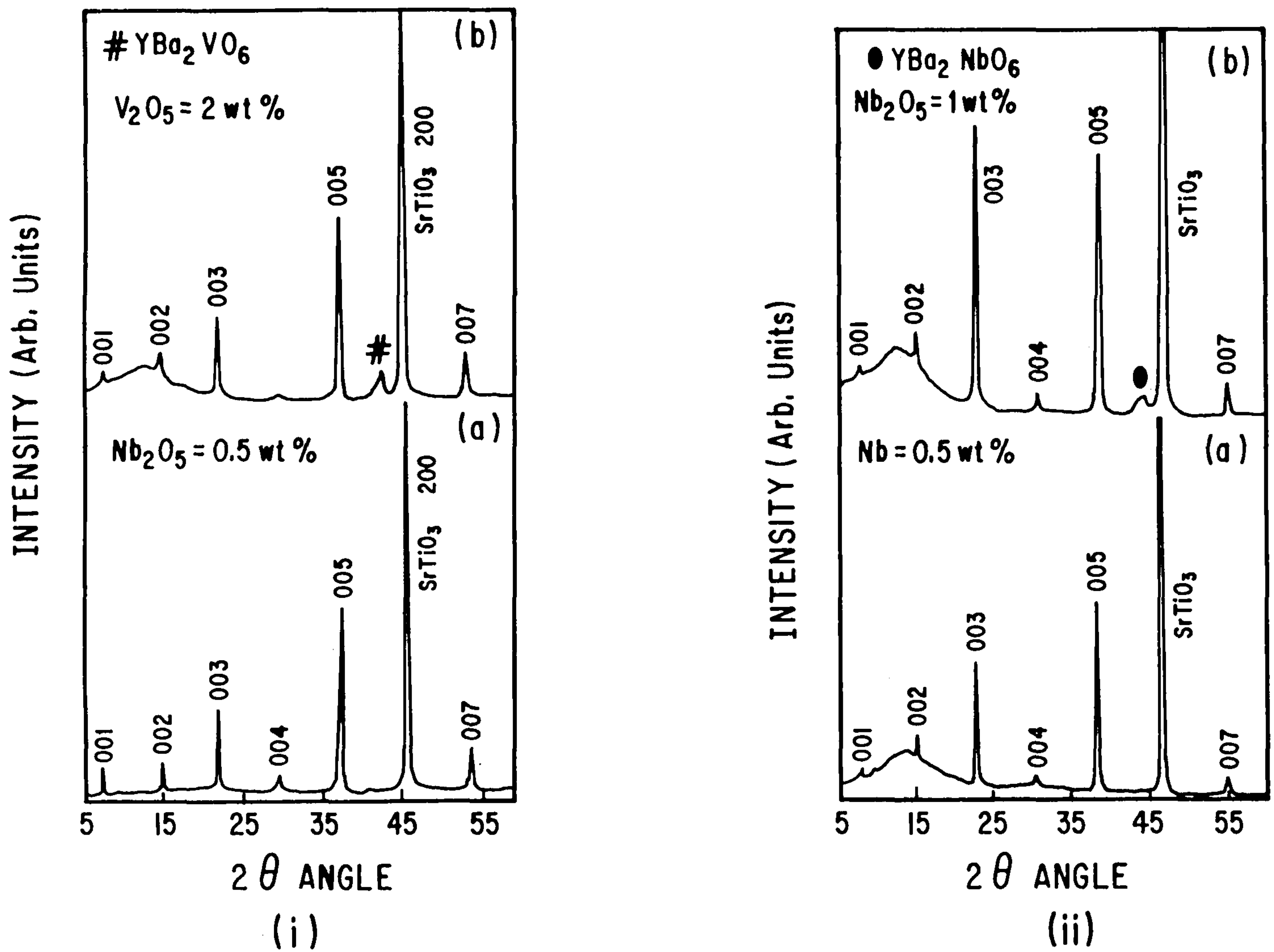
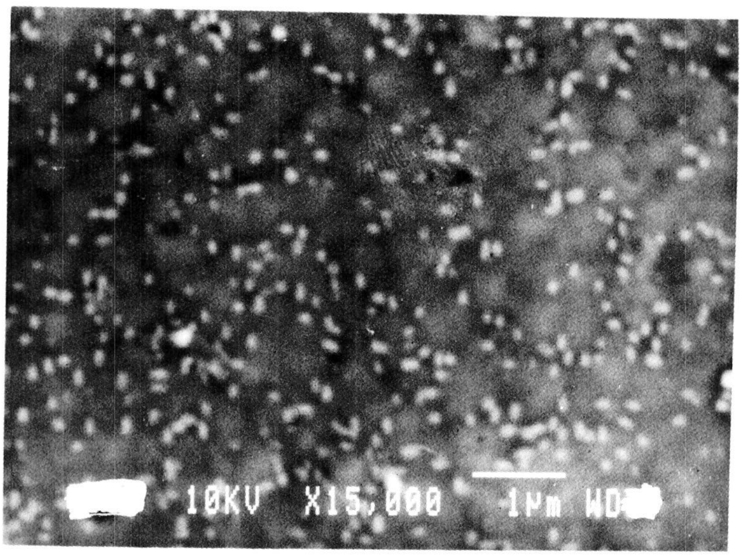


Fig.3. Xrd Patterns of (i) V_2O_5 (ii) Nb_2O_5 added YBCO Thinfilms.

(A)



(B)

Figure 4.- Scanning Electron Micrograph for (A) V_2O_5 and (B) Nb_2O_5 doped YBCO thin film.