INFLUENCE OF STRONG DISORDER ON SUPERCONDUCTIVITY OF MgB_2 THIN FILMS

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Abstract

We investigated the influence of disorder on superconductivity of MgB_2 films, prepared in a single deposition run onto two different substrates: (100)-MgO and on (128° rot)-$LiNbO_3$ with trigonal crystal structure which does not match to the MgB_2 structure. As expected, the microstructure of both films crucially differs. The REM study shows a very homogeneous, smooth morphology of the MgB_2 film on MgO, but a very rough inhomogeneous film structure on $LiNbO_3$. Although the MgB_2 film on $LiNbO_3$ is strongly disordered, its critical temperature $T_c=33.5\ K$ is practically the same as for the film deposited on MgO. Possible reasons of such unusual T_c behavior are discussed.

Introduction

The recent discovery of superconductivity in MgB_2 raised questions about the origin and peculiarities of the superconducting state in this compound. MgB_2 exhibits a hexagonal crystal structure with boron planes separated by magnesium layers [1], strongly influencing their superconducting properties [2]. Thin films with a high quality crystal structure and a smooth surface are the basis of microelectronic applications. Unfortunately, Mg is highly volatile and easily reacts with ambient materials, so that the deposition of high-quality MgB_2 thin films has proven to be very difficult. Two-step *ex-situ* techniques, which require Mg diffusion into precursor films at high temperatures, have been quite successful in growing films with high T_c and preferentially oriented grains. However, the surface quality for microelectronic-device applications is still far from being achieved.

The dc-magnetron sputtering is a well developed method to obtain films with smooth surface and suitable microstructure. In the present paper we report about the growth and properties of high-quality films prepared by this technique.

Sample preparation

Samples were grown by a two-step process using dc-magnetron sputtering from a Mg-MgB_2 composite target. Before sputtering a target has to be prepared. To generate the MgB_2 phase during the film deposition and to provide sufficient target conductance for the dc-sputtering, a composite target was used containing MgB_2 and pure Mg in approximately equal amounts. The Mg-MgB_2 target was sputtered in a 99.999% purity argon atmosphere at a pressure of 3 Pa. The deposition rate was about 1.3 nm/s. The substrate temperature was held at 200 °C during 15 min and then increased up to 600 °C. Next, the films were annealed in a saturated Mg vapor atmosphere during 1 hour *ex-situ*. The annealing was performed at 850 °C in Ta envelope, placed inside an evacuated quartz tube. The procedure of MgB_2 film preparation is described in detail in [3, 4].

The films were deposited on two different substrates: (100)-MgO and (128° rot)-$LiNbO_3$ with trigonal crystal structure, the latter not matching to the MgB_2 structure. The thickness of the films was about 3 μm. The resistivity was measured by a standard four-probe technique using Cu wires soldered with In.

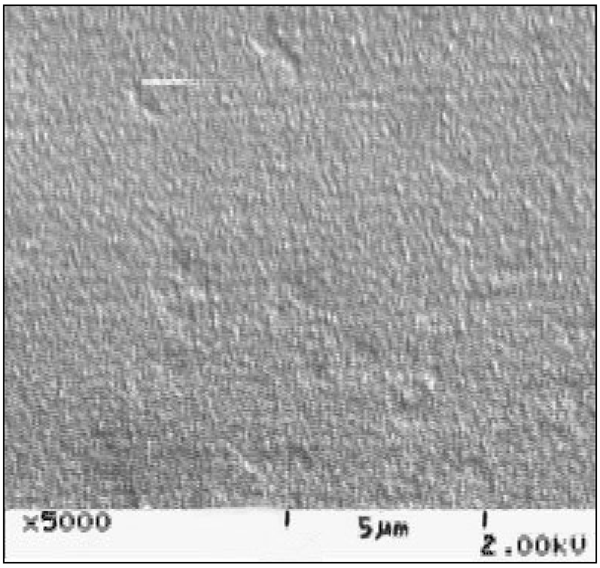

Fig. 1. REM image of MgB_2 film deposited on MgO substrate.

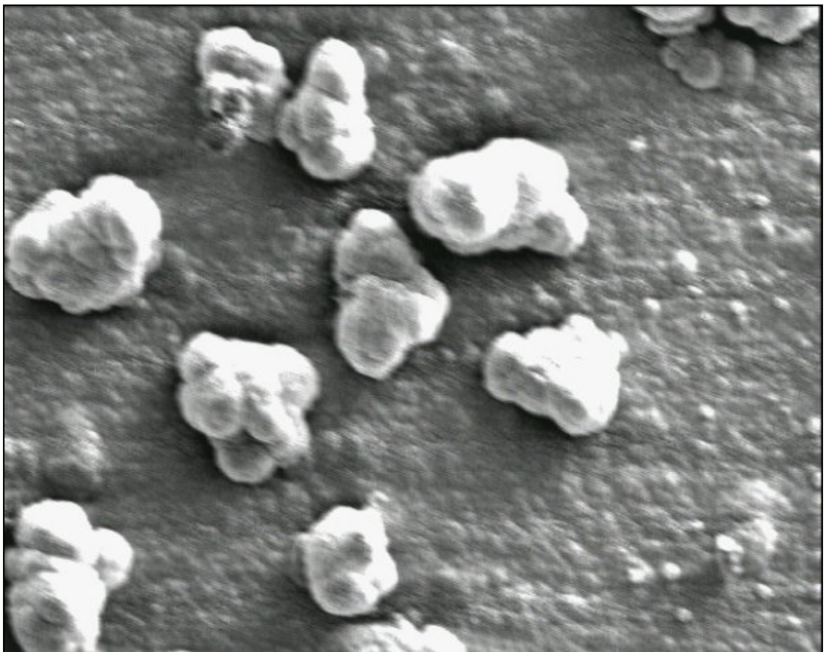

Fig. 2. REM image of 3 μm thick MgB_2 film deposited on $LiNbO_3$ substrate.

Results and discussion

The elementary analysis (EDX) was made for all prepared films. The EDX spectra for one of the samples, prepared on $LiNbO_3$ substrate, are shown in Fig. 3 and demonstrate the absence of ambient contaminations in prepared film.

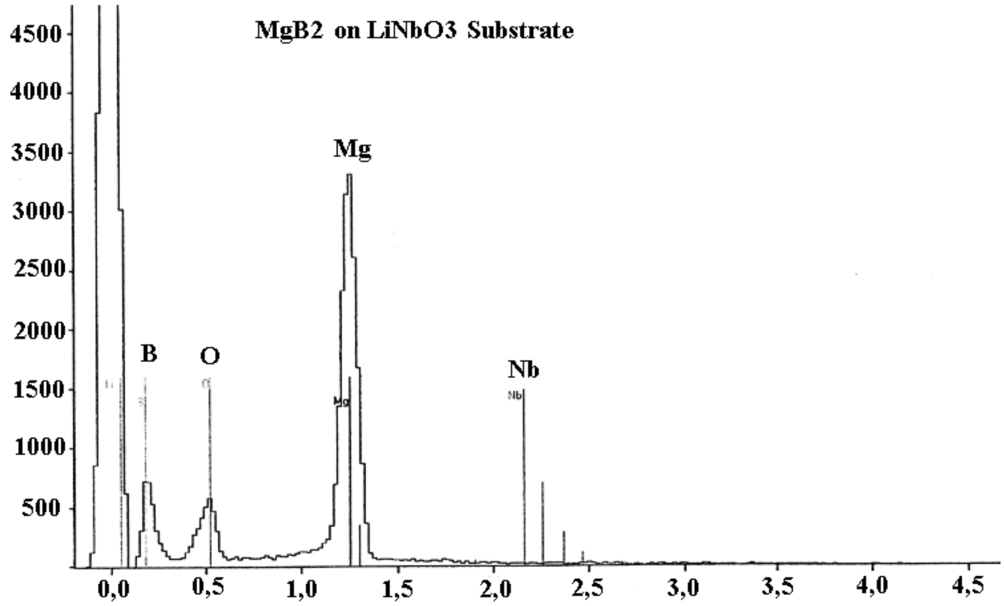

Fig. 3. EDX spectrum for 3 μm thick MgB_2 film deposited on $LiNbO_3$ substrate.

Resistive measurements, performed in the temperature range 300-10K in "Quantum Design" cryosystem, demonstrate a sharp transitions R(T), as shown in Fig. 4. Specific resistance of the MgB_2 film on $LiNbO_3$, $\rho_n = 4.6 \cdot 10^{-4}$ Ohm·cm, is higher by a factor of ~10 than ρ_n for MgB_2 film of better quality on MgO substrate. The ratio R_{300}/R_{Tc} was 1.5 for film on MgO and 1.13 for film on $LiNbO_3$. As one expected, the microstructure of both films, crucially differs. REM study detected a very homogeneous, smooth morphology of the MgB_2 film, deposited onto MgO (Fig. 1), but very rough inhomogeneous film structure on $LiNbO_3$ (Fig. 2).

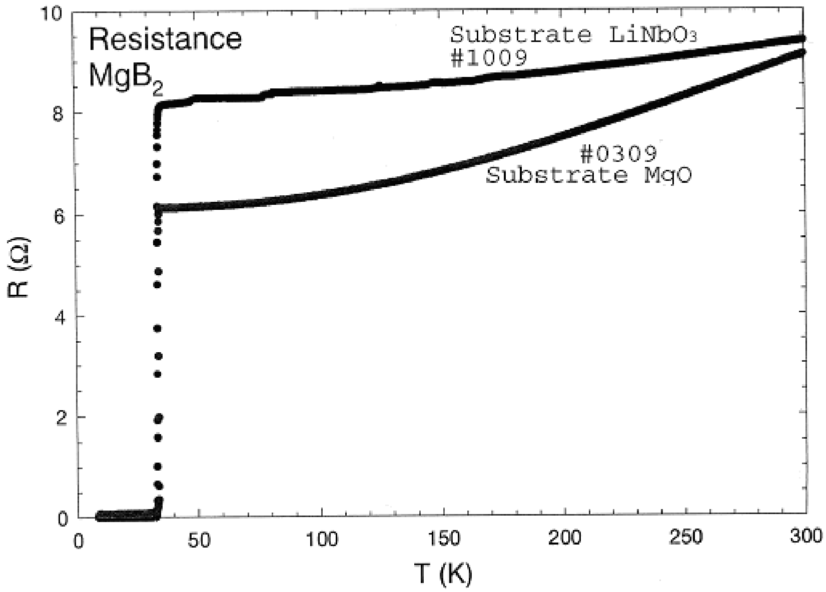

Fig. 4. Resistive curves for MgB_2 films on MgO and $LiNbO_3$ substrates.

These experimental data evidence strong disorder of the film on $LiNbO_3$. Apparently, the films were formed by two different mechanisms of growth. In spite of strong disorder of the MgB_2 film on $LiNbO_3$, its critical temperature $T_c = 33.5K$ is the same as for the film deposited on MgO (Fig. 4) although with some broadening of superconducting transition. This phenomenon seems to be unexpected, because the critical temperature for most superconductors crucially depends on quality of the films; disorder and strains in superconducting films usually suppress their T_c. The similar independence of T_c on disorder and presence of impurities was observed only for Pb. This phenomenon may be one of peculiarities of the superconducting state of the multiband-superconductor, MgB_2, and needs further investigation.

Acknowledgements

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