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Superconducting properties of $LuNi_2B_2C$ films and junctions

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$LuNi_2B_2C$ films have been prepared by a Pulsed Laser Deposition technique. The deposition parameters have been optimized to reach good superconducting, structural and morphological properties with high reliability. In order to deposit different patterned layers for in-situ junctions production, a special set-up for the in situ interchanging of shadow masks has been developed. We studied the growth of different materials to be used as barrier layers. New results on the temperature dependence of the $LuNi_2B_2C$ gap using S/N contact junctions are presented and discussed.

1. INTRODUCTION

On the route of discovering new superconductors, the finding of the intermetallic compounds of the class RE-Ni_2B_2C (borocarbides, RE=rare earth) [1] can be considered one of the main events of the last years in the field. Though many measurements indicate an overall conventional BCS behavior for these materials, the occurrence of a square symmetry of the vortex lattice, found at low temperatures and high fields both by neutron scattering [2] and STM imaging techniques [3] has suggested the possibility of d-wave symmetry of the order parameter [4].

This paper reports on preliminary results of a research aimed to realize high quality planar junctions based on borocarbide thin films in order to perform both tunnel spectroscopy and Josephson effect experiments to clarify the nature of superconductivity in these compounds.

2. EXPERIMENTAL

$LuNi_2B_2C$ thin films are prepared using a Pulsed Laser Ablation (PLA) deposition system in high vacuum condition [5] from a stoichiometric target. Different parameters have been explored to optimize the properties of $LuNi_2B_2C$ thin films grown on (001) MgO substrates. Fig.1 shows the dependence of the transition temperature from the deposition temperature and the $T_c$vs RRR (residual resistivity ratio). Resistivity measurements give, for the best samples, an onset critical temperature T_c=16.1 K, with ΔT_c=0.3, and RRR=13, not far from high quality single crystal sample results [6].

The samples were deposited varying the target-substrate distance from 1cm up to 4cm using a laser energy density of 2-8J/cm^2 at a pulse rate ranging from 4Hz up to30Hz. The film thickness was between 300Å and 6000Å. Low density energy (2-3J/cm^2), high pulse rate (30Hz) and small target-substrate distance (1.0-1.5cm) gave the good superconducting and morphological properties required for this application. AFM analyses confirm

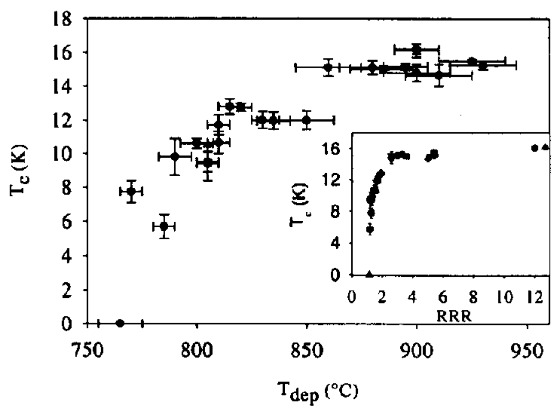

Figure 1. Critical temperature vs deposition temperature and (inset) T_c vs RRR for $LuNi_2B_2C$.

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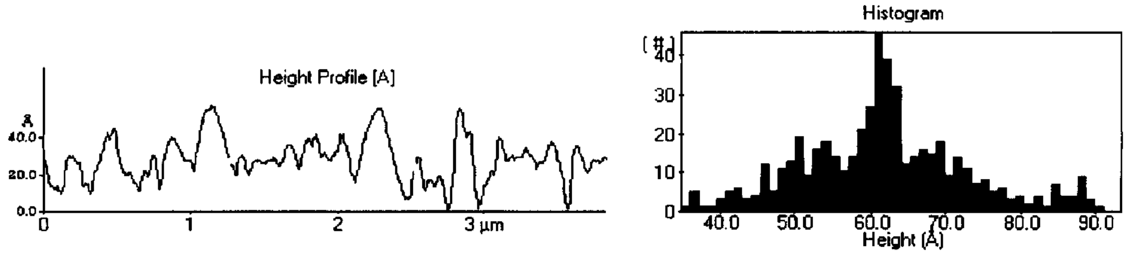

Figure 2. Profile of an AFM scan (left) and distribution of the height (right) of a $LuNi_2B_2C$ film.

that the surface is free of particulate and the surface roughness is about 15-20 angstrom, as shown in the profile reported in fig.2. X-ray diffraction measurements reveal in all cases a dominant c-axis orientation with a misorientation less than 1°.

To produce planar junctions we have developed a special set-up for the in situ interchanging of tantalum shadow masks. With a multitarget rotating carousel, we can deposit different patterned layers sequentially without breaking the UHV conditions and preserving the quality of interfaces. In situ cross-type junction geometry (cross-section about 100µmx100µm) can be produced without using photolithography, which reduce the quality of interfaces. $LuNi_2B_2C$ bottom layer and the barrier were in-situ deposited, while the upper layer is a narrow stripe of lead evaporated in a following stage. For each deposited base film we prepared samples with barrier of different materials and thickness. MgO, Al_2O_3, CeO_2 were grown at a temperature of about 600°C in high vacuum and in a oxygen pressure of 10^{-6}mbar.

3. RESULTS

Preliminary I-V measurements indicate an insulating behavior of MgO and CeO_2 barriers, but junctions of sufficient quality were not obtained. On the contrary junctions with Al_2O_3 barriers exhibited pinholes and were frequently shorted. Occasionally, however, the junctions exhibited a clean and stable S/N interface behavior at temperatures T> T_c of the Pb counterelectrode. A typical I-V curve is reported in the inset of Fig. 2. The I-V curves and their numerical derivatives were well described by the standard BTK theory [7]. From the conductance minima the value of the superconducting gap Δ for $LuNi_2B_2C$ was obtained. Fig 3 shows the temperature dependence of Δ which agrees very well with the BCS prediction. The extrapolated value of Δ_0 = (2.0±0.1) meV, obtained by fitting the experimental data, leads to $2\Delta_0/kTc = 3.0 \pm 0.2$ in agreement with STM results [3] but in contrast with previous determination of Δ(T) of $LuNi_2B_2C$ by point-contact spectroscopy [8] as well as with the prediction of the pair-breaking model [9].

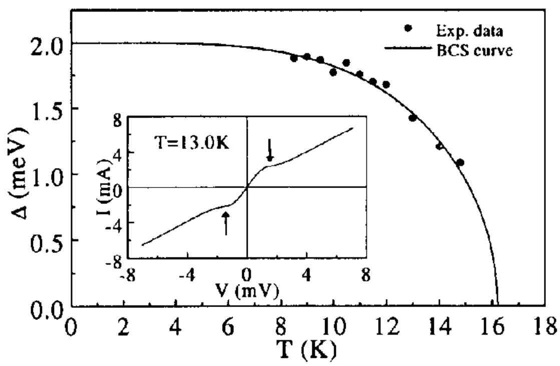

Figure 3. $LuNi_2B_2C$ gap as a function of the temperature together with the theoretical BCS curve (solid line). Inset: typical I-V curve recorded at T=13.0K. The arrows show the gap value.

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