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Investigation of the Upper Critical Magnetic Field and Activation Energy in MgB_2 Thin Film

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Abstract MgB_2 film with a thickness of about 600 nm was deposited on the MgO (100) single crystal substrate using a "two-step" synthesis technique. First, deposition of boron thin film was carried out by rf magnetron sputtering on MgO substrates and followed by a post deposition annealing at 850 °C in magnesium vapor. The upper critical field H_{c2} has been estimated from temperature dependences of resistivity curves in both directions of the magnetic fields perpendicular and parallel to the c-axis. Resistivity measurements of the film were performed using a standard four-probe method under different magnetic fields up to 70 kOe in zero fields cooling regime. The upper critical magnetic field $H_{c2}(0)$ at $T = 0$ K for 90 % of R_n was calculated by the extrapolation $H_{c2}(T)$ to the temperature $T = 0$ K. The results showed that $H_{c2} \parallel ab(0)$ and $H_{c2} \parallel c(0)$ was found to be around 22 T and 18 T, respectively. Using extracted data, the zero-temperature coherence lengths and field anisotropy ratio were calculated. In order to determine the activation energy of thermally activated flux flow of the film, Arrhenius law was taken into account.

Keywords MgB_2 thin film · Upper critical field H_{c2} · Anisotropy ratio · Coherence length · Activation energy · MgO substrate

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1 Introduction

Since the discovery of superconductivity in binary MgB_2 compounds, extensive studies have been carried out because of its excellent properties for technological applications, such as high transition temperature ($T_c = 39$ K) [1], high upper critical field (H_{c2}) [2, 3], high critical current density (J_c) [4, 5]. The upper critical magnetic field H_{c2} in superconductors is important factor since they give the most direct information about the microscopic parameters like the superconducting coherence length and its anisotropy within the superconducting state. MgB_2 displays less anisotropy and larger coherence length than the high-T_c superconductors. The anisotropy degree of MgB_2 is still unresolved, reports giving values ranging between 1.1 and 9 [6–9]. The impact of two band nature on critical parameters like upper critical field, H_{c2}, is needed to be investigated in MgB_2.

Broadening of superconducting transition in the presence of a magnetic field for MgB_2 thin films was investigated by Sidorenko et al. [10]. Several different reasons were discussed for broadening of superconducting transition in the presence of a magnetic field. TAFF (thermally activated flux flow or flux creep) mechanism from broadening of superconducting transition is more responsible than the other reasons. In a type-II superconductor in the mixed state, the flux lines are fixed at "pinning centers," i.e., for example, at defects or impurities. The main mechanism for the flux creep, which broadens the resistive transition in a magnetic fields, is the thermal activated motion of flux-lines over the energy barrier, U_0, of the pinning center. The layered structure of MgB_2 is likely to influence the fluxoid motion leading to a resistive transition broadening similar to high-T_c superconductors [10]. Although the activation energy of the thermally activated flux flow (TAFF) for MgB_2 is significantly higher than that of HTS, TAFF is still detectable through the resistivity temperature curves for different applied fields [11].