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Temperature dependence of conduction noise of MgB_2 superconductor

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Abstract

Temperature dependent behavior of conduction noise of MgB_2 superconductor has been studied. The frequency spectrum of conduction noise shows $1/f^{\alpha}$ type of behavior, with $\alpha = 0.7$–0.8. Temperature dependence of conduction noise is found to exhibit two peaks at ~26 K and ~38 K respectively. The peak at ~38 K is attributed to movement of vortices and due to fluctuation in resistance from change of state from superconducting to normal state. The peak in the conduction noise at ~26 K is ascribed to the movement of vortices due to enhanced thermally activated vortex hopping. The analysis of enhanced conduction noise in the low temperature region indicates the presence large density of fluctuators with activation energies around 0.048 eV.

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Keywords: MgB_2 superconductor; Conduction noise; Vortex dynamics

1. Introduction

Since the discovery of superconductivity in MgB_2 at transition temperature, T_c ~39 K [1], this binary intermetallic superconductor has become most studied superconductor. The studied aspects include critical current density [2,3], nature of grain boundaries [4–6], energy gaps [7] and vortex dynamics [8–14]. The relatively high upper critical field (~18T) [8] of polycrystalline MgB_2 superconductor is a very interesting feature of this superconducting material. The vortex dynamics in the MgB_2 is very interesting and has been attracting lot of attention [8–14]. An unusual behavior in magnetic relaxation was found in MgB_2 superconductor [9]. Fluctuation in M–H loop at temperature below T_c was also observed, which was attributed to flux jumps [10]. The occurrence of vortex avalanche effect has also been noticed at ≈15 K in MgB_2, which lowers the critical current density [11]. The deposition of Au film on the MgB_2 films has been found to improve critical current density by avoiding the occurrence of avalanche effect [11]. Magneto optical studies on MgB_2 samples have shown the appearance of turbulence structure occurring in MgB_2 at the abrupt dendritic flux penetration well below T_c [12]. Mumtaz et al. [15] have noted unusual noise in the magnetization relaxation in MgB_2 superconductor, which was attributed to presence of highly unstable vortex pattern at low temperature and low field.

Conduction noise is another versatile technique to explore the kinetics of vortices in superconductors and it has been used by several workers for investigating high-T_c superconductors [16,17]. Recently, conduction noise measurement has been used for studying the vortex avalanche phenomena in MgB_2 at 4.2 K [18,19], where a peak in frequency spectrum was found in the presence of magnetic field that was attributed to vortex–antivortex annihilation. Kim et al. [20] have used voltage noise characteristics along with current–voltage characteristics to investigate dynamic vortex property of MgB_2 near the

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peak effect region. Temperature dependence of conduction noise in MgB_2 superconductor has not yet been reported, which can provide more information on the dynamics of trapped vortices and the superconducting transition in MgB_2. The present paper reports the temperature dependence of conduction noise for investigating the vortex dynamics of polycrystalline MgB_2 superconductor. Temperature dependence of conduction noise shows two peaks at ~26 K and ~38 K, which are attributed to enhanced thermally activated vortex hopping and change in superconducting to normal state transition respectively.

2. Experimental

MgB_2 bulk sample was prepared using commercially available MgB_2 powder (99% Alfa Aesar, Johnson Mathey) and sintering it in Rf induction furnace. The MgB_2 powder was ground thoroughly in a dry box and the powder was palletized at a pressure 3.0 tons/inch^2. The MgB_2 pellets along with a pellet of pure Mg powder was kept in graphite crucible and inserted into silica tube. Argon gas was flown in the silica tube during the sintering and cool down duration. The sintering was done in Rf induction furnace (12 kW) at 950 °C for 10 min and then Rf power was switched off. The sample was left in silica tube in the flowing Argon to cool down to room temperature. The details of sample preparation are described elsewhere [21]. The X-ray diffraction studies confirmed the phase purity of MgB_2. The lattice parameter of the sample was found to be $a = 3.085$ Å and $b = 3.515$ Å. The resultant MgB_2 sample was polycrystalline with grain size ~1 μm. The superconducting transition temperature was determined by the temperature dependence of resistance (R–T) and by the ac susceptibility measurements. Standard four-probe technique was used for the R–T measurement. For ac susceptibility measurement, an ac signal of 491 Hz was applied.

Conduction noise of the sample was measured by four-probe technique. Fig. 1 shows the schematic diagram of the conduction noise measurement. A 1 mA current was passed through the sample by a battery operated low noise current source. The voltage signal was dc filtered and amplified by a low noise preamplifier and detected by a dynamic signal analyzer (DSA), which performs rms averages of fast Fourier transform (FFT) of the input signal.

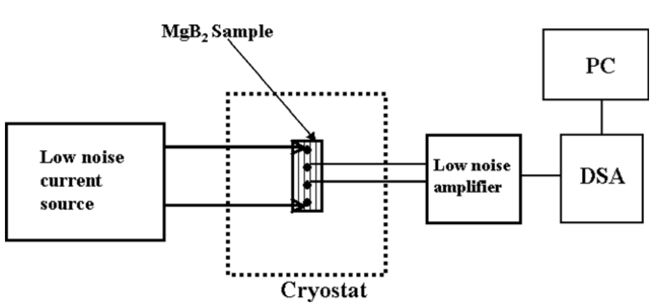

Fig. 1. Schematic of set up for conduction noise measurement.

The measurement was carried out in the temperature range of 4.2–45 K and frequency range of 1.5–40 Hz. The background noise of experimental set up was 1×10^{-15} V^2/Hz.

3. Results and discussion

Fig. 2 shows variation of resistance of MgB_2 sample with temperature. The figure shows metallic behavior of the sample before the superconducting transition. The onset and end point transition are 39 K and 38.5 K respectively that indicates the transition temperature of ~39 K. AC susceptibility of MgB_2 as a function of temperature is shown in Fig. 3. The curve also indicates the transition temperature ~39 K.

Fig. 4 shows the frequency spectrum of noise power spectral density ($\sqrt{S_v}$) at different temperatures of MgB_2 superconductor in the frequency range of 1.5 Hz to 40 Hz. The conduction noise typically shows $1/f^{\alpha}$ type of behavior, with $\alpha = 0.7$–0.8. The temperature dependence of conduction noise with temperature is also evident from the frequency spectrum. In order to see the temperature dependence of conduction noise more clearly, we have plotted the variation of noise power spectral density ($\sqrt{S_v}$) at

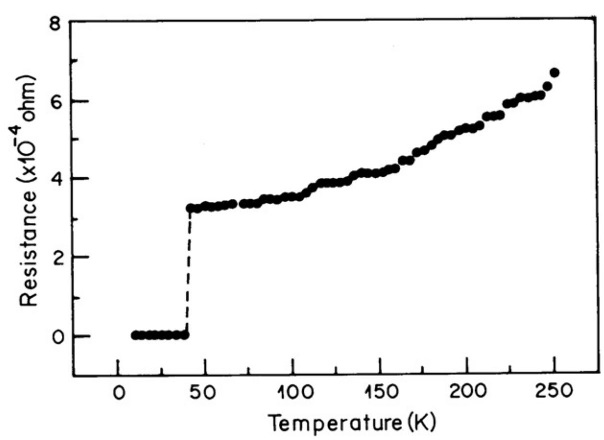

Fig. 2. Temperature dependence of resistance of MgB_2 sample.

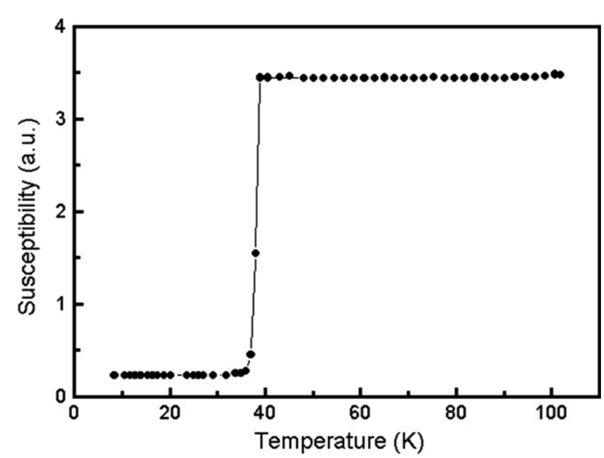

Fig. 3. AC susceptibility versus temperature curve for MgB_2 sample.