

Persistent Supercurrents in MgB₂

J.P.Franck,J.Jung,M.Abdelhadi ^{a,1},

^a*Department of Physics, University of Alberta, Edmonton AB, Canada T6G 2J1*

Abstract

Persistent currents were induced in rings of superconducting granular MgB₂. We measured the magnetic self-fields generated by these currents using a scanning Hall probe. We obtained both the temperature dependence of the persistent current at the critical level between 15K and T_c (39K) and the time decay of the persistent current for up to 10^5 sec. The time decay for this time interval is less than 1% at temperatures between 15K and 35K. This rate is much smaller than that observed in high critical current rings of YBCO thin films, which is about 10% at 15K.

Key words: MgB₂ ;persistent current; magnetization; magnetic relaxation

Recently discovered binary metallic superconductor MgB₂ with a transition temperature of 39K [1] is a potential material for superconducting solenoids in a persistent mode, since its T_c is 2-4 times higher than those of conventional metallic superconductors like Nb₃Sn or Nb - Ti, and its critical current density reaches high values [2]. We investigated properties of persistent (self-supporting) currents circulating in a ring-shaped samples of MgB₂. Persistent current flowing in a ring generates its own magnetic field (self-field). The magnitude of the axial component of the self-field B_z (parallel to the axis of the ring) has a maximum value on the ring's axis and drops gradually with an increasing radial distance r from the center of the ring. Spatial distribution of $B_z(r)$ resembles "bell-shaped" curve, and can be measured above the ring with a scanning Hall probe. On the other hand, if the ring is cut, the Hall probe detects only the field generated by the vortices trapped in the bulk of the ring. In this case $B_z(r)$ exhibits two maxima above the ring's bulk and a minimum at the ring's center. Time decay (dissipation) of the persistent current equals that of the persistent current's self-field [$B_z(r)$ is proportional to the current I , according to the Biot-Savart law], and therefore it can be measured directly with the Hall probe.

We studied persistent currents as a function of temperature, magnetic field, and time in granular MgB₂ rings (of outer and inner diameters, 8mm and 5mm, respectively, and approximately 1mm thick). MgB₂ was prepared by rapid reaction of stoichiometric quantities of powdered amorphous boron and magnesium. The samples show very clean powder x-ray diffraction patterns with all major MgB₂ peaks the same as those observed in [1]. T_c as determined by resistivity and susceptibility measurements is about 39K, and the resistive transition width is 0.23K (10 – 90%). A scanning electron microscope revealed that the size of the crystal grains is within the range between 0.15 and 0.30 μm . MgB₂ used to prepare the ring shows a large zero-field-cooled (ZFC) magnetic moment, but a small Meissner (field-cooled) moment due to strong magnetic flux pinning.

Persistent current was generated in a ZFC ring at a fixed temperature by applying an external magnetic field parallel to the ring's axis (using a copper-wound solenoid) and subsequently switching this field off. An axial component of the persistent current's self-field $B_z(r)$ was measured for different applied magnetic fields (see Fig.1). $B_z(r)$ at the ring's center increases with an increasing applied field, and at high enough fields $B_z(r)$ saturates. The saturation value of $B_z(r)$ corresponds to the critical value of the persistent cur-

¹ E-mail:franck@phys.ualberta.ca

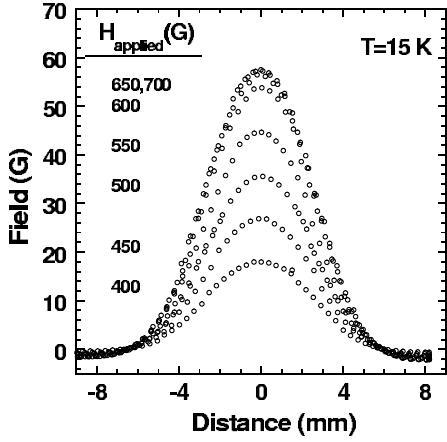


Fig. 1. The axial component of the self-field of the persistent current B_z , measured at a height of 2.5mm above the ring, as a function of the radial distance from the ring's axis. Persistent current at 15K has been induced by applying a magnetic field along the ring's axis and subsequently switching this field off. Critical current value is reached after applying fields above 650G.

rent I_c . The dependence of I_c on temperature (see Fig.2) resembles that of granular YBCO rings [3].

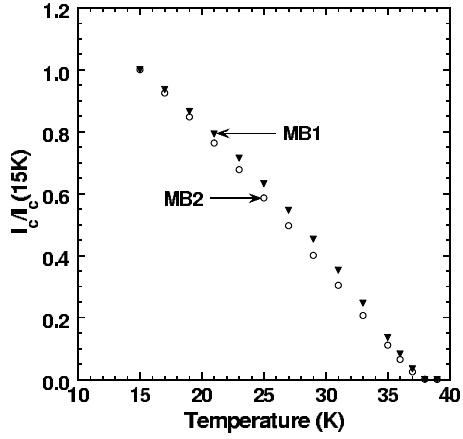


Fig. 2. Temperature dependence of the critical current for two rings of MgB_2 .

Time decay of the persistent current $I(t)$ from its critical value was obtained over a temperature range between 15K and 37K, from the measurements of the time decay of the self-field $B_z(t)$ (see Fig.3). At temperatures between 15K and 35K, the time decay of I is less than 1% of the initial value I_c for a time interval up to 10^5 seconds. For YBCO thin film rings of high $J_c \simeq 10^7 A/cm^2$ at 15K, the time decay at this temperature reaches 10% of the initial value after waiting 10^5 seconds [4].

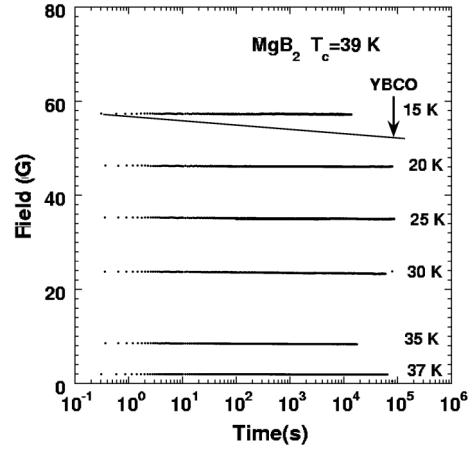


Fig. 3. Time-decay of the persistent current from the critical value measured at temperatures between 15K and 37K. Thin solid line: time-decay of the persistent current at 15K in a ring-shaped YBCO thin film with $J_c \simeq 10^7 A/cm^2$.

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