Magnetization and irreversibility field in powdered MgB_2 superconductor

Tadahiro Akune [a,1], Hiroyuki Abe [a], Nobuyoshi Sakamoto [a], Yasukuni Matsumoto [b,c]

[a] *Department of Electrical Engineering, Kyushu Sangyo University, 2-3-1 Matsukadai, 813-8503 Fukuoka, Japan*

[b] *Department of Electrical Engineering, Fukuoka University, 8-19-1 Nanakuma, 814-0180 Fukuoka, Japan*

[c] *Advanced Materials Institute, Fukuoka University, 8-19-1 Nanakuma, 814-0180 Fukuoka, Japan*

Abstract

Magnetizations and AC susceptibilities were measured on powdered new superconductor MgB_2 using a SQUID magnetometer and a PPMS susceptometer at temperature range $4.5 - 40$ K under DC magnetic fields up to 14 T. Particle diameters d of powdered MgB_2 specimens are $20 < d < 30$ μm (MgB_2-20) and $50 < d < 63$ μm (MgB_2-50). Magnetization curve for MgB_2-50 sample is symmetric and larger than that for MgB_2-20 sample. The irreversibility fields are determined by the width of magnetization curves and the imaginary parts of the AC susceptibilities. Temperature dependence of the irreversibility field almost agrees for both powder samples and is smaller than that of oxide superconductors. In addition these characteristics are also discussed by comparing with the flux creep theory.

Key words: MgB_2; magnetization; AC susceptibility

1. Introduction

The recent discovery of the binary metallic MgB_2 superconductor [1] with high transition temperature T_c of 39 K has attracted great scientific interest. This material with the strongly linked nature of inter-grains is expected to be a very promising candidate for practical application [2,3]. The irreversibility field B_{irr} is one of the important parameters to characterize a superconducting material. Thus it is important to investigate the magnetic properties and the irreversibility field for practical applications in this new material with its metallic and simple composition.

In this paper we report the irreversibility field obtained from the magnetization widths and AC susceptibilities of powdered MgB_2 with different particle dimension.

[1] Corresponding author. Fax: +81-92-673-5091, E-mail: akune@te.kyusan-u.ac.jp (T. Akune)

2. Experimental

Commercial MgB_2 powder (Alfa Aesar Co., 98% purity) was ground in an agate mortor and were divided into two samples with different particle size d (μm) by sieves with several mesh sizes : $20 < d < 30$ μm (MgB_2-20) and $50 < d < 63$ μm (MgB_2-50). These powders were fixed in epoxy resin. Magnetization and AC susceptibility were measured using a SQUID (Quantum Design) magnetometer and a PPMS (Quantum Design) susceptometer at temperatures ranging from 4.5 to 40 K and DC magnetic fields up to 14 T. Superposed AC magnetic fields are up to 0.5 mT.

3. Results and discussion

Superconducting transition temperatures T_c of samples were obtained from the temperature dependence of magnetization in an applied field of 0.5 mT for both samples in zero field cooled (zfc) and field cooled (fc) conditions. The values of T_c are 38.5 K for both samples. Magnetization curve for MgB_2-50 sample is symmetric and larger than that for MgB_2-20 sample. Asymmetric curve for MgB_2-20 sample may be caused by the effect of surface screening current. The value of B_{irr} was defined by the field at which the magnetization width is reduced to 0.1 mT in the DC magnetization characteristics and by the peak appeared in the imaginary component χ'' of AC susceptibilities. B_{irr} data for MgB_2-20 and MgB_2-50 samples are plotted as a function of $1-(T/T_c)^2$ in Figs. 1 and 2, respectively. B_{irr} values defined by the peaks of χ'' shift to higher temperature region. This is ascribed to a difference in the electric field criterion for the determination of the critical current density. In these figures, the relationship is linear and the slopes of the B_{irr} versus $1-(T/T_c)^2$ give exponents $n = 1.7 - 1.9$ at low temperatures and $n = 5.4 - 6.2$ at high temperatures. This difference in n is considered to be caused by different pinning mechanisms at different temperatures. n values at low temperatures are smaller than the power $n = 3.9$ obtained for $HgBa_2CaCu_2O_x$ and $Bi_2Sr_2Ca_2Cu_3O_x$ tape wire under the magnetic field parallel to the c-axis by Noda *et al.* [4].

According to the flux creep theory [5] B_{irr} is expressed as,

$$B_{irr} \propto \left\{1-\left(\frac{T}{T_c}\right)^2\right\}^n \ , \ n = \frac{2m}{3-2\gamma} \ . \tag{1}$$

The pinning parameters m and γ could be estimated by analyzing the temperature and magnetic field dependence of the critical current density J_c. A scaling law of J_c in the absence of thermal activation is assumed in the form :

$$J_c \propto \left\{1-\left(\frac{T}{T_c}\right)^2\right\}^m B^{\gamma-1}. \tag{2}$$

At low temperatures $\gamma = 0.7$ (MgB_2-20) and $\gamma = 0.9$ (MgB_2-50) are estimated from $J_c \propto B^{\gamma-1}$ and at low magnetic fields $m = 2.7$ (MgB_2-20) and $m = 2.5$ (MgB_2-50) are deduced from $J_c \propto \left\{1-(T/T_c)^2\right\}^m$. The calculated values of n at low temperatures are 3.4 for MgB_2-20 sample and 4.2 for MgB_2-50 sample and are larger than those obtained experimentally.

In conclusion, magnetizations and AC susceptibilities of powdered MgB_2 were measured to estimate the irreversibility field B_{irr}. B_{irr} values obtained from the magnetization widths were smaller than the values obtained from the AC susceptibilities. The slopes of the B_{irr} versus $1-(T/T_c)^2$ were smaller than those of oxide superconductors and those calculated with the flux creep theory.

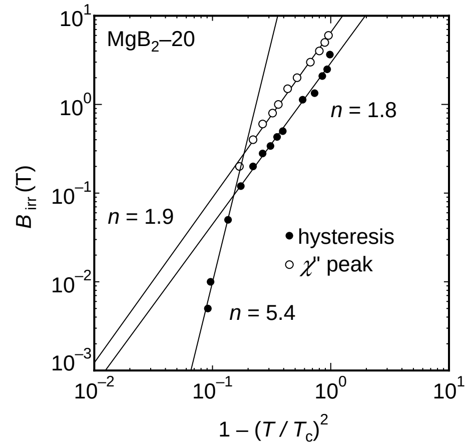

Fig. 1. Irreversibility field B_{irr} for MgB_2-20 sample as a function of $1-(T/T_c)^2$. The slope of the line gives n value. Symbols of open circle and solid circle present B_{irr} values evaluated by the peaks of χ'' of the AC susceptibilities and the magnetization widths, respectively.

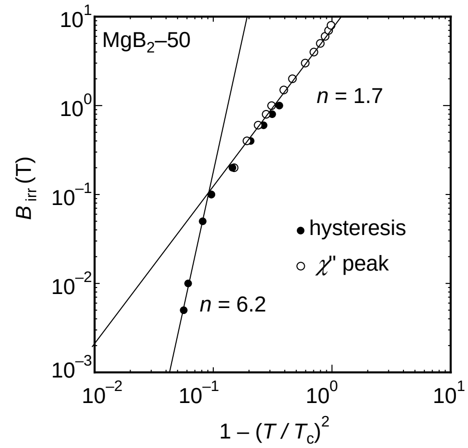

Fig. 2. Irreversibility field B_{irr} for MgB_2-50 sample as a function of $1-(T/T_c)^2$.

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