Pinning Properties and AC Susceptibilities in Superconducting Pb-Bi Alloys

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Abstract

The pinning strengths of the superconducting Pb-Bi alloys can be controlled easily by varying the Bi content. The pinning potential are investigated for superconducting Pb-Bi alloys with different pinning strength. In this study, we will try to clarify the relation between the large decay of critical current density and the pinning properties in superconducting Pb-Bi alloys.

Key words: pinning strength; pinning potential; critical current; Pb-Bi alloys

1. Introduction

The flux pinning properties of high temperature superconductors is a key characteristics in their possible application. However, these are largely influenced by flux creep because of the weak pinning strengths. The phenomena caused by the flux creep, such as magnetic relaxation, have been discussed well by using the appropriate pinning model[1]. The magnetic relaxation and pinning potential are investigated for superconducting Pb-Bi alloys with different pinning strength. We could also fabricate them with much weaker pinning strengths successfully.

2. Experimental procedure

Specimens were prepared in the following manner: Pb and Bi shots were mixed with the atomic ratios of bismuth, 20at% $\sim$ 46at%. The mixtures were melted at 500°C for 5 hours in glass tubes in a vacuum of 10^{-4} Torr, and then quenched in liquid nitrogen. The alloys were kept at the temperature of liquid nitrogen after the quench to prevent room-temperature-aging. The superconducting Pb-Bi with the purity of 99.99% alloys specimens, were mixed in a desired composition into glass tubes in a vacuum of 10^{-4} Torr and melt at 500°C for 5 hours. We fabricated some specimens with atomic ratios of bismuth, 20at% $\sim$ 46at%. In general, Pb-Bi alloys consist of the superconducting epsilon phase and the normal bismuth-rich phase (non-superconducting). The optical observation on specimen's microstructure was carried out. It was confirmed that the alloy with Pb-28at%Bi is homogeneous epsilon phase while the alloy with Pb-46at%Bi is an eutectic with fine and dense Bi precipitates of about $1.0 \sim 4.0$ μm in diameter in the matrix of epsilon phase. Magnetic moment measurements were carried out using a SQUID magnetometer. The magnetization measurement was carried out, the critical current density, J_c, were evaluated from the magnetization data[2]. The Bean model was used for the calculation of J_c. The fundamental AC susceptibilities were simultaneously measured with a fundamental frequency, f=100Hz. The temperature was controlled in an atmosphere of He gas in the range of 4.2K to T_c. The temperature dependence of the AC susceptibility was measured at constant DC magnetic field. The DC and superposed AC magnetic field were applied along the long axis of the specimen.

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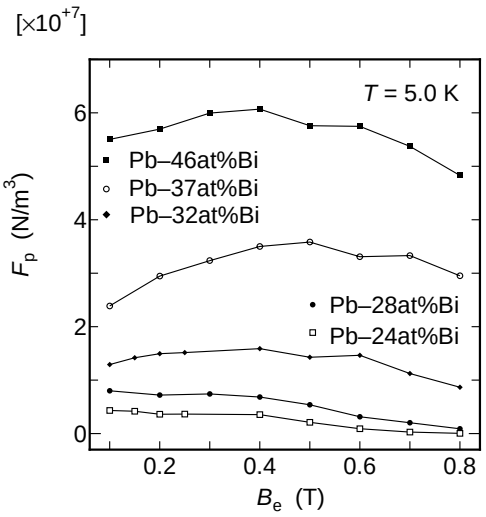

Fig. 1. Pinning strength of Pb-Bi at T=5.0K.

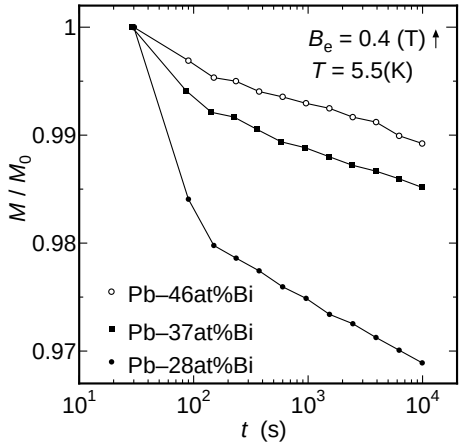

Fig. 2. Magnetic relaxation of Pb-Bi at $B_{\rm e}$=0.4T.

3. Results and discussion

Figure 1 shows the pinning strength $F_{\rm p}$ computed from the $F_{\rm p} = J_{\rm c} \times B$. The typical magnetic relaxation curves at T=5.5K are shown in Fig. 2. The $B_{\rm e}$ was applied as $0 \Rightarrow 0.4$(T) after zero-field cooling from room temperature. For all temperatures, the magnetization was found to decay almost logarithmically with time. Therefore, we could obtain a very reliable normalized relaxation rate from the linear regression of M versus $\ln t$ [3]. Figure 3 shows the field dependence of the apparent pinning potential U_0^*, for different pinning strength specimens. The U_0^* of Pb-46at%Bi increases at 5.0∼5.5K, and decreases at 5.5∼7.0K.

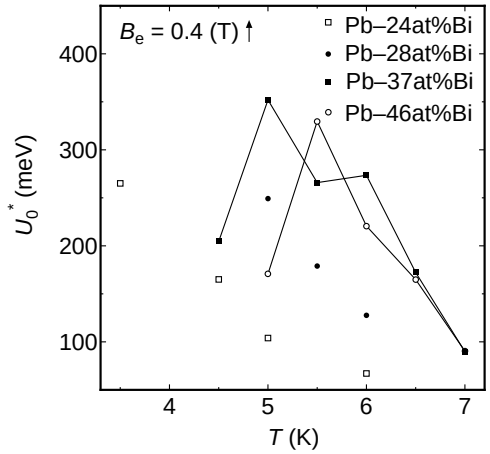

Fig. 3. Temperature dependence of U_0^* at $B_{\rm e}$=0.4T obtained from magnetization relaxation.

4. Conclusions

The values of $F_{\rm p}$ for the weakly pinned specimen (Pb-24at%Bi) at T=5.0K are about 10 ∼ 20 times smaller than those of strongly pinned specimen (Pb-46at%Bi). The U_0^* of Pb-24, 28at%Bi decrease gradually at the temperature ranging T=3.5∼6.0K, and have no peak. On the other hand, the U_0^* of Pb-37,46at%Bi have peak near T=5.0, 5.5K. The peak phenomena of U_0^* is similar to that of high-temperature superconductors. These results suggest that the U_0^* can be sensitively influenced with the pinning strengths.

Acknowledgements

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