Low field magnetic relaxation of superconducting $C_{60}Rb_3$

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The relaxation of magnetization M in superconducting $C_{60}Rb_3$ have been measured at different temperature ranges in low magnetic fields below T_c to explore the flux pinning. The measurements were performed with a superconducting quantum interference magnetometer. The applied magnetic field was 300 G - 600 G and the measured time at each temperature was 1×10^4 sec. M versus $\ln t$ shows a linear behavior for $t \geq 3600$ sec. The data were analyzed in the framework of the flux pinning model of Anderson-Kim. The analyses give the activation energy of $U(5K) \approx 20$ meV, and the critical current density based on $J_c(T) \propto [dM/d\ln t] \times [U/kT]$ shows $J_c \propto (1-t)^m$, with the exponent $m \approx 2.0$. The results are discussed.

1. INTRODUCTION

Recently, it has been discovered that dopings of C_{60} with the alkali metals form a new class of superconductor [1]. The transition temperature is $T_c = 18K$ for $C_{60}K_3$ [2] and $T_c = 28 K$ for $C_{60}Rb_3$ [3]. The first findings were suggestive of a type-II superconductor, then the critical field, the field penetration depth λ and the coherence length ξ of these materials were measured [4,5]. In this paper we report the magnetic relaxation of $C_{60}Rb_3$, and derive the effective pinning energy U and the critical current density J_c based on the flux creep model of Anderson-Kim.

2. EXPERIMENTAL PROCEDURE

$C_{60}Rb_3$ samples were prepared in a way similar to that reported originally by Kratschmer et al. [6]. A SQUID magnetometer (Quantum Design Inc.) was employed to measure the magnetization M as a function of time in an applied field, $H = 300$ G or 600 G. The sample was first zero-field-cooled to a desired temperature T below the transition temperature $T_c \approx 27K$; a magnetic field was then applied to the sample. The magnetization of the sample was measured as a function of time t .

3. RESULTS AND DISCUSSION

Figure 1 shows the magnetic relaxation data as

a function of t at $T = 9, 11$, and $13 K$ respectively in a magnetic field of 300 G. The common feature of these curves was that the magnetization data decrease as one increases t and a linear behavior in $M(t)$ versus $\ln(t)$ for $t \geq 3600$ sec. The slope, $S(T) = dM/d\ln t$, varies considerably at different temperatures.

Figure 1. Magnetization vs $\ln(t)$ at a given field $H=300G$, and the temperatures are indicated.

Using $S(T)$, we calculated the flux-creep apparent activation energy based on the flux creep model of Anderson Kim [7] which can be written as

$$U = kTM(0)[dM/d\ln(t)]^{-1}, \quad (1)$$

where $M(0)$ is the initial magnetization. Figure 2

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shows the temperature dependence of $U(T)$ derived from Eq (1). One can see that as one decreases T , $U(T)$ increases with T and reaches a $U_{\max}$ and then decreases with T . $U_{\max}(17K) \approx 77.5$ meV in 300 G, and $U_{\max}(15K) \approx 50.8$ meV in 600 G. A percolation model predicts the formula $U = B + AT^2$ at $kT \ll U$, and this observation on high- T_c superconductors was reported by A. Gurevich et al. [8]. We observe a similar dependence of $U(T)$ in $T \leq 11$ K. These results are similar to those reported by C. Pollitt et al. [8]. They observed that $U(T)$ increases with T when T increases from 5K to 20 K, and U can be well described by the formula $U = B + AT^2$ with B and A independent of T , while U we obtained increases with T^2 linearly at $T \leq 11$ K.

Figure2. Apparent pinning energy U vs T at 300 and 600 G.

To study the temperature dependence of the critical current density J_c , the following formula [10],

$$J_c \propto (dM/d\ln t) \times (U/kT), \quad (2)$$

based on the Anderson-Kim model was used. Using Eq(2), we derive J_c as a function of T as shown in fig[3], and J_c can be fitted to the formula, $J(T) \propto (1-t^n)^m$, with $n \approx 3$ and $m \approx 2.0$ in 600G, where $t \equiv T/T_c$. Near T_c , $(1-t^n) \approx n(1-t)$ for $t \rightarrow 1$, we thus expect the approximation $J_c(T) \propto [1-t]^2$. This result is analogous to the high- T_c superconductor $J_c(T) \propto [1-t]^p$ with p typically ranging from 1 to $5/2$ [10-11].

In summary we measure the magnetic relaxation of $C_{60}Rb_3$ in different temperature ranges in low magnetic fields. Using the flux creep model of Anderson-Kim, we derive the behavior of $U(T)$ and

$J_c(T)$. The relaxation rate S grows linearly with $\ln t$ for $t \geq 3600$ sec. $U(T)$ show concave downward features, and $J_c(T) \propto (1-t)^2$ for T near T_c .

Figure3. The dependence of critical current density on temperature.

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