Critical Current and Scaling Laws in Evaporated Two-Phase \( \text{Cu}_{2.5}\text{Mo}_{6}\text{S}_8 \)

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We have measured critical currents \( I_c \) of an evaporated \( \text{Cu}_x\text{Mo}_6\text{S}_8 \) \((x = 2.5 \pm 0.3)\) film as a function of an external perpendicular field \( B \) up to the upper critical field \( B_{c2} \), at several temperatures \((T < 4.2 \text{ K})\). Results for the pinning force per unit length \( F = I_cB \) do not obey a scaling law. That is, \( F = K(T)f(b) \), where \( K \) and \( f \) are general functions of the temperature \( T \) and the reduced field \( b = B/B_{c2} \), respectively. By comparing data with other evaporated and sputtered \( \text{Cu}_x\text{Mo}_6\text{S}_8 \) with \( x < 2 \), we have separated the pinning force into two parts, each one obeying a scaling law. The recently published phase diagram of \( \text{Cu}_x\text{Mo}_6\text{S}_8 \), along with our results, suggests that critical current and pinning in this material are controlled by two superconducting phases.

1. INTRODUCTION

The extremely high critical fields\(^1,2\) of the Chevrel-phase materials suggest the possible application of those compounds in magnets for the production of very high fields. Recently\(^3,4\) critical current densities were measured in a sputtered Chevrel phase material (also called ternary molybdenum sulfide, TMS) \( \text{Cu}_x\text{Mo}_6\text{S}_8 \) with \( x \leq 1.9 \). Scaling laws for the critical current are reasonably well obeyed in these materials.\(^4-6\) An estimate of the critical current attainable in \( \text{PbMo}_6\text{S}_8 \) (a single-phase material) was made, and found to be high at very high field. Since evaporated (superconducting) TMS is now available,\(^7\) we measured the superconducting properties\(^8\) of several \( \text{Cu}_x\text{Mo}_6\text{S}_8 \) samples with \( x \) up to \( 2.5 \pm 0.3 \). A striking similarity between the evaporated, sputtered, and sintered samples is found in normalized critical field \( b^* \) vs. \( t \) plots, where \( b^* = B_{c2}/T_c(dB_{c2}/dT)_{T_c} \) and \( t = T/T_c \). Similarities are also found in the normal state resistivity at low temperatures for all samples.\(^9\) However, the shapes of the pinning force per unit length \( F \) vs. \( b(b = B/B_{c2}) \) are nearly identical.
for sputtered and evaporated samples with $x \leq 2$. There are no critical current measurements on sintered samples, because of the large number of voids in those materials. We have measured, for the first time, critical currents in a sample with copper content high enough that we are in the two-phase regime of the phase diagram.\textsuperscript{10}

2. EXPERIMENTAL METHOD AND RESULTS

Samples were prepared by a method described elsewhere,\textsuperscript{7} and current was applied through pressure contacts of freshly cleaned indium. The magnetic field, supplied by a 14-T superconducting solenoid, was directed perpendicular to the film plane. The sample was immersed in liquid helium to avoid heating of the contacts, thus restricting temperatures to the range 1.4–4.2 K. Critical currents were defined by the 100 $\mu$V/m criterion. The field was monitored by a copper magnetoresistance probe calibrated against a Hall effect device.

The upper critical field $B_{c2}$ used in this analysis of critical current data is lower than that determined by mid-resistance point measurements.\textsuperscript{4,11}

![Graph](image)

**Fig. 1.** Total pinning force per unit length $F = I_c B$ vs. the parameter $b^{1/2}(1 - b)^2$, where $b = B / B_{c2}$ is the reduced field, for sample #39 at several temperatures and for samples #32 and #191.