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Determination of the Pinning Forces and the Scaling Laws Behavior in Al-doped YBCO Superconducting Thin Films near Transition Temperature

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Declaration

I certify that this thesis submitted for the degree of Master of physics is the result of my own research, except where otherwise acknowledged, and that this thesis (or any part of the same) has not been submitted for a higher degree to any other university or institute.

Signed: Mahmoud

(Mahmoud Soliman)

Date: 30.12.2002

Dedication

I would like to dedicate this thesis to my parents, and my wife. I am deeply grateful for their support and help in achieving my graduate study.

Aknowledgments

I would like to express my profound gratitude to my research advisors Dr. Abdelkarim Saleh and Dr. Mohammed Abu-Samreh for their guidance and continuos support through all stages of this work. My thanks will be extended to the faculty and staff members of the physics department for their help and support during my graduate work.

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Abstract

Magnetization data of Al-doped YBCO laser ablated superconducting thin films were used to calculate critical temperature, critical currents and magnetization of samples having different dopant concentrations. The results were found to be greatly dependent on dopant concentrations. Magnetization curves of samples with no anomalous behavior have been detected.

The magnetization width was used to estimate the critical current density, J_c. The crtical current results were scaled according to the scaling law $J_c(T)=J_o(T)(1-T/T_c)^n$, where n is an exponential parameter whose typical value is of the order ~ 2.3. Besides, results of the pinning force dependence on temperature for the given samples are also scaled according to the following scaling law:

$$F_h = F_{p0}(T)h^p(1-h)^q$$

where h is the reduced applied magnetic field and p and q are parameters having values of the order of 0.70±0.02 and 1.72±0.05, respectively. The pinning force F_p exhibits a peak in the F versus H_{max} curves. This peak was also scaled according to a power law of the form $F_p \alpha H_{max}^n$. The predicted scaling behaviors are in good agreement with the flux-line shear model (FLS) at low-temperatures as well as around the transtion temperature.

Chapter One

Introduction and general considerations

1.1 Introduction

Superconductivity is a state of some materials that was first discovered by Onnes in 1911 during his study of some physical properties of mercury in the low-temperature region when a mercury sample was cooled down to 4 K (Reitz, Frederick, Milford, and Christy, 1993). The main observation indicated that the resistance of the sample falls rapidly by decreasing temperature until it is completely reached zero around 4.2 K. In another investigation to test the results using more sensitive equipment such as persistent current induced in a loop of superconducting wire, Onnes was able to estimate a resistance value of (10^{-12} Ω) for the mercury metal. The general resistance dependence on temperature for mercury wire as observed by Onnes (Reitz *et al.*, 1993) is shown in Figure 1.1.

In a separate investigation to test Onnes results it was found that an induced current of several hundred amperes in a superconducting ring made of lead has shown no change in the current magnitude for a period of almost one year. The investigation results came in favor of Onnes observations and confirmed the resistance in the superconducting state is indeed zero (Reitz *et al.*, 1993).

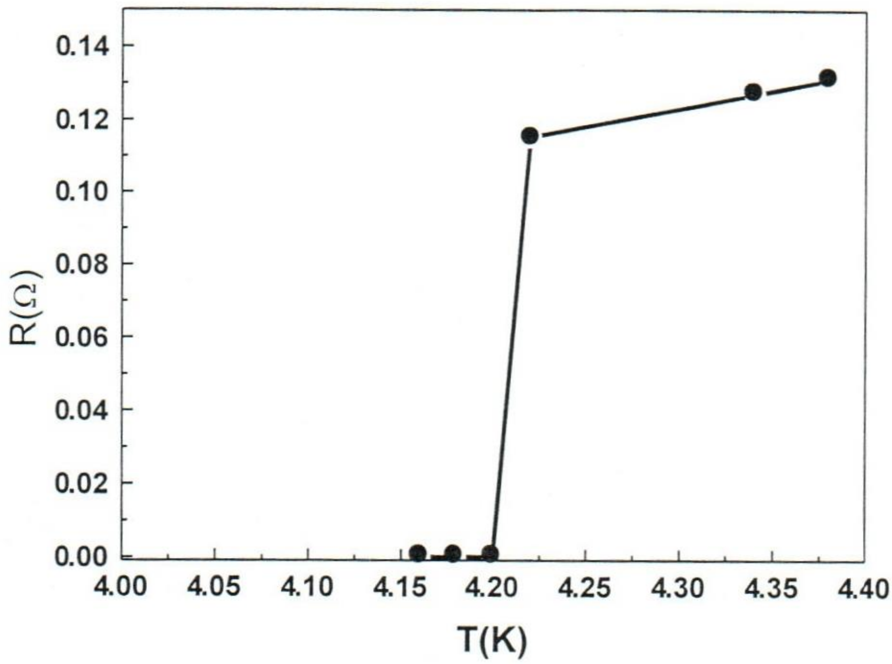

Figure 1.1. Resistance dependence on temperature for mercury.

Shortly after such observations, the superconducting phenomenon had attracted the attention of thousands of scientists during the last century. Investigations were conducted on different metals, copmounds as well as alloys. Early investigations were aimed at exploring physical properties for the so-called low-temperature superconducting materials and alloys and on fabricating such materials. The first attempt for investigating superconducting materials at high transition temperature, T_c, of about 23.2 K was reported in 1973 for Niobium-Germanium thin films near the stoichiometric composition Nb_3Ge (Tinkham, 1996). More than 20 elements and hundreds of alloys and intermetallic compounds have been prepared and used as superconducting materials.

Since the discovery of superconductors in 1911 until 1986, it was believed that superconductivity is limited to low-temperatures (Robert, and Richard, 1994) (T_c < 25 K). In the first half of the year 1986, Bednorz and Muller reported transition temperatures of about 30 K for the, Oxygen-deficient compounds of Barium, Lanthanum, Copper Oxide metallic system (BaLaCuO) (Bednorz and Muller, 1986). After that, the search for a room temperature superconductor began to be intersting. By the end of 1986 other Lanthanum compounds having transtion temperature close to 40 K were fabricated and shortly after that, the Yttrium Barium (YBCO) system superconductor at T_c of about 85-95 K was reported. Early 1988 the superconductivity state has reached a transition temperature of 120 K for both BiSrCaCuO and TiBaCaCuO superconducting systems (Tinkham, 1996). Indeed, understanding the appearance of superconductivity at higher temperatures above 77 K is of major concern in physics today (Robert *et al.*, 1994). In general, every material with transition temperature above 77 K is considered as a member of the high-T_c superconductor (HTSC) family. The temperature dependence of resistance for a typical high-T_c superconductor compound, namely ($YBa_2Cu_3O_7$), is displaced in Figure 1.2.

The discovery of high-T_c superconductors in materials having antiferromagnetic properties opened a new era in physics, technology, and engineering. For the past fifteen years, there has been a dramatic intensification of activity in the superconductor search field at room temperatures (Robert *et al.*, 1994).

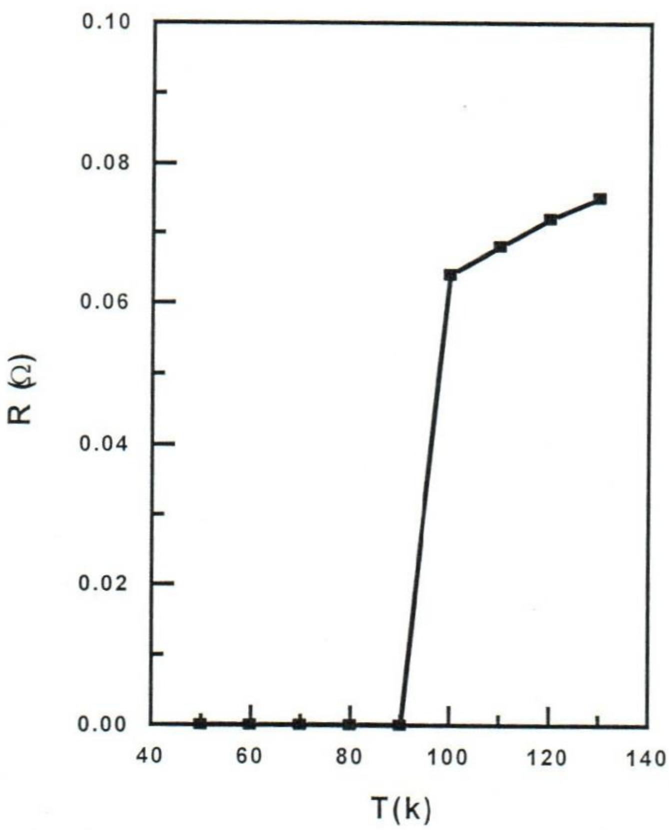

Figure 1.2. Typical resistance dependence on temperature for YBCO high temperature superconductor

All superconducting materials are characterized by several common properties. Firstly, each superconducting metal or alloy is characterized by a transition temperature, T_c. The transition temperature is that temperature at which the state of the metal or alloy transforms