Characterization of YBCO Superconducting Thin-Films for Fluxonic Applications

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Abstract:

The use of superconducting materials for thin film oxides has recently sparked interest in a new field of engineering research called "Fluxonics," named after the physical quantization of magnetic flux lines that occurs in such materials when a threshold current has been injected. Structures consisting of patterned indentations, termed "antidots," have been fabricated using standard ultraviolet (UV) lithography methods on high-temperature Type II superconductors such as yttrium-barium-copper-oxide (YBCO) to structurally guide and support magnetic flux vortices. Various growing and processing conditions concerning film qualities, topological constructions, and antidot geometry arrangements have been investigated for their effectiveness in meeting the criteria for several electronic and computing applications, one of which is the development of a super-fast method for storing and processing data [1].

The focus of this project was to characterize critical parameters of a superconducting thin film to be used for antidot patterning. Novel samples of YBCO with a cerium oxide (CeO_2) buffer layer were previously grown on an R-cut sapphire substrate. For characterization, a liquid helium cryostat and an inductive coil system with a built-in heater were implemented. Automatic testing algorithms were written and administered through LabVIEW. Extracted critical temperature and voltage values were indicative of the sample's successful onset of superconductive behavior.

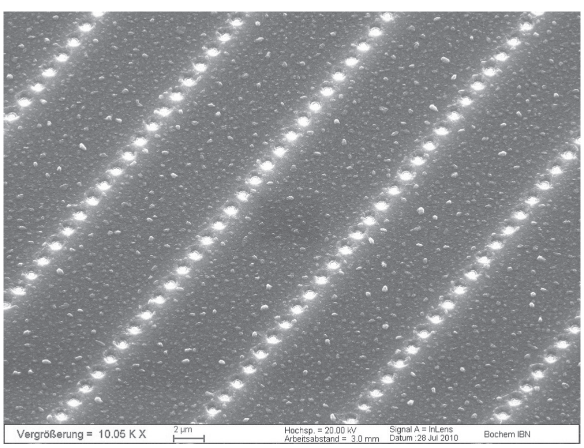


Figure 1: SEM image of the surface topology for a completed antidot structure (2010).

Introduction:

Recent developments in the field of complex oxide thin films have led to the study of magnetic flux vortex movements within patterned indented structures. These antidot structures, comprised of a Type II superconducting layer on an appropriately buffered substrate, are useful for their potential in understanding vortex dynamics. It has recently been determined that for microwave experiments, YBCO may be optimally grown on a suitable substrate such as aluminum oxide (Al_2O_3, sapphire) with an introduced CeO_2 buffer layer, which acts as both a lattice-matched interface between dissimilar unit cells and an inhibitor to the possible diffusion of aluminum [2]. Figure 1 depicts a scanning electron microscopy (SEM) image of the surface topology of a fully completed antidot structure.

Prior to its utilization as a finished structure, a sample wafer must first be characterized to ensure its functionality as a superconductive material [3]. In this experiment, we have successfully characterized the critical temperature and voltage of a previously grown thin-film sample (R2Z5-47.c), consisting of 100 nm of YBCO grown on a 30 nm thick CeO_2 buffer layer on an R-cut sapphire substrate.

Experimental Procedure:

For characterization, a sample of R2Z5-47.c was structurally supported between two inductive coil pads and suspended

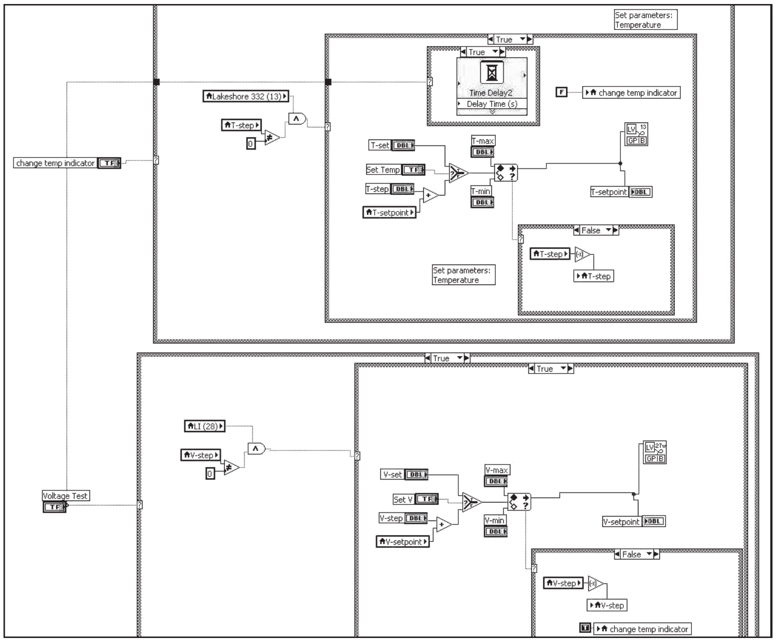
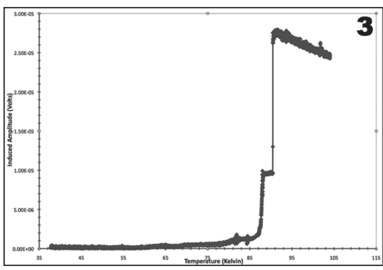


Figure 2: Sample screenshot of LabVIEW program used for characterization.



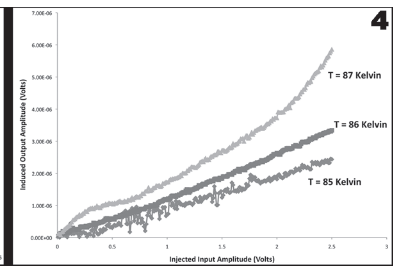


Figure 3, left: Critical temperature measurements of R2Z5-47.c.

Figure 4, right: Critical voltage measurements of R2Z5-47.c.

Results:

Figures 3 and 4 depict the results of the characterization tests for critical temperature and voltage respectively. The critical temperature is seen to fall within the onset-offset range of 85 to 95°K, with the 50% critical temperature value falling at 90.8°K. The critical voltage graphs similarly delineate the sample's increase in nonlinear response with increasing temperature, indicating the existence of a critical current and the onset of superconductive behavior.

Possible explanations for the measurement fluctuations seen in Figures 3 and 4 include inaccuracies associated with the cryostat apparatus and failures regarding sample orientation and stability within the sample holder.

Conclusions and Future Work:

Critical temperature and voltage values of a YBCO thin-film were successfully characterized, and the results obtained are indicative of the sample's successful superconducting behavior. Further characterization of the sample may include measuring the sample's field dependence and complex susceptibility with varying degrees of applied external magnetic fields. In addition, improvements regarding the sensitivity of the equipment, including the coil and stability of the sample holder, may be further improved.

within a pressure sealed cryostat chamber. A constant flow of liquid helium and a built-in heater were then conjunctively introduced to maintain a controlled temperature, while a lock-in amplifier was employed for the generation and recording of input and output voltages.

An automatic algorithm written in LabVIEW was used to administer the experiment and record the critical temperature of the sample without heater incorporation; modifications were later made to the algorithm to account for the systematic alteration of an enclosed heater and to measure the critical voltage of the sample. Figure 2 depicts a sample screenshot of the updated program's block diagram from LabVIEW's graphic user interface.

To characterize critical temperature, a constant input voltage was injected while temperature was slowly decreased from 105°K to 35°K. Induced output voltages measured from the other coil were recorded. For critical voltage, temperatures were steadily maintained at 85, 86, and 87°K, while input voltage was swept from 0 to 2.5 volts. Induced output voltages were similarly measured.

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