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14. ABSTRACT

Liquid helium cooled TEM/STEM sample holder with electrical access to thin film samples is developed. The cryogenic sample holder was used together with a Nabity Nanometer Pattern Generation System to investigate important issues, such as the threshold energy and amount of exposure, in the fabrication of electron beam modified planar Hg-1212 Josephson junctions. The results indicate that for beam energy less than about 80 keV the changes in the superconducting properties of Hg-1212 thin films are temporary. In addition, the amount of exposure required to make junctions with stable properties makes the technique useful only for circuits of a few junctions.

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Final Technical Report

Low Temperature Scanning Electron Microscope for Fabrication and Characterization of High-T_c Josephson Junctions and Circuits

AFOSR DURIP Grant/Contract #F49620-98-1-0326

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OBJECTIVES

- Fabrication of planar Josephson junctions on Hg-HTS thin films by electron beam irradiation below critical temperature.
- In situ tailoring of junction parameters

PARTICIPANTS' ACTIVITY

- Two senior investigators (Judy Wu and Siyuan Han) and two graduate students (Yang Yu and Yiyuan Xie) have contributed significantly to the project. Wu and Xie made Hg-HTS films used in the experiment. Han designed the cryogenic TEM sample holder for *in situ* current-voltage measurement, set up the instrument and data acquisition system. Yu fabricated Hg-HTS thin film microbridges used in the low-T e-beam junction experiment, and studied the effect of e-beam irradiation on Hg-HTS films and the properties of the junctions made under Han's guidance.

ACCOMPLISHMENTS and NEW FINDINGS

For the past two years we have focused on setting up the equipment for fabricating and characterizing planar high-temperature superconductors (HTS) Josephson junctions made by focused e-beam irradiation as described below:

1. We have integrated a Nabity nanometer pattern generation system to our Phillips EM420 TEM/STEM which was used to study the effects of electron beam on Hg-1212 superconductor thin films and to fabricate the e-beam modified planar Josephson junctions.

2. We have set up a low-noise computer controlled data acquisition system for Josephson junction characterization. The system includes battery powered low-noise preamplifiers, electronic filters, a signal generator, and high precision voltage source. All of them are home designed and made. The system has been successfully used in the study of e-beam modified junctions' electrical properties.

3. We have designed a specialized liquid He-4 cooled cryogenic TEM sample holder capable of *in situ* measurement of the sample's current-voltage characteristics. The special probe was manufactured by the Electron Microscopy Division of Oxford Instrument and has been installed, tested, and used for beam irradiation and planar junction fabrication studies.

4. We have obtained results on the effect of e-beam dose and energy on the T_c and resistivity of YBCO, Tl- and Hg- based HTS thin films, at room temperature and low temperatures ($T < T_c$). In our test T_c of the HTS thin films was lowered by a maximum of about 60 K. The dependence of T_c reduction on the beam energy and dose (beam current × exposure time) was investigated (see Figure 1).

5. We have fabricated, characterized, and compared various properties of bicrystal grain boundary and low temperature e-beam modified and Hg-1212 Josephson junctions. The properties studied include magnetic field and temperature dependence of critical current, switching statistics, and response to microwave irradiations.

6. Our study shows that the energy of the e-beam must exceed certain threshold, ⊔ 80 keV, to have irreversible effect on T_c of the Hg-1212 films. Although we have obtained substantial reduction of T_c on films irradiated with beam energy less than 80 keV the films' superconducting properties, including T_c, gradually returned toward their pre-irradiation values after being stored at room temperature for a few days to several weeks. Since most SEM has acceleration voltage less than 50 keV it is difficult to fabricate junction using conventional SEM.

7. Using the cryogenic SEM Josephson junction sample holder we have studied variation in Hg-1212 microbridge's properties as a function of beam dose. We found that the dose needed to make junctions with reasonable characteristics required many hours of e–beam exposure. Thus the technique's throughput is very low which makes it useful only for the fabrication of devices and/or circuits that contain a few junctions.

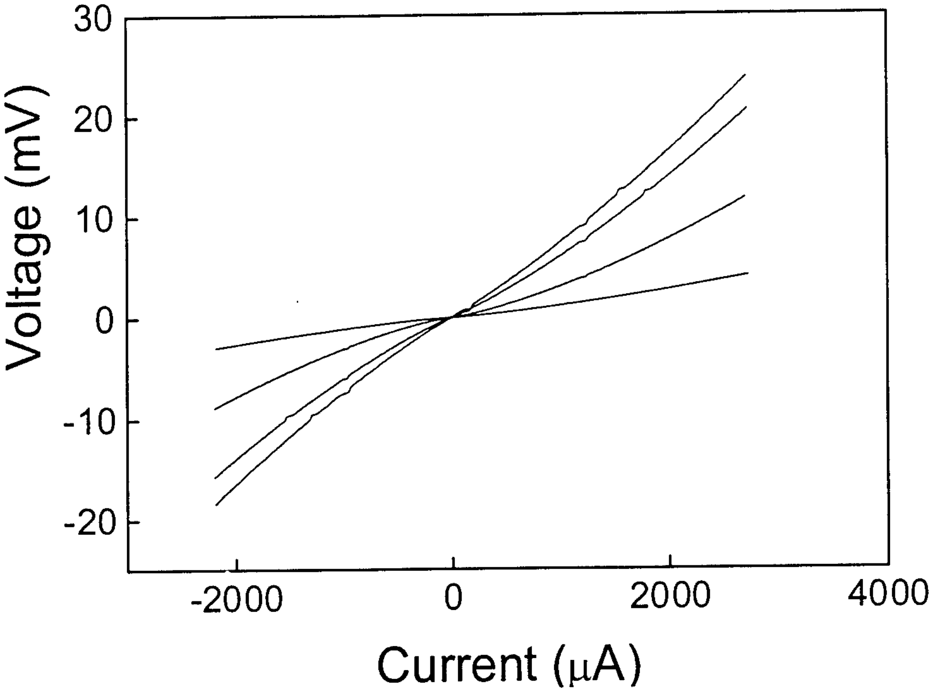

Figure 1. The *in situ* measurement of I-V curves of Hg-1212 microbridge as a function of beam exposure time. The e-beam irradiation was performed at 88 K with 80 keV electron beam. The beam current is 60 nA. The cumulative exposure times are 0.1, 2.0, 3.5, and 5.5 hours, from small slope to large slope. The thickness of the film is 100 nm with T_c=101 K before the irradiation.