Crack-free phase transition of tin-germanium alloy

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A metastable state is stable with respect to small fluctuations, but is different from the system's ground state of the least energy. Recently, researchers demonstrated the metastable superconductivity of the super-cooled state in IrTe2 caused by the pulse-heating and the subsequent rapid cooling*. This metastable superconductivity is a result of the suppression of the first-order phase transition by rapid cooling, applicable for the nonvolatile resistance switching from non-zero to zero and for the reversible optical lithography of superconducting circuits. However, from the viewpoints of applications, the small resistance difference due to the metallic ground state of IrTe2 with low resistivity limits the possibilities in multiple fields. In this thesis, we show the nonvolatile phase transformation from the high-resistance semiconductor into the metastable superconductor by applying the current pulse in the bulk tin-germanium alloy, as well as the inverse transformation. We also observed the stepwise partial phase transition followed by the pulse trains with a microscope system and showed that the metastable superconductor can coexist with the semiconductor at sufficiently low temperatures. Our results demonstrate that the reversible writing and the spatial patterning of superconductor in semiconductor are indeed possible in our procedure. Since resistivity of the semiconductor increases exponentially as the temperature decreases and thus make a stark contrast to metastable superconductor, this study opens the way for applications of superconducting physics in various filed, including superconducting circuits and plasmonics devices.

I. INTRODUCTION

II. METHOD

A. Sample preparation

Pure Ge (Furuuchi chemical GEM-33001A) and Sn (Furuuchi chemical SNM-67027A) were mixed in a mass ratio1:99 in a quartz tube, and heated up to $1050°C$ and cooled slowly in 48 hours in a electric oven. The melted sample were metallic, and we converted to semiconductor phase in a household freezer for a week.

B. Resistivity measurement(Transport)

The resistivity under slow cooling was measured with the conventional four-probe method. A load resistor of 150 ohms was connected in series with the sample. An AC voltage excitation of 105 Hz with a magnitude corresponding to ? μ A was generated at a lock-in amplifier (Stanford Research SR830) and applied to the circuit. Signals from the voltage probes were amplified with a transformer amplifier (Stanford Research SR554) and measured with the lock-in amplifier. The current flowing through the circuit was measured by probing the voltage drop at the load resistor with a multimeter (Keithley 2001).

C. Pulse application

A rectangular voltage-pulse generated in a source meter (Keithley 2400) was amplified using a precision power amplifier (NF Corporation 4502) by A=100. A load resistor of 5.4 ohms was connected in series with the sample and used to calculate the current flowing through the circuit. The time-varying voltages at the load resistor and the sample voltage-probes were were monitored using a data logger (Measurement Computing DT8824). Thus, we obtained the time profiles of the current and sample resistivity during the pulse application.

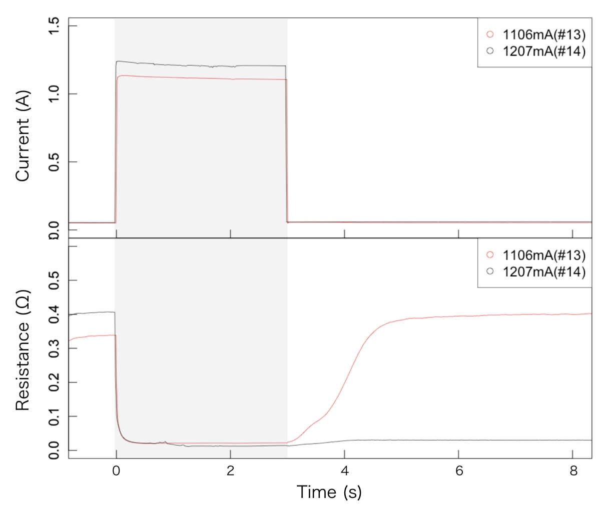

FIG. 1.

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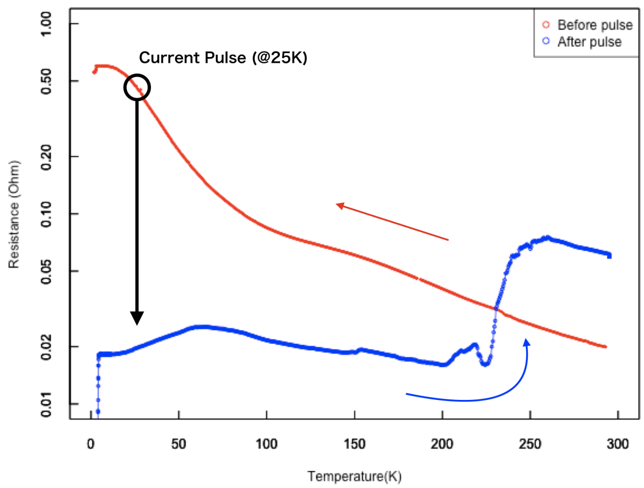

FIG. 2. a graph that demostrates superconductivity should be inserted in the inset

III. DISCUSSIONS

slow[?]

IV. CONCLUSION

V. SUPPLEMENTARY MATERIALS

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