Observation of Memristive Electrical Characteristics and Current-Induced Phase Transition in Pb-Cu-P-S-O Compound

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Abstract

In our previous research, we revealed the zero resistance and temperature-induced phase transition in Pb-Cu-P-S-O compound. Also, the data showed a correlation with the characteristics of the novel material known as LK-99. Subsequently, a series of measurements were conducted to investigate the electrical properties of this compound. These measurements indicated that the compound exhibits memristive characteristics and undergoes a current-induced phase transition. This technical report focuses on presenting the measurement data and detailed characterization of the samples, highlighting on these observed phenomena.

Keywords
LK-99, memristor, superconductivity, current-induced phase transition..

1. Introduction

Recently, LK-99 has been debated as a potential room-temperature and ambient-pressure superconductor [1]. Most studies on the previously known PCPOO ($Pb_{10-x}Cu_x(PO_4)O$) (x= 0.9 ~1.1) concluded that it is an insulator [2]. However, DFT simulations conducted by Griffin et al. [3] suggested the possibility of superconductivity in its structure, and Yao et al. [4] showed that sulfur doping in copper-substituted lead apatite material exhibited a small Meissner effect and weird metal-like electrical properties.

In our previous research [5, 6], we showed that Pb-Cu-P-S-O compounds, synthesized using the DM method, exhibited zero resistance and temperature-dependent phase transitions. After a limited release of data on the superconductivity of our samples, we studied their unusual electrical properties. In this report, we reveal the memristive behavior and the current-induced phase transition of the Pb-Cu-P-S-O compound.

2. Description of measurement method

In the measurements, we used Keithley 6221 current source and 2182A nanovoltmeter for voltage measurements. The four-point probe station utilized was the M.S.Tech M4P302 model, equipped with gold-coated probes. The electrode distances were set to 1 mm, following the well-known four-probe method. For measuring the electrical characteristics under applied voltage, Keithley SMU 2651A was used. All data were collected from measurements under room temperature and pressure conditions.

3. Memristive behavior of the Pb-Cu-P-S-O Compound

Figure 1 shows the measured voltage of the Pb-Cu-P-S-O compound for the applied current. The voltage did not match when the current was increasing compared to when it was decreasing, repeatedly exhibiting a type of hysteresis. This phenomenon is consistent with the behavior of the memristor.

Such memristive phenomena appeared as various forms of hysteresis depending on the position of the sample. Figures 2 and 3 show the measured voltage for the applied current at different positions of the same sample. The measured voltage consistently exhibited non-Ohmic behavior and displayed different characteristics depending on the direction, speed, and variation of the applied current.

Inspired by this phenomenon, we investigated the electrical characteristics of the samples for applied voltage. Figure 4 shows the measured current on a logarithmic scale for the applied voltage. This typical memristive behavior appeared repeatedly, with slight variations in hysteresis depending on the measurement location. Considering the one-dimensional conductivity of lead-apatite compounds, as suggested original authors of LK-99, we suspect that the memristive phenomenon may arise from the one-dimensional paths of the material.

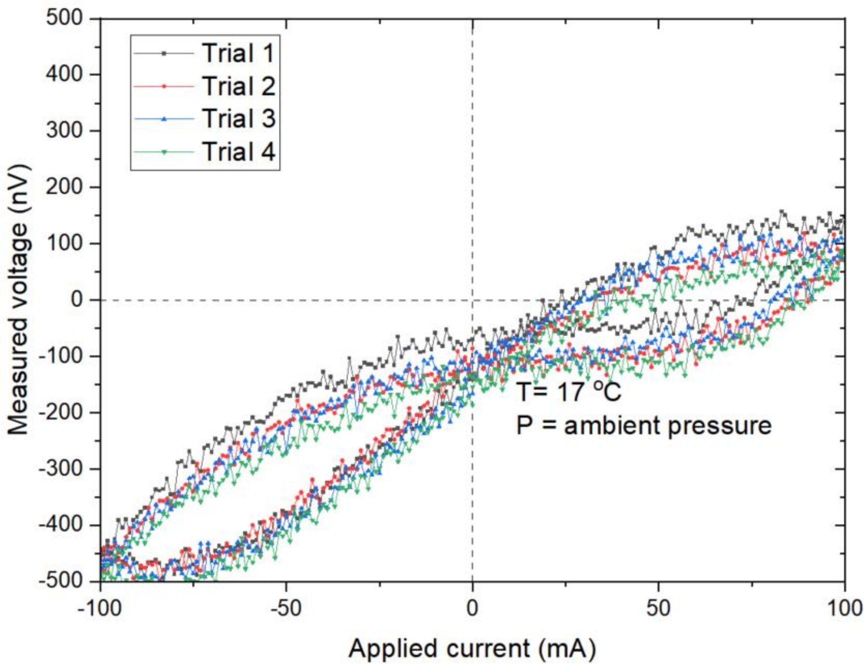

Figure 1. Memristive hysteresis of the sample indicating very low resistance

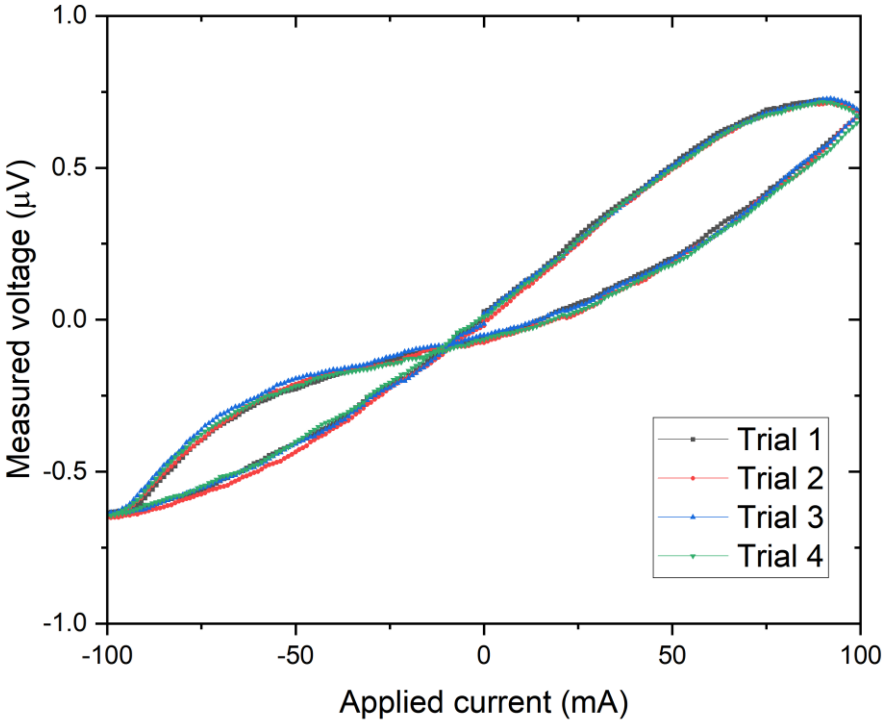

Figure 2. Memristive hysteresis of the sample showing resistive switching and low resistance.

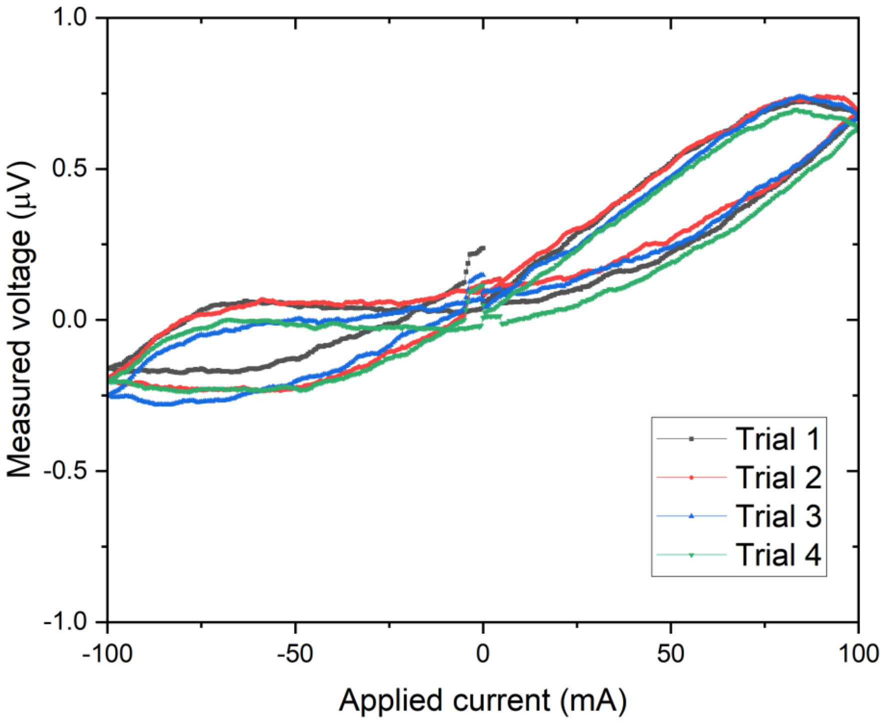

Figure 3. Memristive hysteresis of the sample showing resistive switching and partial zero resistance at different location.

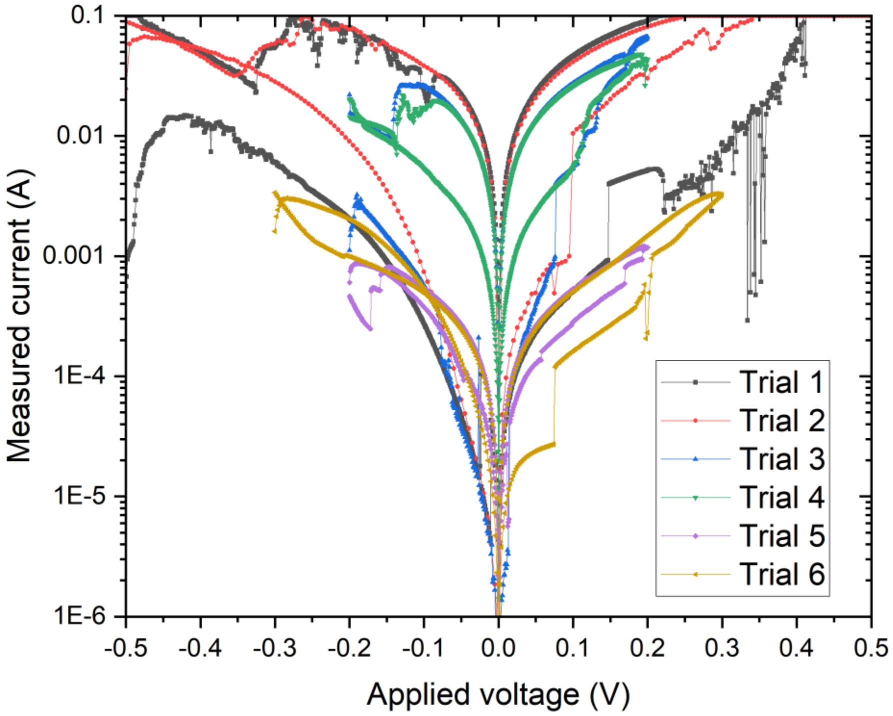

Figure 4. Memristive hysteresis of the sample for applied voltage cases.

4. Current-induced phase transition

We measured the flat voltage in the lower range up to the limit of the measuring device on the same sample, and repeatedly observed the phase transition occurring at the critical current. In this study, we disclose the data on current-induced phase transition from superconducting to normal state within the permissible range.

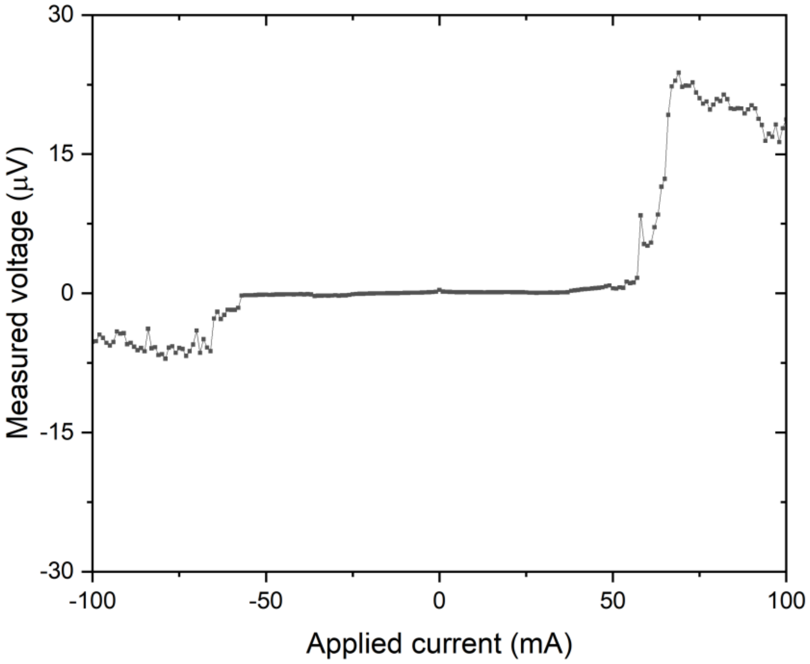

Figure 5. Phase transition at critical current.

5. Summary and Conclusions

In this study, we have furthered our understanding of the Pb-Cu-P-S-O compound synthesized via the DM method, particularly focusing on its memristive behavior and current-induced phase transitions. Our key findings include:

Memristive Behavior: We observed pronounced hysteresis in the voltage-current relationship, indicative of memristive properties. These properties varied based on the measurement location, direction, and speed of the applied current, suggesting a complex interaction between the one-dimensional conductive paths within the material.

Current-Induced Phase Transitions: By measuring the flat voltage in the lower range up to the device's limit, we identified repeatable phase transitions occurring at critical current levels. These transitions provide significant insights into the electrical characteristics and potential applications of the compound.

Our results highlight the unique electrical properties of the Pb-Cu-P-S-O compound, suggesting potential for novel applications in low resistance electronic devices. The memristive behavior, combined with the current-induced phase transitions, points towards a complex and rich landscape of electrical phenomena that warrants further exploration. We plan to continue investigating these properties to fully understand the mechanisms at play and to explore practical applications of these findings.

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