3. Theory

1) Introduction

Superconductivity was discovered in 1911. We define the temperature at which a superconductor begins to lose resistance as the superconducting transition temperature or superconducting critical temperature, usually expressed as T_C. After the discovery of superconductivity, experimental and theoretical research and applications have been greatly developed, but the increase in critical temperature has been very slow.

The discovery of superconductors in the liquid nitrogen temperature zone at the beginning of 1987 shocked the whole world. It was called one of the most significant scientific and technological breakthroughs in the 20th century.

2) Superconducting properties

Superconductors have many properties, the main electromagnetic properties of which are as follows.

a) Zero resistance phenomenon: when a metal or alloy is cooled below a certain temperature T_C, its DC resistance suddenly drops to zero. This phenomenon of zero resistance at low temperature is called the superconductivity. A substance having superconductivity is called superconductor. Temperature T_C is called the critical temperature of the superconductor. Above T_C, both superconductors and normal metals have limited resistance, and such superconductors are in a normal state. The transition from the normal state to the superconducting state is completed within a limited temperature range, i.e., there is a transition width ΔT_C, which depends on the purity of the material and the integrity of the crystal lattice. For an ideal sample, $\Delta T \leq 10^{-3}$ K. Based on the change in resistance, T_C can be determined by electrical measurement. Usually, the temperature at which the resistance of the sample reduced to half of the normal state is defined as the critical temperature T_C of the superconductor.

b) Completely diamagnetism: when the superconductor is placed in an external magnetic field, the magnetic flux cannot penetrate the superconductor, and the magnetic induction intensity in the body is always kept at zero (i.e. $B \equiv 0$). This property of the conductivity is also called as Meissner effect.

These two properties of superconductors are independent but also closely related. Full diamagnetism cannot be derived from the zero resistance characteristic, but the zero resistance characteristic is a necessary condition for the Meissner effect.

3) Measurement principle

The purpose of this experiment is to measure the transition temperature of superconducting materials, i.e., the temperature when a superconductor changes from a non-superconducting state to a superconducting state under normal atmospheric pressure. Since the resistance of the superconducting material in the superconducting state is zero, we can use the method of measuring resistance changes with temperature to determine its transition temperature.

The resistance of the sample is measured by the four-lead method. Measure the voltage between the two ends with a constant current flowing through it. The change in measured voltage signal reflects the change in its resistance.

Because the resistance of the experimental sample at room temperature is naturally very small, on the order of 10^{-3} Ω, the voltage signal at both ends is as small as several hundred micro-volts (μV). In order to facilitate measurement and display, an operational amplifier is used to amplify the voltage signal by about 5000 times and then displayed on the digital voltmeter.

The temperature of the sample is measured with a platinum resistance thermometer. Its resistance will change with temperature with good linearity. During the experiment, the resistance of the platinum resistance is measured with temperature changes. The corresponding temperature can be found from the temperature-resistance table.

The temperature change is obtained by immersing the sample in liquid nitrogen or taking it out of the liquid nitrogen to the room temperature environment. The current and voltage signals of the sample and platinum resistance can be recorded from the digital meters manually or can be acquired by the software automatically.