Non-temperature dependence resistor at low temperatures

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Abstract

We measured the temperature dependence of metal film chip resistors (SUSUMU Co.,Ltd. RR1220 100 Ω , 1 KΩ , 10 KΩ and 1 MΩ) from 45mK to 300K. Although the temperature dependence of these resistors R are not monotonic, the changes in resistance $(R(T) - R(T = 300\mathrm{K}))/R(T = 300\mathrm{K})$ are ~ 1 % (except 1 MΩ). Therefore we can make a filter and a divider without taking the temperature dependence of the resistor into consideration. Below liquid helium temperature, the resistance of the chip resistor increase $\log T$ with decreasing temperature. It is expected that the temperature dependence of $\log T$ is due to the Kondo effect.

Key words: Resistor; Application; Thermometer; Kondo effect

1. Introduction

The electrical resistance of metallic elements changes with temperature. Therefore some kinds of resistor made by metal or semiconductor has been used as a secondary thermometers [1]. Although the thermometers are useful for our experiments, in the case that used the resistors for a circuit at low temperatures is inconvenient.

We are groping for the application of a single electron transistor (SET) [2]. The temperature dependence of SET resistance depend on oxidization conditions in the fabrication process. It is easy to design a circuit that include the SET if the temperature dependence of other circuit elements, a resistor or a capacitor, are small.

In this paper, we are concerned with the resistor with very small temperature dependence. We measured metal film chip resistors R1220 (100 Ω , 1 KΩ , 10 KΩ and 1 MΩ) that were made by SUSUMU Co.,Ltd. [3].

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2. Experimental and Results

The resistance of the metal film chip resistors was measured by PICOWATT AVS-47 resistance bridge from 45 mK to 300 K. The temperature measurments for RuO and Pt100 thermometer were also made with AVS-47.

The changes in resistance are defined as

$$r(T)_R \equiv \frac{R(T) - R_{300}}{R_{300}}, \qquad (1)$$

where R_{300} is the resistance of each resistor at room temperature. Figure 1 shows the variation in $r(T)$ of 100 Ω , 1 KΩ and 10 KΩ , respectively. The variation in $r(T)$ of 1 MΩ is shown in Fig. 2. The resistance of 100 Ω and 1 KΩ was found to decrease from room temperature to liquid helium temperature, and increase $\log T$ with decreasing temperature below liquid helium temperature. The resistance of 10 KΩ and 1 MΩ was found to increase with decreasing temperature, and increase also $\log T$ below liquid helium temperature. The measurement accuracy of the resistance 100 Ω , 1 KΩ and 10 KΩ was 0.1 %, and 1 MΩ was 1 % below liquid helium temperature. The resistance reproducibility of the chip resistor between room temperature and liquid

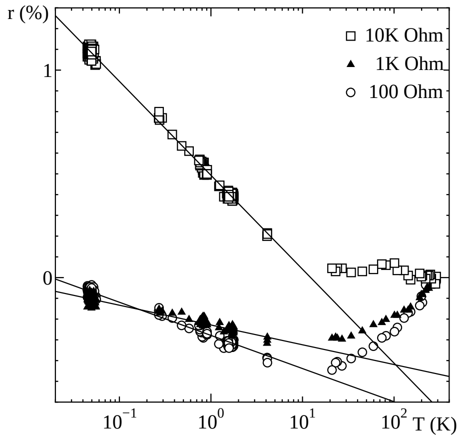

Fig. 1. Variation of $r_{100\Omega}$, $r_{1K\Omega}$ and $r_{10K\Omega}$ plotted against $\log T$. The solid lines are the least square fitting lines below liquid helium temperature.

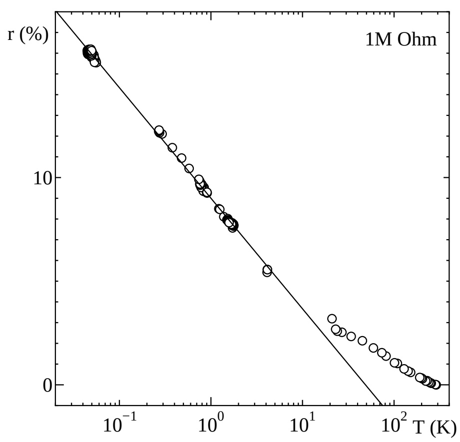

Fig. 2. Variation of $r_{1M\Omega}$ plotted against $\log T$. The solid line is the least square fitting line below liquid helium temperature.

helium temperature was 0.01 % in 100 Ω , 1 KΩ and 10 KΩ , and 0.1 % in 1 MΩ . We checked the thermal cycle at five times. These reproducibility of the resistance are extremely small.

It was found that the temperature dependence of the resistor at low temperatures becomes large with increasing the nominal value of the resistor. Specifically, the $r(T)$ of 100 Ω and 1 KΩ were -0.1 %, 10 KΩ was 1.1 % and 1 MΩ was 16 % at 45 mK, respectively. It is shown for comparison that the $r(T = 1K)$ of a discrete type metal film resistor which usually used to make a circuit is a few hundred percent. What is important is the $r(T)$ of the chip resistor 100 Ω , 1 KΩ and 10 KΩ are only ~ 1 % from 45 mK to 300 K. The variation of these resistors are comparable with the resistance tolerance. Therefore we can make a filter and a divider without taking the temperature dependence of the resistor into consideration.

We have only limited information on the chip resistor. Then, we cannot say for certain whether the small temperature dependence comes from the material or mechanical dimension, especially thin film ($0.1 \sim 0.01$ μm), of the resistor. Below liquid helium temperature, however, the temperature dependence of $\log T$ is explained due to the Kondo effect caused by the scattering electrons for the magnetic impurities. In fact, the variation of the resistor 100 Ω and 1 KΩ in Fig. 1 shows the typical resistance minimum of the kondo effect. Because of lack of definite information on the material of the chip resistor, as we have seen, it is difficult to discuss the temperature dependence in detail.

In this paper, we mentioned the resistor with very small temperature dependence, practically non-temperature dependence resistor. If there is a capacitor that is not dependent on the temperature, it is more useful for the application circuit at low temperatures. Experiments for the non-temperature dependence capacitor are now being carried out.

Acknowledgements

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References

[1] See, for example, Guy K. White, *Experimental Techniques in Low-Temperature Physics*, Oxford Univ. Press, UK, 3rd ed. P.74.

[2] A. Iwasa, A. Sato, accepted for 2002 Conference on Precision Electromagnetic Measurements Digest.

[3] You can get the specification of the resistors from http://www.susumu.co.jp.