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APPLICATION OF A SILICON LINEAR THERMOMETER FOR SUPERCONDUCTING TRANSITION TEMPERATURES MEASUREMENTS

ПРИМЕНЕНИЕ КРЕМНИЕВЫХ ЛИНЕЙНЫХ ТЕРМОМЕТРОВ ДЛЯ ИЗМЕРЕНИЙ ТЕМПЕРАТУРЫ ФАЗОВОГО ПЕРЕХОДА В СВЕРХПРОВОДНИКАХ

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The use of forward biased semiconductor diodes as temperature sensors over a wide range of temperatures has previously been reported [1, 2, 3]. However, within the liquid helium and hydrogen temperature range the thermometric characteristics (voltage drop at a constant forward current) are generally non linear even for commercially available thermometric diode sensors [4], recommended for the 4.2 K to 400 K range.

On the other hand, if suitable technology is used (a heavily doped semeconductor substrate with a sharp transition profile of the impurity concentration), the diodes exhibit a linear *V—T* (voltage-temperature) dependence in the very low temperature region [5]. The temperature dependence of the voltage drops at a constant forward current of a silicon thermometric diode *DTS* 105 (made from a *p-n* structure used in the production of the planar silicon diode KB 105) in the region of 1 K to 25 K may be expressed by the linear equation

$$U_f = U_0 - \beta T\,,$$

where U_0 is the current dependent constant ($U_0 \cong 1.352$ V/100 μA) and β is the current independent temperature sensitivity ($\beta \doteq 8$ mV/K).

Such a sensor may be used as a very convenient thermometer since it enables a direct recording of temperature depencences by means of an *X-Y* recorder.

In our case we have applied this thermometer to the determination of the transition temperature characteristics of Nb_3Sn superconducting tapes by direct measurements of the loss of resistance [6, 7].

The apparatus which we have used is actually a simple cryostat shown schematically in Fig. 1.

Before the measurement, the whole cryostat is filled by He gas up to the atmospheric pressure. During the measurement a constant pressure of 10^{-2} Torr is being kept by the rotary vacuum pump. The whole apparatus is of course kept immersed in the LHe bath.

The temperature change speed rate for the interval 4.2 K to 20 K is less than 10 sec with a simultaneous thermal stability better than ±0.02 K. The linear sensing element enables direct recording of temperature dependences by means of an *X-Y* recorder. The differential ability of the graphical record of the apparatus is at the same time better than ±0.03 K.

A very low sample holder mass, a good transfer of heat from the heater winding into the sample holder through direct contact as well as through the residual He-gas of 10^{-2} Torr, guarantee a very low

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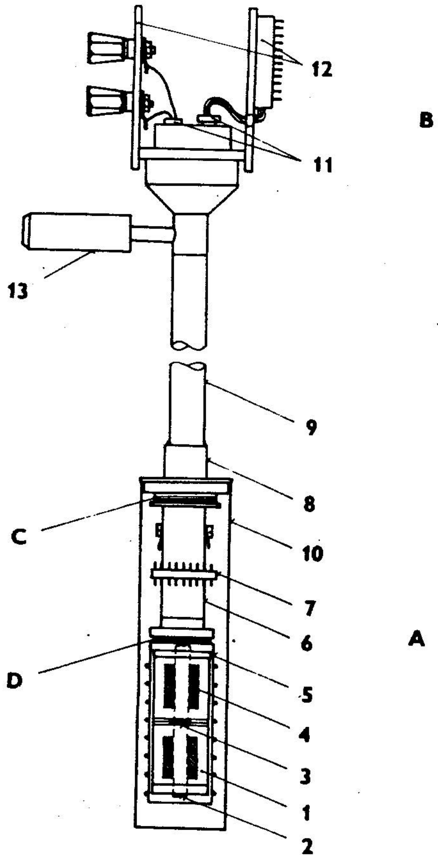

Fig. 1. Schematic diagram of apparatus. A — lower measuring part of cryostat, B — upper terminal part of cryostat, C — sample current leads (Cu, 0.4 mm o.d.), temperature anchored at liquid helium temperature on the sample holder flange, D — sample current leads (Cu, 0.1 mm o.d.), sample voltage leads and thermometer leads (Cu, 0.1 mm o.d.), temperature anchored directly on the sample holder copper block. 1 — sample holder (cylindrical plug of copper 19 mm o.d. and 65 mm in length), 2 — accurate Pt-thermometer, 3 — Si-thermometer, 4 — measured samples isolated from the copper block, 5 — can of tombak with heating wire (manganin 0.1 mm o.d., 100 Ω), 6 — teflon plug, 7 — terminals, 8 — brass flange, 9 — stainless steel tube, 10 — tombak jacket, 11 — vacuum feed through, 12 — terminals.

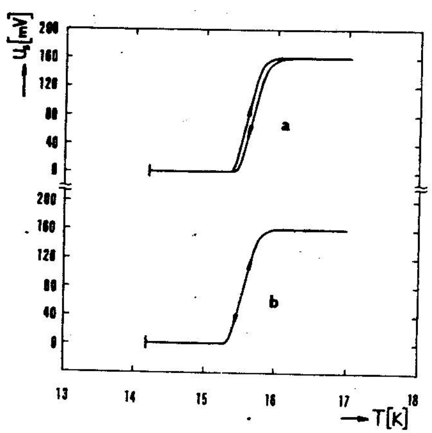

Fig. 2. The transition temperature curve of superconducting tape measured in the apparatus of Fig. 1. a) sudden switching on and off of full heating power 0.46 W; b) heating power increasing gradually from 0 to 0.46 W during time period of 1 min.

thermal inertia of the apparatus with a simultaneous excellent thermal stability which does not require stabilization by an electronic controller.

The measured tape samples 4.20 mm in length and 2 mm to 3 mm wide were glued with GE 7031 varnish [8] to the tissue paper of the copper sample holder 1 so as to establish a good thermal contact. The current and voltage leads were soldered with indium to the samples, the voltage leads being separated by about 10 mm to 15 mm. The measuring current of the samples was 1 mA, the sample voltage has been brought through an amplifier to the y-axis terminals of the X-Y recorder. The signal from the linear thermal sensing element (the thermometric Si-diode) has been brought to the x-axis terminals directly. The sensitivity of the sensing element was 8 mV/K in the temperature interval 4.2 K to 25 K. As a result, the temperature recording on the x-axis has been performed with a sensitivity of 25 mm/K. Transistor regulated power supplies have been used for feeding both the thermometers and the measured sample as well. The current of the Si-thermometer was 100 μA, the current of the Pt-thermometer was 1 mA.

A graphical record of the measured superconducting transition curve is shown in Fig. 2a and Fig. 2b as a dependence of the sample voltage versus the sample temperature. The curve of Fig. 2a has been obtained by a sudden switching on and off of the full heating power of 0.46 W so as to heat the whole measuring assembly from 4.2 K to 20 K with the heating time being equal to about 10 sec (i.e. 1.6 K/sec). A similar diagram for the sample is in Fig. 2b. In this case the heating power has been increased to the value of 0.46 W and decreased gradually with the duration time period of 1 min (i.e. 0.25 K/sec). As it is seen from the diagrams, the thermal inertia of the measuring device is real minimal.

We have shown that one of the important regions for the applications of silicon thermometric diode sensors could be also the region of measurements of superconducting transition temperatures T_c. The linear V—T dependence of a silicon thermometer in the temperature interval 4.2 K to 25 K enables very convenient and comfortable measurements of the T_c-s mentioned above.

REFERENCES

[1] McNamara A. G., Rev. Sci. Instrum. *33* (1962), 330.
[2] Sclar N., Pollock D. B., Sol. State Electronics *15* (1972), 473.
[3] Cohen B. G., Snow W. B., Tretola A. R., Rev. Sci. Instrum. *34* (1963), 1091.
[4] Lake Shore Cryotronics Inc., *Short Form Catalogue*.
[5] Janšák I., Kordoš P., Bláhová M., Inst. Phys. Conf. Ser. *26* (1975), 65.
[6] Cooper J. L., RCA Review *25* (1964), 405.
[7] Webb G. W., Vieland L. J., Miller R. E., Wicklund A., Sol. State Commun. *9* (1971), 1769.
[8] Stephens R. B., Cryogenics *15* (1975), 420.

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