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Multisample Data Acquisition System for Resistance Measurement of High-temperature Superconductors

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ABSTRAK

Pembinaan satu sistem pengukuran rintangan superkonduktor suhu tinggi berbilang sampel secara serentak dilaporkan. Sistem perolehan data ini menggunakan kad geganti PCLD785B yang dikawal menggunakan input-output selari emulasi 8255A PIA melalui kad PCL724B untuk melaksanakan ujian berbilang sampel dalam masa serentak melalui kalihan isyarat. Sistem yang dikawal oleh mikrokomputer 80486 ini berupaya mencatat, menyimpan dan memplot graf bagi bacaan-bacaan suhu melawan rintangan dan dapat diubahsuai untuk menguji sehingga enam sampel secara serentak. Suhu boleh diukur dengan kepersisan 0.1 K dan ketepatan ±1 K. Nilai imbangan sifar-mutlak adalah kurang daripada 0.1 K. Nilai voltan maksimum, arus maksimum dan rintangan pengasingan salur terbuka adalah masing-masing 125 V, 2 A dan 100 MΩ. Nilai rintangan saluran tertutup adalah kurang dari 1Ω setiap saluran dan ofset terma saluran kurang dari 5 μV. Tempoh diam minima 1 s digunakan kerana mengambil kira masa operasi geganti dan tempoh lepasnya dan juga untuk membolehkan bacaan jangkasuhu dan pengawal untuk menetap pada setiap perubahan saluran. Pengukuran rintangan melawan suhu bagi superkonduktor $RBa_2Cu_3O_{7-\delta}$ (R=Y dan Er) dan variasinya telah dijalankan dan dibandingkan dengan keputusan yang terdahulu.

ABSTRACT

The construction of a system for simultaneous multiple sample resistance measurement of high-temperature superconductors is reported. The data acquisition system uses the PCLD785B relay board controlled by parallel input-output 8255A PIA emulation through a PCL724B card to perform multisample measurements by signal switching. The system, which is controlled by a 80486 microcomputer, is able to log, store and plot temperature and resistance readings and can be modified to accommodate up to six samples per run. The temperature can be measured with a precision of 0.1 K and accuracy of ±1 K. The absolute-zero offset value is less than 0.1 K. The maximum switching voltage, maximum current and open channel isolation resistance are 125 V, 2 A and 100 MΩ, respectively. The closed channel

Resistance measurement was done using the 4-point-probe technique. A LakeShore dc current source (Model 120 CS) was employed. The voltage across the sample was measured by Keithley Model 197 (5 ½ digit) digital multimeter (DMM) connected through the IEEE-488 interface to the computer. A second DMM was used to measure the resistance across the platinum resistor temperature sensor.

The current on/off switching and multisample switching were achieved using the PCLD785B 24-channel relay output board connected to a PCL724B, which is a 24-bit digital I/O card using a 50-pin OPTO-22 connector. Each channel of the PCL724B card has single pole, double throw (SPDT) relay switches each with a normally closed (NC) and normally open (NO) terminal. The relay operates for a TTL low on the input and releases for a TTL high. The maximum switching voltage, maximum switching current and open channel isolation resistance are 125 V, 2 A and 100 MΩ, respectively. The closed channel resistance is less than 1 Ω per pole and channel thermal offset is less than 5 μV. A minimum scan dwell time of 1 s was used to accommodate the relay operation time of 8 ms and a similar release time to allow the thermometer and controller to settle on channel changes.

In our configuration we used only the NC terminals of the relays for electrical contact to prevent any open circuit voltage and magnetic mechanism of the relay from contributing noise to the system. The samples were connected to the DMM and current source through the relays (*Fig. 1*). In this configuration, a total of four NC output of the relays were used for each sample. The system can be easily programmed for a specific scan sequence and can also accommodate up to six samples per run. *Fig. 2* shows the 4-wire switching configuration which allows current to be sourced to two closely spaced samples, one at a time and

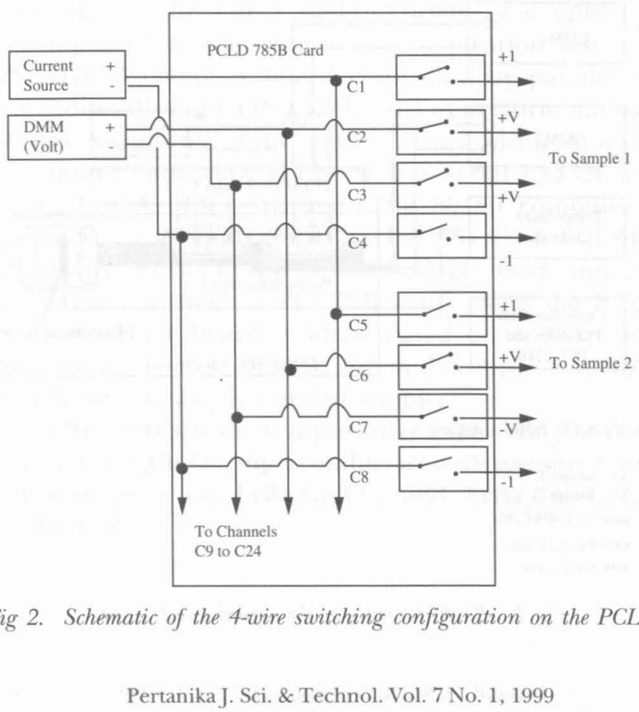

Fig 2. Schematic of the 4-wire switching configuration on the PCLD785B card

simultaneously reading the voltage drop across each sample. The sample holder was made from oxygen-free high conductivity copper (OFHC) material from LakeShore Cryotronics, USA, which has a very high thermal conductivity (500-550 $W/m^{-1}.K^{-1}$) to ensure uniformity of temperature between samples.

Experimental Procedure

Two samples were mounted on a copper sample holder attached to the cold head of the cryostat. The distance between the current leads was about 10 mm and the distance between the voltage leads about 5 mm. Silver conductive paint was used for electrical contact and a 30 mA direct current was used. A typical value of voltage across the sample at room temperature was 200 μV.

Resistance was measured between 78 - 300 K. During a particular acquisition cycle, the sample temperature T was increased at a specified rate (for example 5 K/min). The system can be programmed to log in data for a specified temperature interval (for example, 3 K) or changes in voltage (for example, 2 μV) across the sample. Since the relay operation and release time were around 8 ms, the appropriate delay time was introduced before each measurement was made. The computer then switched the electrical connections to the next sample where the corresponding (T, V) values were measured. During the measurement, a voltage-temperature curve was plotted on the computer screen along with a numerical display of the data (T, V). The software flow diagram is shown in *Fig. 3.*

RESULTS AND DISCUSSION

The powder X-ray diffraction (not shown) of the $YBa_2Cu_3O_{7-\delta}$ and $Y(Ba_{0.9}Ca_{0.1})_2Cu_3O_{7-\delta}$ indicates a single phase, orthorhombic "123" phase belonging to the space group P4/mmm . The $ErBa_2Cu_3O_{7-\delta}$ and $ErBa_2Cu_3O_{7-\delta}$-Ag composite also showed a dominant "123" phase.

Fig. 4 shows the normalized resistance versus temperature curve for $YBa_2Cu_3O_{7-\delta}$ and $Y(Ba_{0.9}Ca_{0.1})_2Cu_3O_{7-\delta}$ samples. Both curves showed metal-like normal state behaviour. The measurements on $YBa_2Cu_3O_{7-\delta}$ are comparable to earlier reports (see, for example, Kirkup 1988) with onset temperature ($T_{c\ onset}$) 92 K and zero-resistance temperature ($T_{c\ zero}$) 89 K. The $T_{c\ onset}$ of $Y(Ba_{0.9}Ca_{0.1})_2Cu_3O_{7-\delta}$ was 89 K and $T_{c\ zero}$ 80 K. Work on the effect of Ca doping on the Ba site in $Y(Ba_{1-x}Ca_x)_2Cu_3O_{7-\delta}$ is in progress and will be reported elsewhere.

The curves for both the pure $ErBa_2Cu_3O_{7-\delta}$ and $ErBa_2Cu_3O_{7-\delta}$-Ag composite also showed metal-like normal state behaviour (*Fig. 5*). The $ErBa_2Cu_3O_{7-\delta}$ sample had $T_{c\ onset}$ of 91 K and $T_{c\ zero}$ of 88 K. The measurements on $ErBa_2Cu_3O_{7-\delta}$ were comparable to earlier reports (Maletta *et al.* 1989; Bichile *et al.* 1990). The $ErBa_2Cu_3O_{7-\delta}$ Ag composite showed significantly higher $T_{c\ onset}$ (95 K) and $T_{c\ zero}$ (90 K). The oxygen content (calculated using results from Bichile *et al.* 1990) of the pure $ErBa_2Cu_3O_{7-\delta}$ sample was approximately 6.9. The increase in T_c of the $ErBa_2Cu_3O_{7-\delta}$ - Ag composite may have been due to a slight increase in the oxygen content (slightly above 6.9) due to the addition of Ag. This seems to be consistent with increase in oxygen intake as a result of Ag addition in $YBa_2Cu_3O_{7-\delta}$ (Moya *et al.*

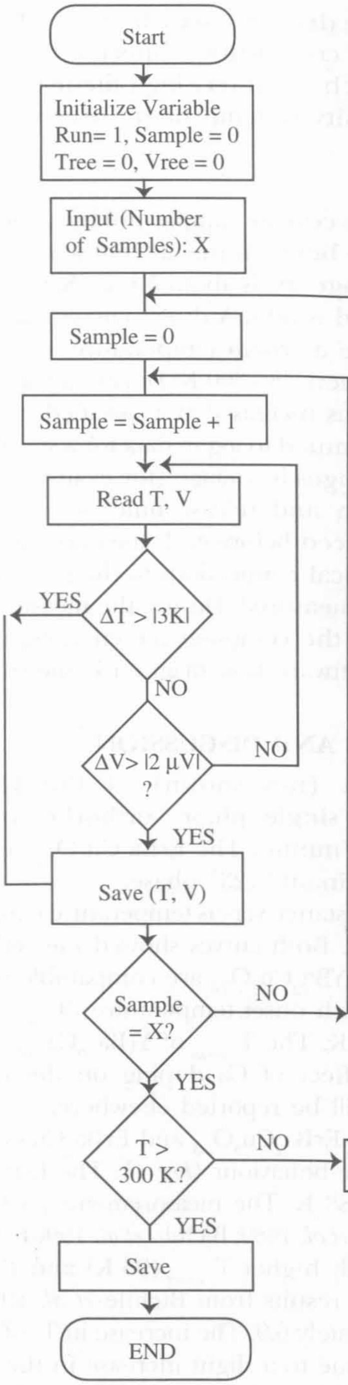

Fig 3. Logic flow diagram of the data acquisition system

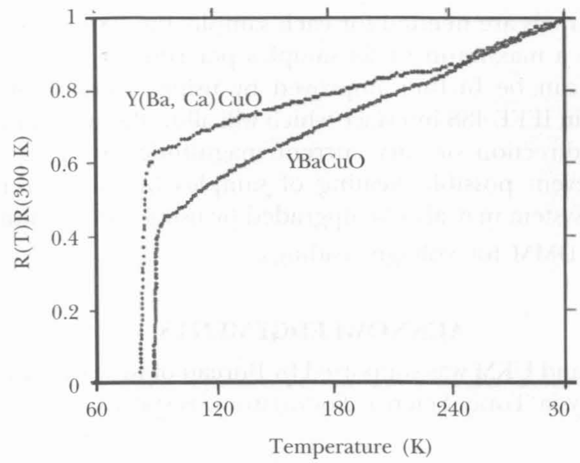

Fig 4. Normalized resistance versus temperature of $YBa_2Cu_3O_{7\text{-}\delta}$ *and* $Y(Ba_{0.9}Ca_{0.1})_2Cu_3O_{7\text{-}\delta}$

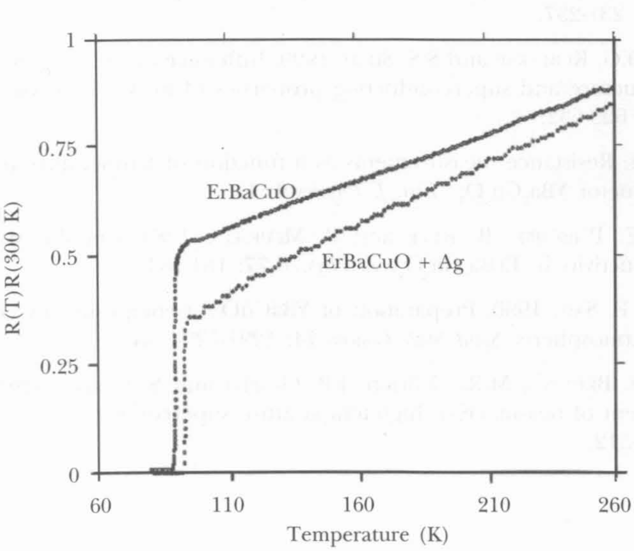

Fig 5. Normalized resistance versus temperature of $ErBa_2Cu_3O_{7\text{-}\delta}$ *and* $ErBa_2Cu_3O_{7\text{-}\delta}$ *- Ag composite*

1990). Further investigations on the effect of Ag in $ErBa_2Cu_3O_{7\text{-}\delta}$ are in progress and will be reported elsewhere.

The data acquisition system was able to detect minute variations in the resistance profile and transition temperature (± 1 K) of high temperature superconductors. These results indicate that the low-cost relays on the PCLD785B 24-channel relay output board did not introduce any noise detrimental to the low temperature measurement when used in the above configuration. Since a total of four channels are needed for each sample, the system can be expanded to accommodate a maximum of six samples per run.

The system can be further improved by using a programmable current source with built-in IEEE-488 interface which will allow the system to automatically reverse current direction or vary current magnitude during a thermal scan, which could prevent possible heating of samples by the current leads. The sensitivity of the system may also be upgraded by using a nanovoltmeter in place of the 5 ½ digit DMM for voltage readings.

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