An Automation Software for ECR Experiment at Cryogenics Temperatures

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ABSTRACT

Low temperature offers an exciting opportunity to understand physical properties of various material and process. Electrical contact resistance which is fairly understood at room temperature behaves in entirely difference way at temperatures below the room temperature. Estimation of contact resistance and its behavior at low temperatures is not only necessary for its application areas but for understanding the contact mechanism and controlling the contact resistance. Low temperature experiments are highly time-consuming, due to the inherent thermal design of these systems, which takes a lot of time to stabilize. Automation of these experiments not only eases the experimentation but also improve the result accuracy.

Introduction

Extensive work has been done in the area of measurement of thermal and electrical contact resistance below ambient temperature. The field of thermal contact resistance is driven primarily by its applications in space technology and superconductivity. Kittel, et al (1994), Zhao, et al (1999), Sunil Kumar, et al (2004) and Xiao (2004) have reported their work on thermal contact conductance tests under low temperature and vacuum. Xu, et al (2005) investigated the thermal contact conductance (TCR) of stainless steel (SS-304) over the temperature range of 125-210 K.

Electrical contact resistance measurement is important for many area besides space and superconductivity domain. Now a day's many high-end applications, sophisticated electronics devices like night vision camera etc, are being operated below ambient temperature to improve their performance. The availability of cryogens, improvement in Thermo-Electrical (TE) based Peltier coolers, accelerated development of these devices. In designing such systems, an accurate measurement of electrical contact resistance below room temperature is very important.

Tamai, et al (2001) studied the electrical contact resistance across copper-copper, zinc-zinc, tungsten-tungsten and gold-gold wire at cryogenic temperatures. These wires are of 1 mm diameter and 20 mm length with load range between 1 - 100 gf. Fujita, et al (2005) measured the contact resistances between two bulk YBCO superconductor blocks for their application to a persistent current switch. Puntambekar, et al (2007) measured the electrical contact resistance of super conducting magnet close loop wire. Current is injected in the loop/coil and the decay current is measured through the voltage signal of hall probe, which is a function of loop resistance. No external load was applied and contact resistance of 4 nΩ per joint is obtained at 4.2 K

Electrical contact resistance

When two surfaces are pressed together, the contact is imperfect, because the real surfaces are not perfectly smooth but consist of microscopic peaks and valleys. When two such real surfaces are placed in contact, solid-to-solid contact occurs only at a few discrete points of the interface and the real contact area will be a very small fraction of the nominal contact area. The electrical current flux lines, which are parallel at a distance from the interface, become increasingly distorted as the contact interface is approached limiting the current to pass through small area or spots, These spots, termed *a-spots*, are small cold welds providing the only conducting paths for the transfer of electrical current. This leads to contact resistance.
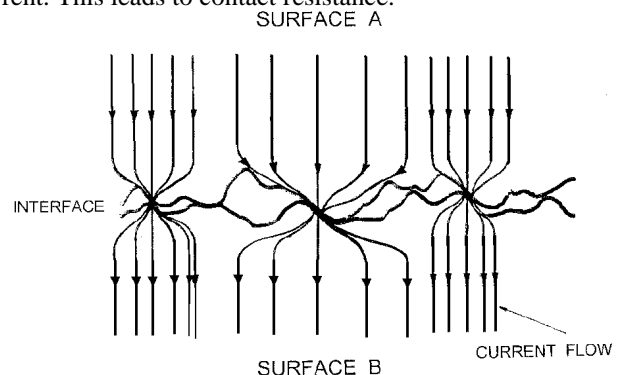

Fig. 1: Current flow through contact resistance
Experimentation Setup

The measurement of Electrical Contact Resistance at low temperature poses various design challenges. At room temperature at variable contact force it is convenient to measure contact resistance by using four-probe method. For low temperate the basic four-probe method remains the same but rest all design parameter radically changed. The setup require cryostat to contain and maintain the inventory of liquid nitrogen, cooling mechanism to reduce the temperature of sample through

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conduction, high quality vacuum system inside which the contact members are kept, and loading mechanism to exert the designed range of contact force, to be usable under vacuum and under low temperature. The commonly used four-probe method is needed to be more sophisticate so as to take care of temperature variation of the order of -250ºC exists between the measuring sample and equipment.
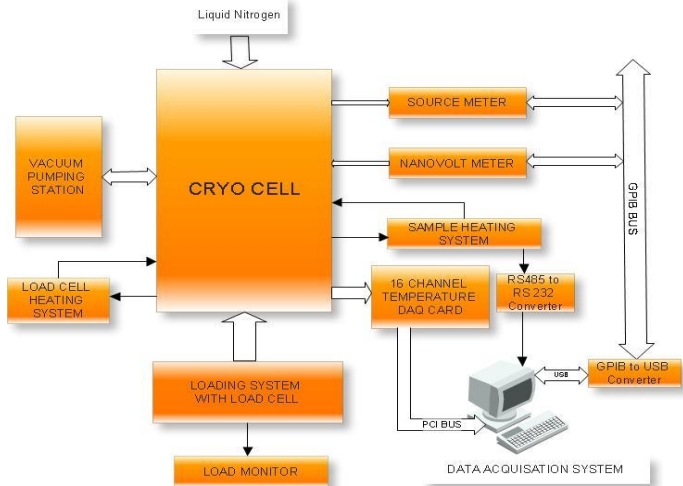
The entire experimental station is design and built in house. There no such other system was developed earlier, the mechanical design, cryogenics design, electronics and instrumentation everything were designed and developed locally. Such custom built system all necessitate the development of software also in house. The final software reported here has gone through many revision of as other subsystems were also developed concurrently.

The experimental set up consists of five subsystems viz.

- Cryostat
- Loading Mechanism
- Sample Stack (mounted inside cryostat)
- Vacuum system
- Instrumentation

Fig. 2: Experiment Chamber with inner cryostat vessel lifted up

The cryostat with inner vessel which containns the liquid nitrogen is shown in Fig-2. A small tip at the bottom of inner vessel is cold tip made of OHFC copper and is in direct contact with liquid nitrogen. The samples mounted on the sample stack are cooled with cryostat and the load is applied through the loading mechanism from the bottom of the chamber.
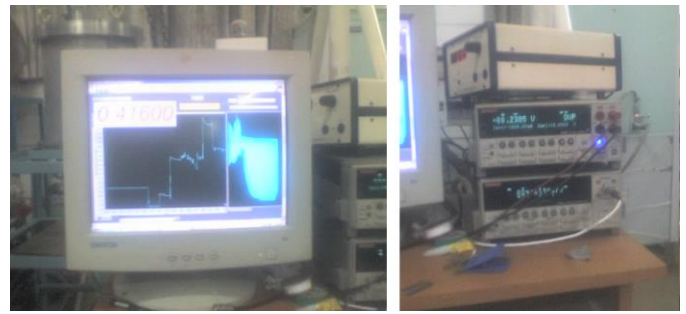

Fig. 3: Experiment Instrumentation setup

Software Description

The measurement of contact resistance, contact force and temperatures inside the chamber are done by a large number of sensors and instruments. These can be primarily divided in to five sub-groups.

- Contact Resistance Measurement
- Contact Force Measurement
- Temperature Measurement
- Temperature Control
- Low Pressure Measurement

The Data Acquisition Software controls and monitors all these parameter and keep log of all the parameter and events for the post-experiment analysis. The Control software for automation of experiment during operation is developed in National Instruments LabVIEW® v7.1 software. Data acquisition and data analysis are the center of this system, both of which are achieved with the use of LabVIEW.
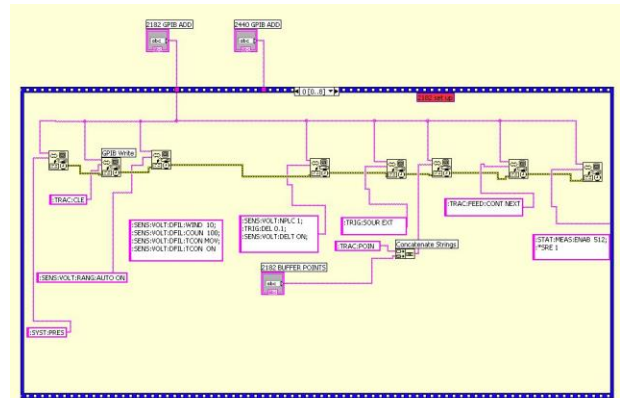

Fig. 4: Controlling the Combo Operation of Source Meter and Nano-Voltmeter over GPIB

The GPIB based instruments for contact resistance measurment are connected to PC using a GPIB to USB converter. The temperature data coming from multiple thermocouples is fed to a PCI based add-on card (PCI-DAC-TC) from Measurement Computing Corp. The communication with WEST PID is native RS485. It is interfaced with the same PC on RS232 port by using an RS485-RS232 converter. Recording the process parameters coming from temperature data coming from six temperature sensors at sample (three each from top sample and three from bottom sample). The program also receiving and record the set-point temperature value and resulting temperature reading at the heater warped at load cell via PID Controller. The closed loop to maintain the temperature of load cell was looked after by the PID controller.

To mitigate the effect of frequent power outrage the process data was stored after each sample. The data is saved as a text file as well as excel file format with the log file information. The log file contains the details of sample and experimental conditions as good experimentation practices. After each sample, the trend

graph is updated with latest value of contact resistance shown in very large font size. This value is obtained by relating the source current with the nanovoltage read. The combo mode of operating is needed at low temperature to eliminate the thermo emf effect on the measurement. The source meter current can be altered at any time during the experiment from within the software program by remote control operation of Agilent source meter.
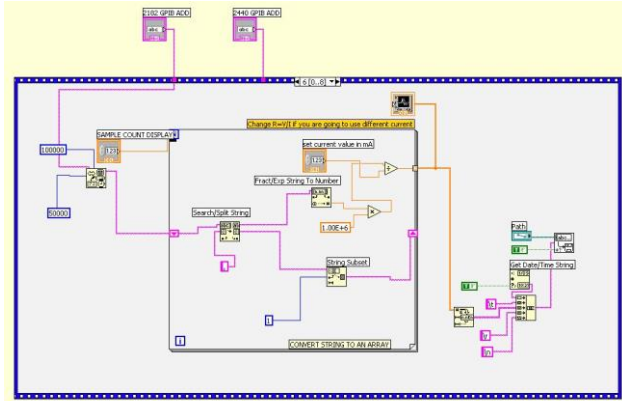
Fig. 5: Combined Data Collection and Storage

Fig. 4 and Fig. 5 shows the partial view of LabVIEW block diagrams, which determine the flow of control software. Error handling is an important task and in a system configuration like this one where multiple devices are connected at different port (RS-232, GPIB) the non response of any attached device is reported to user without interrupting the program execution for other devices. Fig.6 is screenshot while the ECR measurement is in operation. The state of the system is monitored using continuous DAQ at the sampling rate of one second. All the component of experiments was controllable from this software. This helped simple design and Flexible operation of setup.

Fig. 6: Screenshot of ECR measurement window

Results & Conclusion

The software was tested for experimentation on continuous basis for several days and experiments were performed on about 30 different samples. Each process point where temperatures,

contact resistance and applied load are variable, is collected only after attending the thermal stability which normally takes 5 or more minutes to stabilize. Thus each experiment runs for about eight-ten hours continuously with the help of this software.

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