FURTHER IMPROVEMENT IN RESIDUAL RESISTIVITY RATIO MEASUREMENT FACILITY AT RRCAT

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Abstract

This paper presents further improvement in Residual Resistivity Ratio measurement (RRR) facility at RRCAT. This facility is meant to characterize and evaluate Niobium (Nb) used in manufacturing of Super-Conducting Radio Frequency (SCRF) cavities. The new improved setup incorporates automated Data acquisition (DAQ), analysis and presentation system. The DAQ system has been designed using General Purpose Interface Bus (GPIB-IEEE 488.2). The real time communication protocol under the windows environment is implemented using National Instruments LabVIEW software platform.

The paper also describes the RRR test set-up and the measurement procedure. The calibration of modified system was done by re-measuring the Nb samples tested at Fermi Lab, USA, and the test results are also presented.

INTRODUCTION

For optimal performance of SCRF cavities it is important to ensure and maintain the purity and integrity of the parent material throughout the SCRF cavity manufacturing cycle. The RRR measurement of Nb is one of the popular and most convenient techniques for gross qualification of bulk Nb material obtained from various sources and to monitor material quality throughout its manufacturing and processing stages. RRCAT Indore, had successfully developed two prototype 1.3GHz β=1.0 single cell SCRF cavities. These very first cavities were tested at Fermi-Lab have achieved an accelerating gradient of 20MV/m and a quality factor of 1.5e10 [1]. This RRR measurement facility will be very useful in the effort of taking the accelerating gradients to the designed values (>35 MV/m). The facility also supports the ongoing effort to develop high RRR Nb indigenously by Nuclear Fuel Complex, Hyderabad.

Previously RRR measurements our performed by manually acquiring the data [2]. This was quite exhaustive requiring two man-day for testing a single sample with disadvantage of human error involved due to fatigue in manual acquisition of multiple parameters for a prolonged time. In order to reduce the test cycle time, manual errors and uncertainties in measurement, an automated DAQ system was conceived and developed for the RRR measurement facility.

EXPERIMENTAL SET-UP

In our system, RRR is measured using temperature method, which is simpler and becomes feasible with the use of a thermostatic tank (standard liquid helium Dewar) with almost negligible consumption of liquid helium.(Figure-1) We have followed most widely accepted definition of RRR of Nb by international research laboratories. RRR is defined as the ratio of the resistance of sample at room temperature (300K) and resistance at temperature just before its superconducting transition (~10K for Nb) [3].

The resistance measurement is performed using a standard four-probe method. Current is fed by a stable DC source (Keithley 2611 source meter) and voltage is read through Keithley 2182 voltmeter (resolution of 1n-volt). Temperature is sensed using DT-470 silicon diode and is monitored through Lakeshore 218s temperature monitor. It is required to acquire resistance of the sample under test as function of temperature for RRR evaluation.

A four-channel DAQ system is developed to acquire current, voltage drop and temperature at both ends of the sample under test to ensure uniformity of temperature.

Figure -1: Experimental set up

Hardware description

A parallel interface standard GPIB IEEE 488 was deployed for the DAQ system. Looking at the simplicity to design and implement with the easiness for adding additional instruments, star type network topology was adopted [Figure-2]. This also limits the effective length of data cable thus ensures faster data transfer rate. The instruments are connected to a GPIB interface card by double shielded GPIB cable. These shielded cables provide better electrical isolation, reliable & faster Data transfer rates with reduced susceptibility to electrical interference caused by nearby equipment or wires. These cables are terminated on a GPIB multi-connect box in order to avoid excessive mechanical stress on electrical contacts at a particular junction. The GPIB interface card was connected on the peripheral component interconnect (PCI) bus of the computer working as the controller. The complete data acquisition activity is programmed using LabVIEW software.

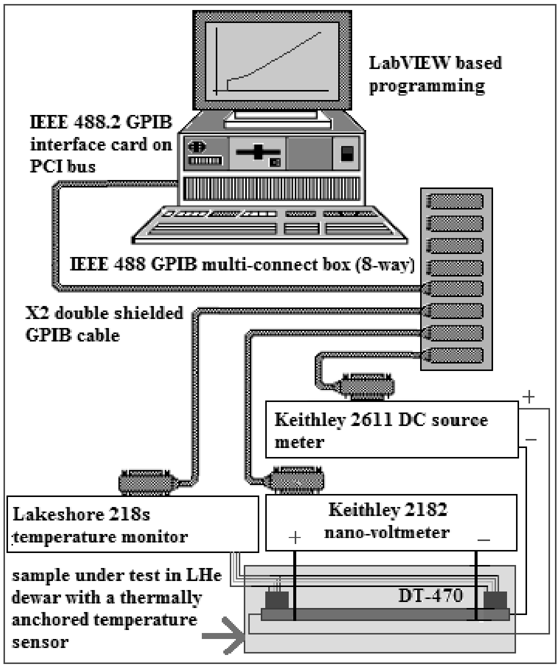

Figure -2: Schematic layout of the DAQ system.

Measurement procedure

After interleaving the test insert in the LHe Dewar the complete test cycle is operated in a sequential mode. The controller using a labVIEW code checks connectivity for remote communication with all the instruments. The code list out all the instruments connected through GPIB bus with their respective address. After that, configuration of instruments is done as per the requirement by execution of their respective initialization and configuration codes [4].

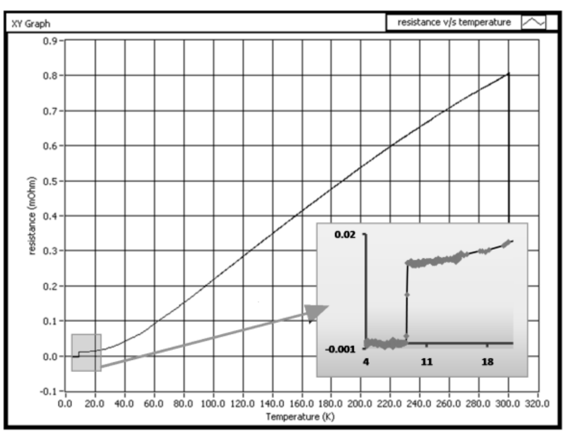

Figure-3: Acquired R-T plot of Nb sample

The instrument & power supply settings are derived from the sample size available. Length to cross section area is maintained ~5.33e-3 per meter. The current levels are kept optimum balancing the signal to noise ratio of voltage signal with the thermal stability issue caused by intrinsic heat generation. Thermal emf is annulled using the auto-null facility available with the voltmeter. To match the thermal time constant of the system, sampling rate is kept low as 0.25 samples per sec per channel. This ensures better thermal stability and uniformity of temperature across the sample during data acquisition. Finally, the RRR measurement code is executed. The data acquired is presented online in the form of resistance- temperature (R-T) graph on the display unit (Figure-3). The data is stored in Microsoft excel format in the user defined locations for future reference.

System calibration & test results

In order to do the system calibration, efforts were made to re-measure the samples tested at Fermi Lab. The test results are tabulated in table-1. The system repeatability was checked by repeated measurements after successive thermal cycling of samples to room temperature.

Table -1: Comparative test results

Sample ID	FNAL Results	RRCAT		
		Result 01	Result 02	Result 03
Oct.09/01	376.2	375.48	374	378.8
Oct.09/02	314	311.88	312	311.6
Oct.09/03	381	372.61	376	374.5
High RRR/01	381	378.48	377	378
High RRR/R1	395	393.7	392	394
weld/ R3	377	384	380	378
weld/ M5	387	390.65	388	385
RRR/L7	392	382	384	384.3
High RRR/L9	386	388.78	394	389
Ti clad/ U1A	99	96.3	98	96.5
Ti clad/ U1B	93.9	95	94	94

CONCLUSION

The improved RRR measurement test facility is operational and the calibration test results have shown good correlation with RRR test results of fermilab (within ±3 %). It is also repeatable within ± 2 % with reduced test cycle time & human interference.

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