DATA ACQUISITION SYSTEM USED IN RADIATION INDUCED ELECTRICAL DEGRADATION EXPERIMENTS – D.P. WHITE (Oak Ridge National Laboratory)

OBJECTIVE

Radiation induced electrical degradation (RIED) of ceramic materials has recently been reported [1-6] and is the topic of much research at the present time. The object of this report is to describe the data acquisition system for an experiment designed to study RIED at the High Flux Beam Reactor (HFBR) at Brookhaven National Laboratory.

SUMMARY

It has been observed [1-6] that some oxide ceramics which have an electric field applied to them while simultaneously being irradiated may undergo a degradation of their insulating properties under certain conditions. An *in-situ* DC conductivity capsule has been constructed to study the effect of neutron irradiation on the electrical conductivity of alumina with an applied electric field at the HFBR. The current capsule differs from a previous design [7,8] in that the current measurements are performed on the low voltage side of the circuit.

The data acquisition system to be described here has been built and will be used to perform the electrical conductivity measurements in an experiment scheduled to begin in October of 1994.

PROGRESS AND STATUS

System Requirements

The phenomenon of RIED is observed to occur at irradiation temperatures within the range 300-600 C [9,10]. Also for RIED to occur it is necessary for the applied electric field to be $\geq 2 \times 10^4$ V/m [9,10]. Under these conditions RIED has been observed to develop at damage doses of from 10^{-5} to 10^{-1} dpa [10].

The capsule to be used at HFBR has three polycrystalline alumina samples. Each sample is supplied with separate high voltage (~100V) coaxial lead lines and separate triaxial return lines. Each sample has a guarded center electrode on the low side necessitating the triaxial return lines. Since an electric field must be applied to the three samples even when no measurements are being made, in this system a matrix switching card (Keithley Instruments model 7153) is used to switch the appropriate sample current to the measurement system.

Alumina which is not in a gamma field has a conductivity of $\sim 10^{-11}(\Omega - m)^{-1}$ at 400 C (the approximate temperature of the samples in this capsule). Conductivities of this order are difficult to measure. However, the gamma dose rate at the HFBR in the V-15 irradiation facility is $\sim 6 \times 10^3$ Gy/s [11]. At this dose rate the conductivity is expected to be $\sim 10^{-7}(\Omega - m)^{-1}$ due to the radiation induced conductivity (RIC) [10,12]. Conductivities of this order are much more easily measured. For the samples in this capsule, which are 0.75 mm thick and have a center electrode diameter of approximately 3 mm and a gap between the center electrode and the guard electrode of 1 mm, this conductivity corresponds to a current through the sample of [13],

$$I = 1.3 \times 10^{-12} V/t \;\; (Amps) \tag{1}$$

where V is the applied voltage (Volts) and t is the sample thickness (meters). As mentioned previously electric fields on the order of $10^5 V/m$ are necessary for the study of RIED. This gives currents on the order of 10^{-7} A for the samples described above which are easily measured with modern picoammeters [14]. For the samples used in this experiment an applied voltage of 75V is necessary to produce an electric field of $10^5 V/m$. The fast neutron flux (E > 0.1 MeV) in the V-15 irradiation facility at the HFBR is $1.5 \times 10^{18} n/(m^2 - s)$ which corresponds to a damage rate in alumina of approximately $1.5 \times 10^{-7} dpa/s$. Thus to obtain doses up to 0.1 dpa will take approximately 8 days of irradiation time. In order to effectively take data over this period of time the data aquistion has been automated.

The data aquisition and control system was required to continuously supply the necessary voltages to the samples and to allow periodic measurements of the conductivity of individual samples via a switching card and the appropriate cable connections. It is also desirable to be able to measure the leakage current of each sample. The leakage current is the surface current which flows from the high voltage side of the sample to the guard electrode. This measurement can be accomplished using the switching card and proper connections to the current measuring unit. The capsule is also supplied with several K-type thermocouples which allow the constant monitoring of the sample temperatures. All of the individual components of the system are controlled via computer over a GPIB bus.

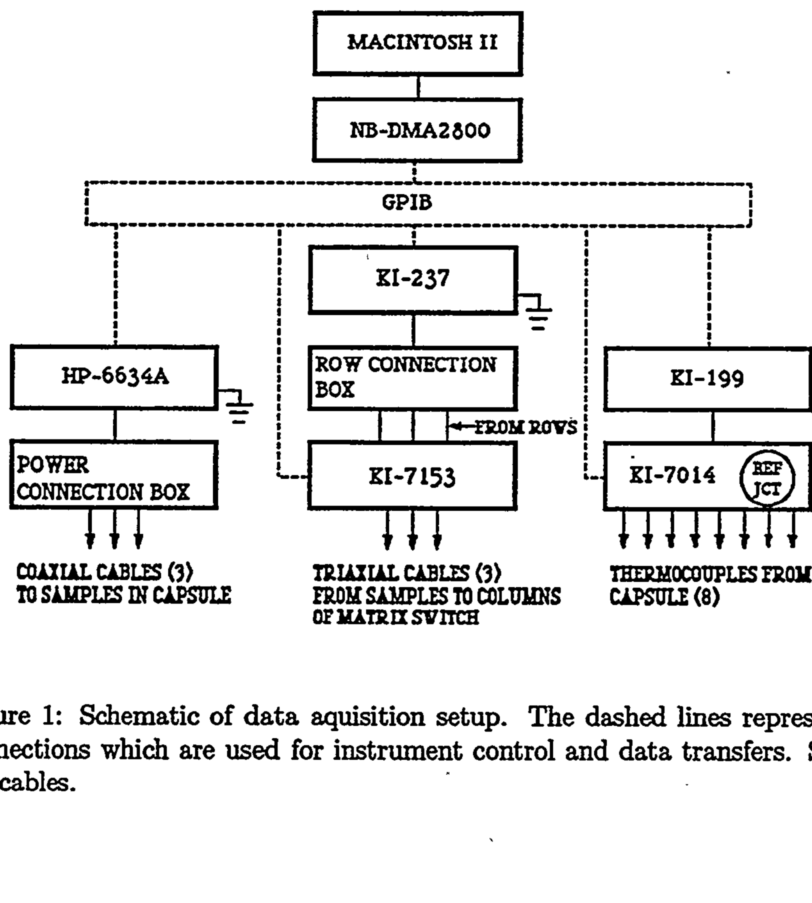

Figure 1: Schematic of data aquisition setup. The dashed lines represent GPIB connections which are used for instrument control and data transfers. Solid lines are cables.

System Details

The power is supplied to the samples by a Hewlett-Packard model 6634A power supply which is capable of supplying up to 120V at 1A. The switching system consists of a Keithley Instruments Model 7001 High Density Switch System with a Model 7153 4×5 high voltage low current matrix card and a Model 7014 thermocouple multiplexer. The current measuring unit is a Keithley Instruments 237 source-measure unit used in measure-only mode. The thermocouple voltages and reference junction voltage are measured using a Keithley Model 199 multimeter. All of these instruments are GPIB (IEEE-488) compatible and are controlled and programmed with a Macintosh IIci computer containing a National Instruments NB-DMA2800 GPIB interface board. This GPIB interface allows data transfers between the computer and the instruments so that all the data are stored on disk. The programming is accomplished using National Instruments LabVIEW II software.

A schematic of the system setup is shown in Fig. 1. The power connection box provides 3 coaxial connections to the power supply for the 3 samples. The 3 triaxial data leads are connected to the columns of the matrix switch card and 3 rows are connected to the row connection box. A schematic of the row connection box is shown in Fig. 2. When the switches on the matrix card are configured

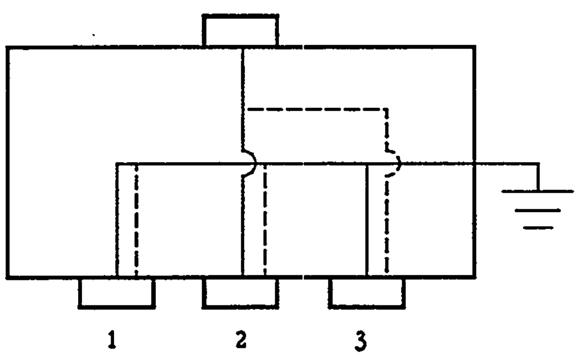

Figure 2: Schematic of row connection box. The solid lines represent the center electrodes of the triaxial cables and the dashed lines represent the guard sheaths.

to connect the three samples to input 1 of the row connection box the data lines go to ground. This is the configuration used when no measurements are being made. When any one sample is connected to input 2 through the matrix card that data line goes to the KI-237 and a current reading is taken allowing a determination of that sample's conductivity. The guard ring of the sample (which is carrying the leakage current) connected to input 2 is routed directly to ground. When any one sample is connected to input 3 through the matrix card the guard ring current (leakage current) goes to the KI-237 for measurement and the center lead goes to ground. Thus by opening and closing various switches on the KI-7153 matrix card (all switch control is handled by the computer) both bulk current and leakage current for all 3 samples may be measured. This system is also capable of measuring the surface resistance between the center and guard electrode. This is accomplished by using the KI-237 to apply a moderate voltage to the center electrode of a sample (after turning off the HP-6634A) through input 2 of the row connection box and measuring the current. This measurement will have a large uncertainty associated with it due to leakage currents in the triaxial cable.

The data aquisition program is written so that after any set of current readings are taken, the KI-7014 multiplexer steps through each thermocouple and the reference junction and these voltages are read by the KI-199 multimeter and downloaded to the computer whereupon the software converts these readings to temperatures. The cycle period to take measurements on all three samples (both bulk and leakage current measurements) and to measure all the thermocouple voltages is approximately 1 minute.

All of the data which are collected are stored on disk and are also displayed graphically on the computer screen. Thus the experimenter has immediate access to the data in the form of current and temperature plots.

CONCLUSIONS AND FUTURE WORK

The data aquistion system described above will be used in the next several months to take data in an experiment at the HFBR studying the RIED phenomenon. This system will allow the experimenters immediate access to the data and will significantly increase the amount of data and ease the subsequent analysis of this data compared to any non-automated data aquistion system.

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REFERENCES

1. E.R. Hodgson, Cryst. Latt. Def. Amorph. Mat., **18** (1989), 169.
2. E.R. Hodgson, J. Nucl. Mater. **179-181** (1991), 383.
3. G.P. Pells, J. Nucl. Mater. **184** (1991), 177.
4. E.R. Hodgson, J. Nucl. Mater. **191-194** (1992), 552.
5. T. Shikama, M. Narui, Y. Endo, T. Sagawa, and H. Kayano, J. Nucl. Mater. **191-194** (1992), 575.
6. X. Zong, C. Shen, S. Liu, Z. Wu, Yi Chen, Y. Chen, B.D. Evans, R. Gonzalez, and C.H. Sellers, Phys. Rev. B **49** no. 22 (1994), 15514.
7. L.L. Snead, D.P. White, S.J. Zinkle, J. Oconor, G. Hartsough, and J. Errante, Fusion Reactor Mater. Semiann. Prog. Rep. DOE/ER-0313/15 (1993), 457.
8. L.L. Snead, D.P. White, and S.J. Zinkle, J. Nucl. Mater., in press.
9. S.J. Zinkle and E.R. Hodgson, J. Nucl. Mater. **191-194** (1992), 58.
10. S.J. Zinkle, Plasma Dev. and Oper. **3** (1992).
11. J.D. Axe and R. Greenberg Eds., *HFBR Handbook BNL 24182* (Brookhaven National Laboratory Associated Universities, Inc., 1992).
12. R.W. Klaffky, B.H. Rose, A.N. Goland and G.J. Dienes, Phys. Rev B **21** (1980) 3610.
13. ASTM D257 *Standard Test Methods for D-C Resistance Or Conductance of Insulating Materials*, (1991).
14. *Low Level Measurements 4th Edition* (Keithley Instruments, Inc. 1992).