LOW TEMPERATURE GROWTH AND ELECTRICAL

CHARACTERIZATION OF INSULATORS FOR GAAS MISFETs

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1. OBJECTIVES

The objectives of this program is the low temperature growth of oxides and layers on GaAs and the detailed electrical characterization of these oxides. Anodic oxides and plasma grown oxides are to be fabricated and MIS layers evaluated using capacitance and conductance measurements as a function of frequency and bias voltage, DLTS, current-voltage and breakdown characteristics.

2. BRIEF DESCRIPTION OF PROGRESS

During the first six months the following progress was achieved:

a) A plasma anodization system has been designed, assembled and put into operation.

b) A measurement set up system has been assembled for determining capacitance and conductance as a function of gate voltage for frequencies in the range from 1 Hz to 1 MHz.

c) Initial measurements have been carried out in $Si-SiO_2$ capacitors in order to test our system and in GaAs MIS capacitors fabricated using liquid anodization.

3. SUMMARY OF WORK

A summary of the work done up to now follows:

A plasma anodization system has been assembled and put into operation. A vertical chamber, 4 1/2" in diameter is used in this system. The plasma is generated by an inductively coupled r.f. system operating at 3.75 MHz. Our system has been designed to operate in the pressure range from 0.5 to 1 Torr, with gas feed through bellow sealed needle valves and flow tubes. It is planned to replace the flow tubes with mass flow controllers in the near future. The system pressure is adjusted by appropriately throttling the pump in an open loop system. This is considerably less expensive than a conventional feedback controller.

A considerable amount of work has been devoted to debugging the system so that meaningful measurements can be taken on it. The problems of electrical interference are very serious, since we are dealing with anodization currents in the milliampere range, and r.f. power at the hundreds of watts level. The electrical decoupling of these circuits is now complete.

A second problem is that of obtaining uniform anodization of the sample. This sample is mounted on a pyrex pedestal through which a platinum wire is fused to connect to its back surface. Some experimentation has been required with the placing of field-shaping electrodes to improve the film uniformity. In addition, the samples are illuminated by tungsten lamps so as to generate the necessary holes required for anodization. Fluorescent lamps have been tried for this purpose but were rejected because they produced considerable r.f. interference. At the present time, we are capable of growing uniform oxides on both n type bulk GaAs as well as on semi-insulating GaAs.

A Langmuir probe has been built, and used to establish plasma parameters such as the plasma potential, the electron density and the electron energy. The actual plasma anodization can be performed using either a constant current or a constant voltage source. In addition to the anodizing current, the growth rate is a function of r.f. power, gas pressure, and the distance between the r.f. coil and the sample. All of these parameters have been pre-set by us, so that our work has focused on the oxide growth as a function of anodizing current. Unlike wet anodization, the plasma method involves sputtering as well, so that we are attempting to minimize this effect.

Our experimental procedure consists of first making a back face ohmic contact using Au-Ge eutectic (450°C, 1 minute alloying cycle). Next the oxide is grown using plasma anodication. We have noted that the sample temperature does not exceed 70°C during this process. After growth, aluminum dots are vacuum evaporated to form a series of MOS capacitors which are tested.

Work has begun on heat treatment experiments (prior to Al-evaporation) to determine their effect on the oxide properties. In addition, an extra gas feed line has been installed to allow the use of gas mixtures.

A serious problem with this system (as with all plasma systems using oxygen) is the rapid deterioration of the pump oil and of pump seals with operation. A circulating filter loop has been designed and is now being constructed. Once installed, we hope it will extend the life of the pump (and of its oil) to some satisfactory value.

Figure 1 shows a schematic of the system in use at the present time.

The measurement system we decided to use for measuring the capacitance and conductance of MIS devices as a function of bias and for different frequencies has as its main component a lock-in amplifier. The lock-in amplifier is a phase sensitive demodulator that is able to

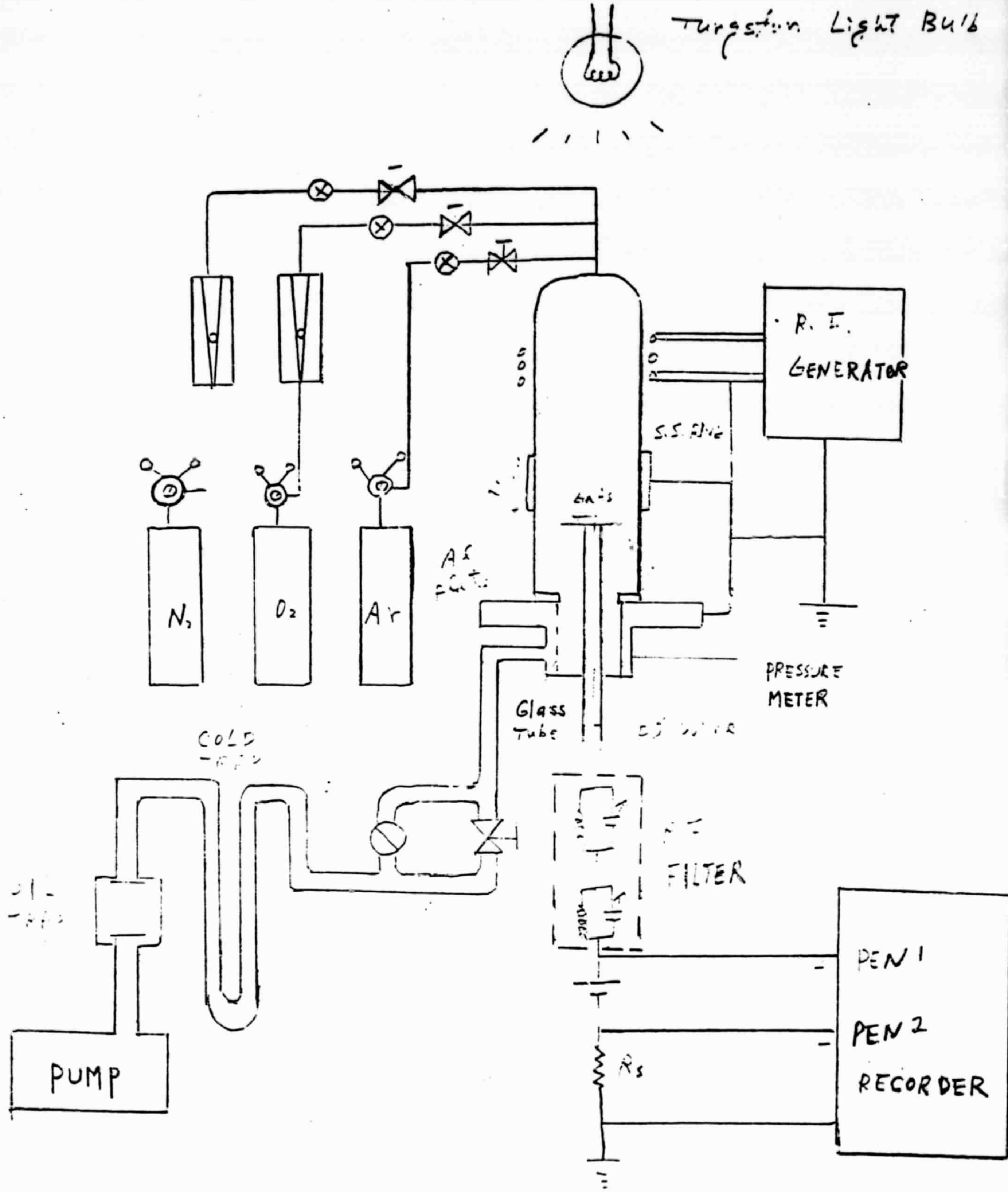

Figure 1 - Schematic Diagram of Anodization Apparatus

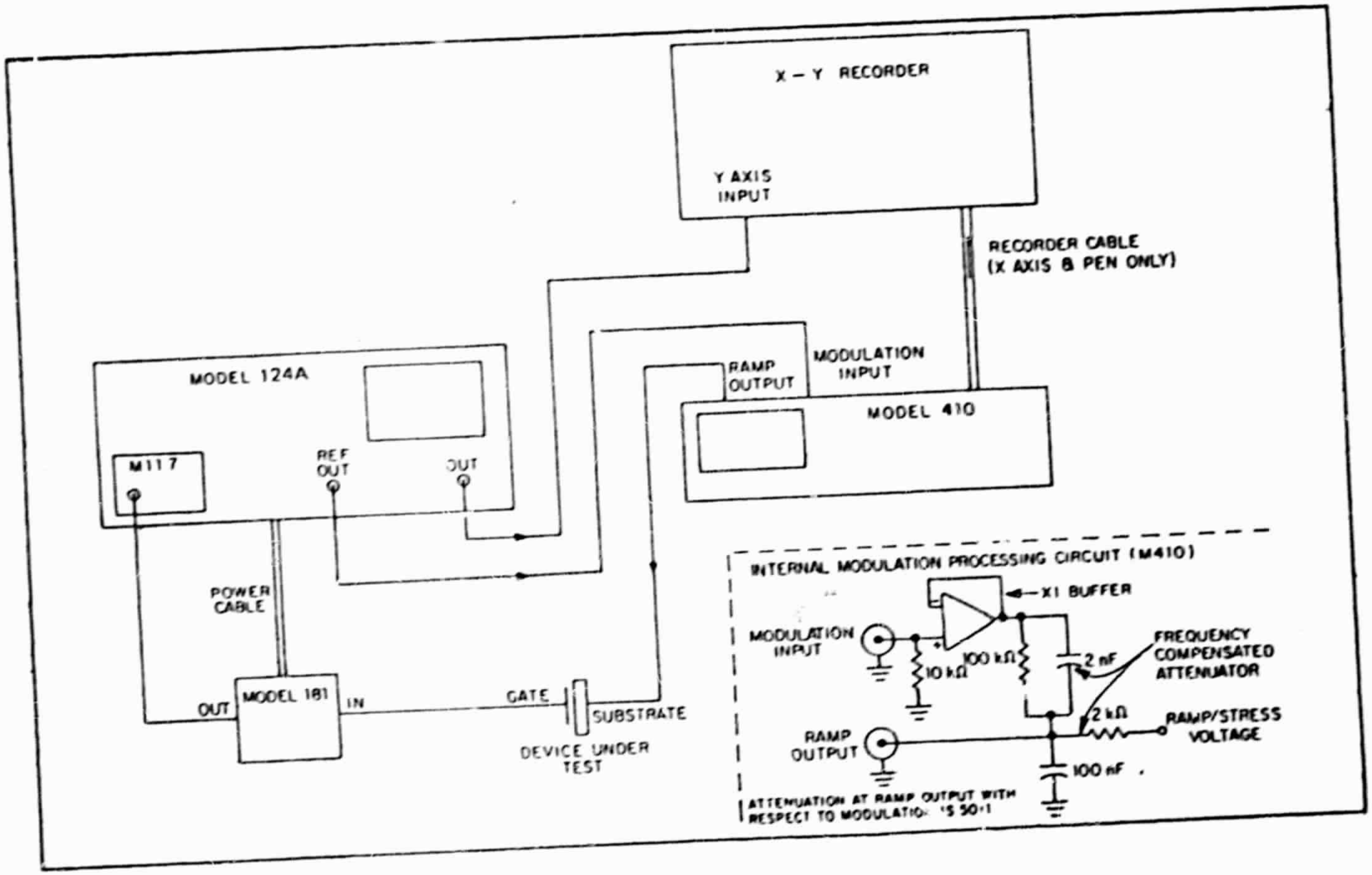

Figure 2 - Schematic Diagram of C-V Measurement System

detect small signals in the presence of noise. When provided with an appropriate reference signal, it will measure the in phase component (conductance) or quadrature component (capacitance) of the AC current signal from the device under test.

A block diagram of the system based on commercially available equipment is shown in Fig. 2. The system consists of a Princeton Applied Research (PAR) Mod. 124A lock in amplifier with PAR Mod. M117 preamplifier, a PAR Mod. 181 current preamplifier, a PAR Mod. 410 C-V plotter, a Houston Instrument Mod. 2000 X-Y recorder and a Tektronix Mod. 2213 oscilloscope (not shown in the diagram) for monitoring the AC signals at several points in the measurement system. The devices under test can be tested either mounted on TO-5 cans or in wafer form by means of a point probe which is placed in a shielded box. The same system can be used for measuring the DC current-voltage characteristics by replacing the 181 current preamplifier for a current pico-ammeter with analog output. The electrical connection among the several instruments has been done with coaxial cables as to have three-terminal type measurements in order to avoid stray capacitances as well as to avoid any leakage currents during DC measurements.

The reference signal channel of the lock-in amplifier provides both the AC signal to the device under test and the reference signal for the phase sensitive detector. The AC signal to the device under test is first applied to the modulation input of the PAR 410 C-V plotter (which in this mode is used only for its ramp generator capability) which attenuates the signal by 50 and superimposes it on the DC ramp voltage. This combined signal is applied to the device.

The current flowing through the devices is applied to the PAR 181 current preamplifier which is operated in its single ended mode. The output voltage of the 181 drives the PAR 117 preamplifier which is contained in the main frame of the lock-in amplifier. The output of the lock in, which is operated in the phase sensitive detector mode, drives the Y-axis of the x-y recorder. The X-axis is driven by the x-output of the PAR 410 and is proportional to the DC voltage ramp applied to the device.

The set up is capable for measuring capacitance or conductance over a frequency range of 0.2 Hz to 210 kHz. Measurements below 5 Hz are somewhat lengthy in time because of the time it takes to the system to settle down. The PAR 410 C-V plotter, with the x-y recorder can be used for measuring capacitance and conductance at 1 MHz which is the highest frequency capability of our system.

Using this system we have made measurements on $Si-SiO_2$ samples as well as on GaAs MIS devices fabricated from liquid anodization. Figure 3 shows the C-V characteristics of the $Si-SiO_2$ sample for several frequencies and as a function of gate voltage. This was an n-type sample with a silicon gate. The doping of the sample, as determined from the capacitance at 100 kHz in the inversion region was 8.6×10^{14} cm^{-3}. Notice at a frequency of 10 Hz, the minority carriers are able to follow the AC signal as shown by the fact that in the inversion region, the capacitance is the same as in accumulation. Figure 4 shows the same type of characteristics as Fig. 3 but for a GaAs MIS sample. The oxide on this sample was grown anodically using the AGW process. A post-growth anneal was carried out in an atmosphere

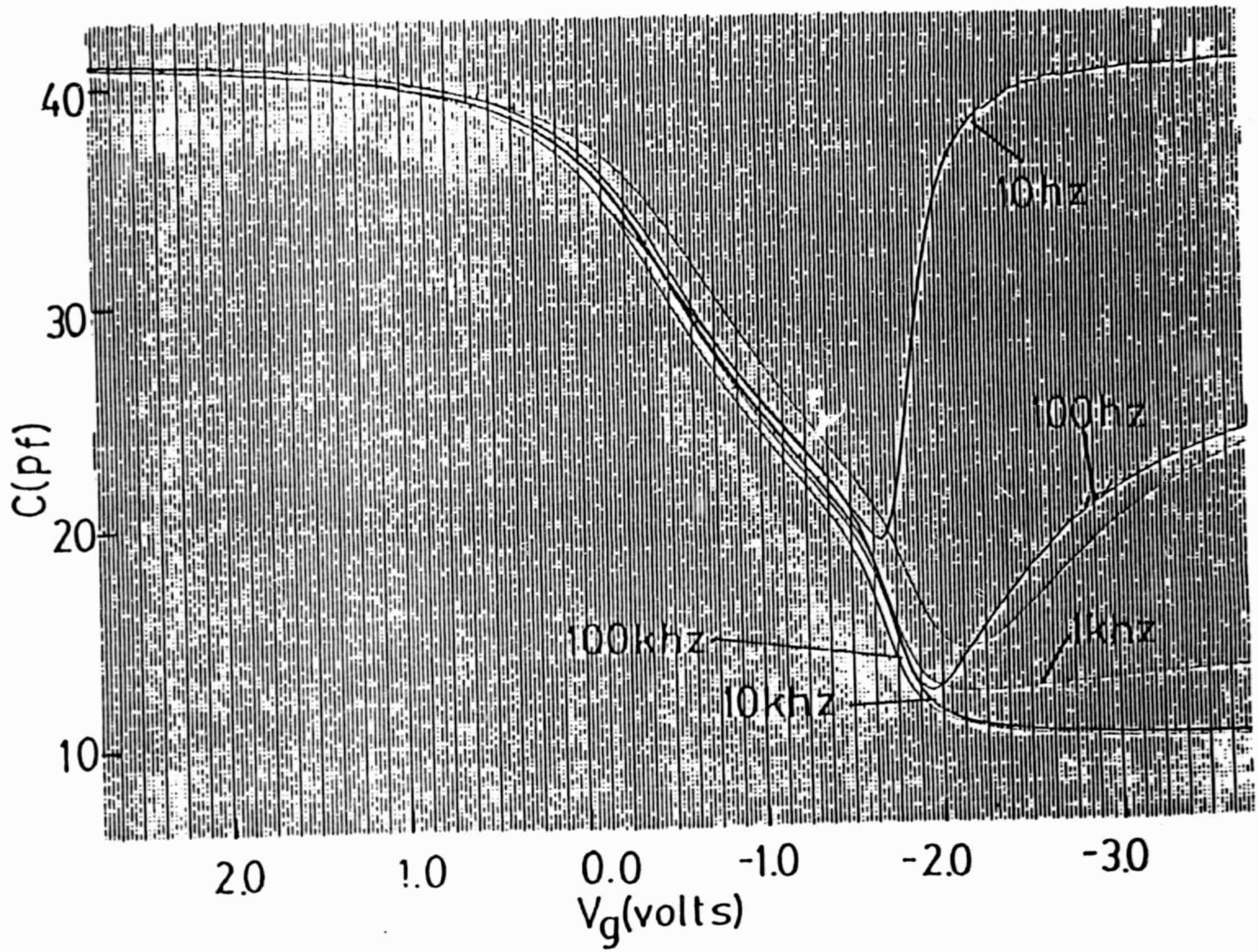

Figure 3 - C-V Plots For An n-Si-SiO_2 MOS Capacitor At Various Frequencies

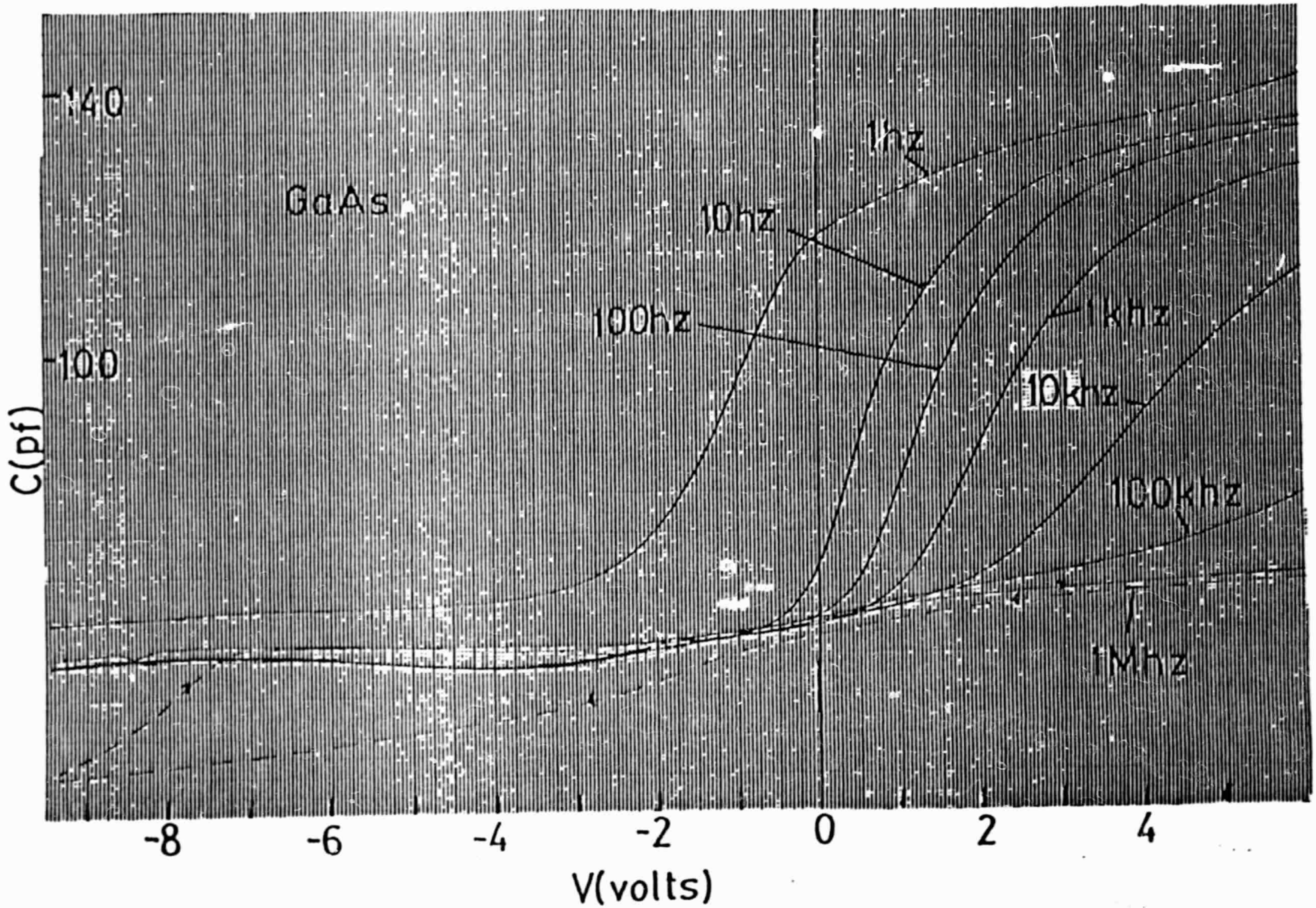

Figure 4 - C-V Plots For An n-GaAs MIS Capacitor At Various Frequencies

of high purity hydrogen at 350°C for 2 hours. The anomalous frequency dispersion observed in the accumulation capacitance also has been reported by other workers. Some analysis has been carried out in the above measurements and will be reported in the final report.

4. PLANS FOR THE NEXT REPORTING PERIOD

During the rest of the program we plan to carry out a detailed evaluation of the anodic oxides grown both in the gaseous system anodization built as well of oxides obtained from liquid anodization.

5. TRAVEL

On July 20 and 21, 1981, S.K. Ghandhi and J.M. Borrego visited the Lewis Research Center at Cleveland, Ohio.

6. FISCAL INFORMATION

The expenditure rate continues at the rate originally scheduled.