A LOW COST HPIB COMPATIBLE INTERFACE TO A THERMOCHUCK FOR COMPUTERISED C-V MEASUREMENT SYSTEM

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ABSTRACT

A low cost hardware is described for interfacing a thermochuck to an HP 86/HPIB based Capacitance-Voltage Measurement system. The design of the interface hardware centres on the Fairchild 96LS488 chip, which greatly simplifies the hardware required to provide the necessary protocols, hence enabling easy communication with unintelligent peripherals.

INTRODUCTION

Capacitance-Voltage (C-V) measurement of Metal-Oxide-Semiconductor (MOS) devices is essential for the characterization of wafer processing. Currently, computer automated C-V measurement systems are available that enable measurement over a wide range of frequencies and d.c. biases. Unfortunately, they do not usually include facilities for Bias Temperature Stress (BTS) measurements. As a result of this, the thermochuck has to be acquired from another vendor. BTS measurement requires the wafer to be heated to a preset temperature with the MOS device under bias for a specific period, cooled down to room temperature and the C-V measurement performed. It is a time-consuming measurement and automation is certainly welcomed. The C-V measurement system schematic is shown in Figure 1. The system is centered around a Hewlett Packard HP 86 computer, which controls the HP 4140B pA meter/DC voltmeter and the HP 4275A LCR meter through the HPIB. The LCR meter performs capacitance measurement with the DC bias supplied by the pA meter. The pA meter is also capable of performing a quasi-static C-V measurement. Data storage and outputting of the C-V measurement are provided by a floppy disk drive, printer and plotter. However, for the BTS equipment, a thermochuck system from Temptronics, TP37D, is used, which has no provision for HPIB compatibility. In this paper,

we describe the design and implementation of a low-cost interface between the HP-IB and the TP37D using the Fairchild 96LS488, enabling intelligent communication between the HP 86 system and the TP37D thermochuck.

Fig. 1 C-V measurement setup

INTERFACE DESIGN

The TP37D is a thermochuck system which can maintain the wafer chuck temperature over a temperature range from -10° to 200°C to within 0.5°C of its setpoint.¹ It has an option for remote control, where the temperature setpoint voltage is obtained by using a 200 ohm 10 turn pot and a switch, as recommended by the manufacturer. The former is for temperature setting and the latter is for the appropriate range selection (-10°C to 100°C or 100°C to 200°C). Such an arrangement is not easily amenable to automation without the provision of an interface between the HP-IB and TP37D. The interface described here provides facilities for determining the temperature setpoint voltage as well as monitoring the wafer chuck temperature.

The thermochuck has been calibrated over its entire temperature range in terms of its temperature setpoint voltage. The thermochuck provides a DC voltage reference of 1.5V for the 200 ohm 10 turn pot in the external mode. Upon calibration, it was found that range of setpoint reference voltage for the lower range (-10°C to 100°C) was from 0.17V to 1.23 V, and for the upper range (100°C to 200°C) was from 0.29V to 1.10V. A temperature-voltage setpoint lookup table was formed and stored as a data file in the HP86.

All the necessary logic instructions for data transfer in accordance with the IEEE 488 Standard^{2,3,4} for programmable instrumentation is provided by the Fairchild 96LS488 chip.⁵ The hardware details of the interface for Listen/Talk mode is given in Figure 2. The analog voltage required for the setpoint is provided from a D/A converter (AD 558). Since all the data on the HP-IB appear as active low, they were complemented before conversion. The least 7 bits of the HP-IB, after complementing, were fed to a D/A converter. The MSB of the HP-IB was used to sense and select the appropriate temperature range. The analog output voltage from the D/A converter obtained from the least 7 bits, was 1.27V maximum and this was sufficient to cover the setpoint voltage range obtained from the calibration measurements.

Upon addressing to the Listen mode, the RXST line of the 96LS488 is driven high and this is used to enable the D/A converter which converts the data to analog voltage. To sense the range from the MSB, a bistable latch (7475) and a tri-state buffer (74LS367) were used. When the MSB is low the latch output is high, causing the output of the buffer to be in a high-impedance state. This is interpreted as the lower temperature range by the thermochuck. When the MSB is high, the converse applies. The thermochuck then takes the sample under test to the required temperature, as set by the controller.

When addressed to the Talk mode, the DRB line of the 96LS488 goes low, hence enabling all the output latches of the interface as well as the A/D converter

Fig. 2 Hardware schematic of the interface

(ADC 0804). The temperature on the wafer chuck of the TP37D is sensed by a Thermistor inside the wafer chuck and the differential voltage of the bridge network is amplified by a differential amplifier. For purposes of monitoring the wafer chuck temperature, the output voltage from the Thermistor arm of the bridge network is buffered into the ADC 0804. The start of conversion pulse is provided by the 74123 multivibrator. The end of conversion pulse from the INTR line of the ADC0804 is latched by the 74112 J-K flip-flop to the TXRDY line of the 96LS488. When the HPIB has accepted the data, the 96LS488 drives the TXST line high which is used to clear the 74112 and drive the TXRDY line low. Since the allowable positive input voltage range of the A/D converter is 0-5V, simple algebraic manipulations were necessary to obtain the actual temperature information, as the analog input voltage from the thermochuck is 1.23V maximum. This is achieved by making the necessary conversions in the software.

Since all the input/output instructions of HP 86 terminate with a carriage return <CR> and Line Feed <LF>, they must be suppressed to prevent undesired voltage levels appearing on the thermochuck. This can be implemented by the HP 86 easily. A typical input/output instruction with a suppressed <CR> and <LF> is ENTER/OUTPUT XYY USING “#, B”; DDD, where X is the HPIB address, YY is the device select address and DDD is the data in binary.

SYSTEM OPERATION FOR BTS MEASUREMENT

The system prompts the user for the desired temperature in °C at which the BTS measurement is to be done. Upon receiving this information, it then makes a search in the lookup table to output to the TP37D the appropriate value of setpoint voltage. It then periodically samples the wafer chuck temperature and once the setpoint temperature has been reached, it is held at that temperature for a user specified time before it is allowed to cool. Upon reaching the room temperature, the C-V measurement is automatically carried out. Data from the C-V measurements before and after the bias temperature stress are stored on the floppy disc and are subsequently plotted using an HP 7470 plotter.

Figure 3 is a typical capacitance-voltage curve before and after a BTS test. The MOS capacitor on n-type substrate was formed from a pyrogenically grown oxide at 950°C. Aluminium was evaporated on both sides of the wafer and was photopatterned on the oxide side to obtain 1 mm diameter Aluminium dots. From the shifts in the C-V curve, the value of the mobile ion concentration in the oxide can be evaluated.

Fig. 3 A typical BTS measurement CV curve on n-type silicon where curve 1 was taken at room temperature, curve 2 was taken after positive temperature bias stress (175°C for 20 min. at +15V) and curve 3 was taken after negative BTS (175°C, 20 min, -15V).

CONCLUSIONS

The design and implementation of a simple, low-cost interface hardware for controlling a thermochuck in BTS measurements has been described. Single input/output instructions are used to input/output data into/from the thermochuck which eliminates the need to programme the interface.

REFERENCES

1. Temptronic Corporation. *Instruction Manual TP37D Thermochuck System*.
2. Summers, J. IEE Interface Bus IEEE 488) simplified. *Electronic Engineering*, Dec. 1979, 45-55.
3. IEEE Standard. *IEEE Standard Digital Interface for Programmable Instrumentation, IEEE Standard 488*, 1979.
4. Gur, M. An Evaluation of IEC/IEEE Interface Bus. *Electronic Engineering*, Sept. 1978, 57-61.
5. Fairchild Camera and Instrument Corporation. *Fairchild 96LS488 GPIB Circuit Data Sheet*, 1983.