HP4280 C METER CONTROLLING PROGRAM AND CHARACTERISTIC CURVES EXTRACTION

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Abstract: This work presents the development of a C Meter controlling program to extract the capacitance and conductance versus voltage (CG-V) or time (CG-t) curves of semiconductor devices, acquiring data to determine physical and electrical parameters. The programming language used was LabVIEW.

1. INTRODUCTION

The MOS capacitor (Metal-Oxide-Semiconductor) is a basic structure used to extract parameters from semiconductor devices and materials through the measurement of the CG-V [1] and CG-t curves.

HP4280 LCR Meter is used for measuring the CG-V curves, controlled nowadays by program developed in QUICKBASIC language [2].

The goal of this work is to present a new program developed in LabVIEW language [3] to control the HP4280 and to make the data acquisition and parameters extraction from the characteristic curves.

2. HP4280 C METER AND LABVIEW

Computer controls HP4280 with a GPIB (General Purpose Interface Bus) board through program developed in QUICKBASIC. It is designed to measure the high-frequency capacitance-voltage (C-V) and capacitance-time (C-t) characteristics of semiconductor devices and materials and has a bias source that ranges through +/-100V with a 1mV resolution.

GPIB is used to make the communication between instruments and computers following the ANSI/IEEE 488.1 international standard.

LabVIEW, graphical programming software created by National Instruments, became our choice to develop the new program because of its programming tools facilities, which allows to decrease the programming time. While most of the programming languages use code lines to program, LabVIEW, as a graphic language, uses block diagrams and frontal panels as the user's interaction window, which facilitate the implementation of the program.

The front panel is a simulation of the real instrument, with enhancements of functions as saving data, plotting graphs, opening data or extracting parameters of them. It creates, through controls and indicators, a controlling ambient of the real instrument, where the improvements in this new program are aggregated.

Inside the block diagram there are icons, corresponding to *controls* and *indicators*, that are placed inside traditional programming structures, as *for* and *while* loops, connected by wires to constants, arithmetical operators, and other types of functions, in a logic order that make the correct data flux.

Each LabVIEW programming is called a VI (Virtual Instrument). Sub-VIs can be used as procedures when the main VI call them. They can run normally or hidden, and exchange data to each other and to the main VI.

3. THE DEVELOPED PROGRAM

The computer controls the equipment through some remote programming codes listed in the HP4280 user's manual, that determine the measurement function (CG-V or CG-t), the connection mode (grounded or floating), the type of internal bias source sweep, besides all types of voltage and time configuration values. LabVIEW, through the *Send* Function, sends a string containing these codes for HP4280.

A main frontal panel was developed to show in the same screen, all the *controls* and *indicators* that are useful to the user, allowing the easy visualization of the acquired data, graphs and functions such as canceling measurement, opening the saved measurement or saving the new one.

Figure 1 shows the frontal panel with the controls configured to do a CG-V measurement. Figure 1a (left side) shows the controls where the user defines the function, connection mode, measurement speed, the voltage and time values of the sweep and other controls, and a table with the measured values. The Figure 1b (right side) presents the measured curves in auto-scale graphical format with auto-definition of C_{MAX} and C_{MIN} for the parameters extraction.

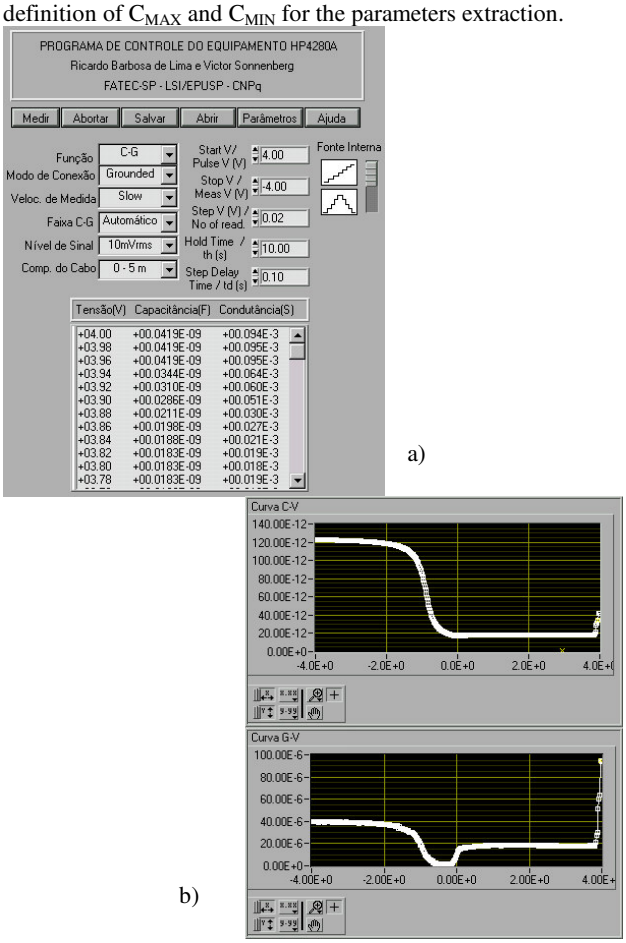

Figure 1 – Main Frontal Panel with a) the measurement variables input and the table with the results and b) the graphical part.

The panel is composed of six buttons, the controls that configure the measurement, two graphs and one table that shows all the measured values. The superior graph plots the capacitance curve and the inferior graph, the conductance curve as function of voltage or time. The *Medir* (Measure) button starts the measurement when pressed. The *Abortar* (Abort) will cancel the measurement that the equipment is doing. The *Salvar* (Save) saves the data in output file together with measurement configuration and extracted parameters, date and hour of the realization. The *Abrir* (Open) opens previous measurements. The *Parâmetros* (Parameters) is explained above. Finally, the *Ajuda* (Help) opens a new screen with easy understanding information about the most important topics of the program operation.

The main VI block diagram runs indefinitely until one button is pressed (turns true). Each button has its while loop, with its sub-VI inside waiting until it becomes true. When it happens, the sub-VI is called and runs hide, returning the values to the main VI, except for *Parâmetros* and *Ajuda*, which opens new windows.

When the *Medir* button is pressed by the first time,, a one time, parasitic capacitance correction of the whole measurement system is done, and only after it is made, the measurement will begin. The correction is done asking to the user to lift the test probe, and asking to let down it just when the correction is completed. When a new measurement is called and if the previous one is not saved, it asks the user whether to save or not, avoiding accidental lose of data.

Figure 2 shows an example of block diagram, with a part of the *salvar-VI* sub-VI, that saves the curve and the parameters in the output file.

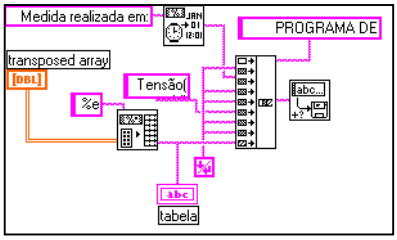

Figure 2 - Block diagram of the *salvar.VI* sub-VI

4. PARAMETERS EXTRACTION

After the equipment has sent the values to the program, the button *Parâmetros* is enabled, which permits the parameters extraction, such as oxide gate thickness (x_{ox}), effective doping concentration (N_A or N_D), effective oxide charge density (Q_{SS}) and threshold voltage (V_T), by the equations 1 to 4 as shown in ref. [1].

Gate oxide thickness (x_{ox}) of the capacitor is calculated with the equation 1.

$$x_{ox} = \frac{\varepsilon_{ox}.A}{C_{MAX}} \tag{1}$$

Where ε_{ox} is the oxide permissivity, A is the capacitor area and C_{MAX} is extracted from the curve.

Effective doping concentration, N_A for P-type and N_D for N-type, is calculated through equation 2. The program does some iterations until it converges to the right N_A.

$$N_A = \frac{4.\varepsilon_{Si}}{q.d^2_{MAX}} \frac{k.T}{q} \ln \frac{N_A}{n_i} \tag{2}$$

Where ε_{Si} is the silicon permissivity, q is the intrinsic charge; d_{MAX} is the maximum depletion width extracted in function of C_{MAX} and C_{MIN}, as shown in ref. [1], kT/q is the thermal voltage and n_i is the intrinsic concentration.

The flat band voltage value (V_{FB}) is found as [1] and by equation 3, the effective oxide charge density (Q_{SS}) can be calculated.

$$\frac{Q_{SS}}{q} = \frac{(\Phi_{MS} - V_{FB})}{q} \frac{\varepsilon_{ox}}{x_{ox}} \tag{3}$$

Where Φ_{MS} is the metal-semiconductor work function.

The equation 4 expresses the threshold voltage (V_T).

$$V_T = \frac{q.N_A.d_{MAX}}{C_{ox}} + 2\Phi_F - \frac{Q_{SS}}{C_{ox}} + \Phi_{MS} \tag{4}$$

Where Φ_F is the Fermi potential.

When *Parâmetros* button is pressed, a secondary front panel will load with the controls for the user insert the characteristics of gate material, oxide permissivity and capacitor area. Clicking on *Extrair* (Extract), the parameters will be automatically calculated with the C_{MAX} and C_{MIN} values selected by the program, but the user can select another values if necessary by *Editar* (Edit). Figure 3 exhibits the parameters that extracted from the measurement of Figure 1.

Figure 3 – Obtained results from the *Parâmetros.VI* sub-VI.

5. CONCLUSION

The developed program makes much easier the visualization of the CG-V curves and the parameters extraction.

The CG-t part is being implemented and the first tests have already good results.

REFERENCES

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ACKNOWLEDGMENT

CNPq for financial support.