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A switching system based on microcontroller for successive applying of MGT and CPT on MOSFETs

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ABSTRACT

A new, low cost switching system based on PIC 18F4550 microcontroller (MCU), called APL-SM v1.0 system, which enables the successive measuring of both the electrical characteristics in midgap-subthreshold technique (MGT) and charge-pumping currents in charge-pumping technique (CPT) of metal–oxide–semiconductor field effect transistor (MOSFET), has been developed. The APL-SM v1.0 system, instead of expensive switching matrix which price is considerably higher, could be used for the switching from MGT to CPT and vice versa. Using the appropriate program, the system allows the monitoring of MOSFETs during long time periods, helping the performing of long lasting experiments. The good agreement in the electrical characteristics, as well as in the charge-pumping currents, obtained using ultra low current, high speed Keithley switching matrix (SM) and APL-SM system, was obtained.

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1. Introduction

During a kind of transistor stress, as ionizing radiation, high electric field, etc., very often the changes in the electrical parameters (threshold voltage and transconductance) of metal–oxide–semiconductor field-effect transistors (MOSFETs) have been only investigated, considering the MOSFET as a "black box" that gives an output, where the stress is considered as an input. However, it is very important to know the defect behaviors in the gate oxide (SiO_2), and at gate oxide/substrate (SiO_2/Si) interface, in the aim of their stability and resistivity to stress improving.

The midgap-subthreshold technique (MGT) [1] for the determination of trap densities created in the gate oxide (fixed traps) and close to the oxide/substrate interface (switching traps), as well as the charge-pumping technique (CPT) [2,3] for the determination of the trap density at the SiO_2/Si interface (interface traps) are widely used techniques in the characterization of MOSFETs [4].

In the case of the transistors with three pins, like the power VDOMSFETs, a system that physically divides the instruments in MGT and CPT is not necessary, but is desirable. However, in the case of the transistors with four pins, like RADiation sensitive MOSFETs (RADFETs), a system for automatic measurements is necessary, and the developed APL-Switching Matrix (APL-SM) version 1.0 system is presented in this paper. The APL-SM v1.0 system is based on PIC 18F4550 microcontroller, and enables the successive performing of the measuring of electrical characteristics in MGT and charge-pumping currents in CPT on MOSFETs.

2. System description

In the case of three-pin transistors with (V)DMOS structures, thanks to their structures, it is easier to successively perform MGT and CPT than in the case of four-pin transistors. Fig. 1 shows the block diagram of the experimental set-up for MGT and CPT of three-pin MOSFETs.

In MGT of three-pin transistors, the transfer characteristics in saturation are recorded using source-measure unit 1 (SMU1; the programmable DC voltage source could be also used) and source-measure unit 2 (SMU2), both controlled

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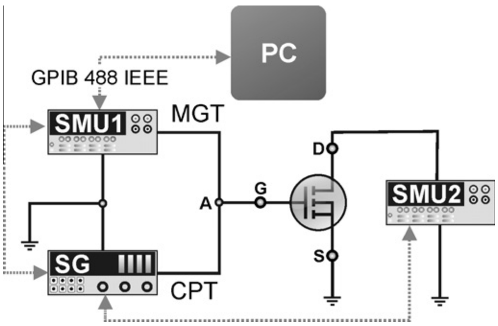

Fig. 1. Block diagram of the experimental set-up for MGT and CPT of three-pin MOSFETs.

by a PC. The SMU2 contains DC voltage source and DC ammeter. Using the DC voltage source by SMU1, the DC voltage step, changed in both the positive and negative gate voltage directions (usually, a step is 0.05 V), is applied to the transistor gate *G*. Using the SMU2, the drain *D* is biased with constant voltage, $V_D = const.$, but the source *S*, which is technologically connected to the substrate, is grounded, and drain–source current I_{DS} is measured. In CPT, the square or triangle pulses are applied on the gate by the signal/pulse generator (SG), and the average substrate (charge pumping) current, I_{cp} ($=I_{DS}$ in this case) is measured by DC ammeter from SMU2.

In principle, in the case of three-pin transistors, a specially designed system for MGT and CPT is not necessary. However, a mutual connection of SMU1 and SG (point A in Fig. 1) could be in conflict, and SMU1 and SG should be divided by a switcher, and, then, there would not be a way for conflict appearing. Namely, although the SMU1 and SG are turned off in the case of MGT and CPT, respectively, they have some internal resistances that could make a problem of low current measuring. Because of that, it is desirable to physically divide an unused unit.

In the case of four-pins devices (e.g. p-channel MOSFET dosimetric transistors, knows as RADFETs [5]), a switching system for automatic, successive performing of MGT and CPT (APL-SM v1.0 system) is necessary. Namely, the aim was to successively perform firstly MGT, then CPT, without changing the connections between transistors and instruments. Fig. 2 shows the block diagram of the experimental set-up for MGT and CPT of four-pin MOSFETs.

A solution was found in a "switching matrix" that contained a series of relays (switchers) controlled by the PIC 18F4550 microcontroller (MCU) (Fig. 3). The block-diagrams of a system we have developed for successive performing of MGT and CPT (APL-SM v1.0 system) are given in Fig. 4. Left and right set-ups are for the same system in two modes (MGT and CPT). PIC 18F4550 MCU (Microchip Corporation) with USB interface has been chosen because of its easy and fast control, and, above all, the popularity of USB port vs. RS232 port (actually, in the new generation of PCs, RS232 port is not incorporated).

The protocol of both the interruption and overlap of the relay matrix is provided by the Windows application written in Visual C# using human interface device (HID) class. PC via USB sends the information to MCU to switch the relays ON or OFF. The relays are not directly driven by MCU

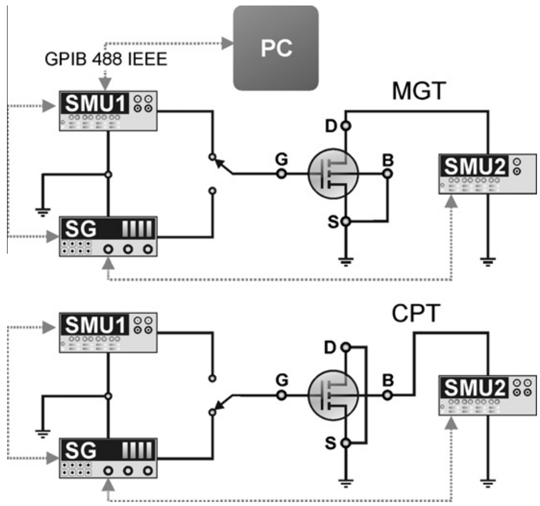

Fig. 2. Block diagram of the experimental set-up for MGT and CPT of four-pin MOSFETs.

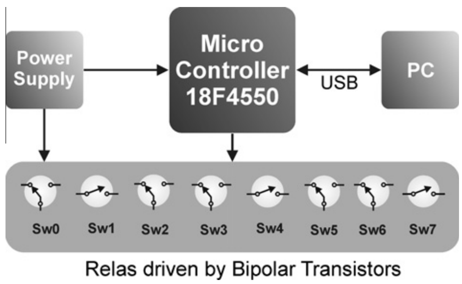

Fig. 3. Block diagram of relay controls; *Sw*0,*Sw*1,...,*Sw*7 are the relays (switchers).

because the output current per MCU pin is not high enough. The maximum output current per MCU pin could be 20 mA, but the current of 50 mA is necessary for relay to be switched on. Because of that, the relay driving circuit (RDC) that operates in switch mode, containing the bipolar or MOSFET transistor, silicon diode and base (gate) resistor at each relay, must be used. We have realized the RDC with bipolar transistors. The current from MCU goes to the base of bipolar transistor (or to the gate of MOS transistor), which switches the relay on. This prevents the overloading of the current in the MCU and its possibly damage, since the currents of base and gate are very small, in order of μA and nA, respectively. Fig. 5 shows the electrical circuit configuration with eight relays necessary for two realizations shown in Fig. 4. The Sw0 relays is connected with the Pt100 thermo-sonde that is used for the temperature measurements. The SMU1 enables the measuring of Pt100 resistance, and the temperature calculations. Namely, during the long last experiment, usually the temperature should be also monitored.

The level of the currents measured in MGT and CPT is in the order of pA, so that the semiconductor switchers cannot be used, because their leakage currents are higher than the current limits that the equipment needs to measure.

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