Influence of low energy proton irradiation on nanowire transistor SOI devices

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1. Abstract

The focus of this work is study the influence of low energy proton irradiation in n-channel SOI Ω – Gate Nanowire. It is possible to observe a reduction in maximum of transconductance value due to the electron mobility degradation and a shift in a drain current once the number of interface traps is higher in radiated devices.

2. Introduction

Nowadays there is a strong scientific and technological interest in understanding the radiation effects on advanced semiconductor devices. This kind of effect is important to electronics that operate in harsh environments as space or medical areas. In case of space environment, the electronic devices are constantly exposure to radiation from many sources, such as, galactic cosmic rays particles, solar particle events, coronal mass ejections, and others [2].

One of the most promising solutions to go beyond conventional planar bulk and fully depleted Silicon on Insulator (SOI) technologies are the Multiple-Gate field-effect transistors. Nowadays the main studied devices are MOSFET transistors, gate-all-around (GAA) [3] - [5], omega-gate [6] - [9], and tri-gate (TG) [10], [11].

This paper will presents the influence of low energy proton irradiation in n-channel SOI Ω – Gate Nanowire.

3. Device Characteristics and Experimental Details

The SOI Ω – Gate Nanowire transistor used in the work were fabricated at CEA-LETI using (100) SOI wafers with 145nm buried oxide thickness. The gate stack is composed by HfSiON (EOT=1.3 nm) and the height (Hnw) is 11µm. In this work, two channel lengths were used (20 and 100 nm) and for each one of them, four widths (W_{NW}), 10, 40, 100 and 20 nm were studied. More details for these devices processes can be found in [1]. Fig. 1 shows the SEM and cross sectional TEM images of the device [1]. Nanowire FETs were characterized using a B1500 semiconductor parameter analyzer. The devices were exposed to low-energy proton radiation at the "Laboratório de Materiais e Feixes Iônicos (LAMFI)", São Paulo, SP. The energy used was 2.2Mev and total ionization dose was 500krad.

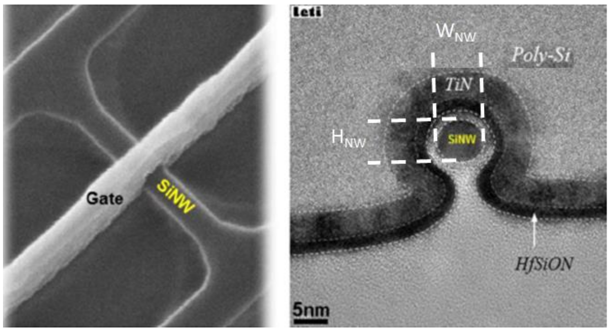

Fig. 1. (Left) SEM and (right) cross-sectional TEM images of ΩGNW MOSFETs with an 8-nm diameter.

4. Results and Analysis

Fig. 2 shows the experimental data of drain current as a function of gate voltage for the n-channel nanowire devices. In narrow devices, no variation was noticed because in these cases, the electrostatic control is stronger than in large devices. On the other hand, in large devices (W_{NW}=100nm and W_{NW}=220nm) a shift is observed in drain current. Proton irradiation provides positive chargers in the gate and buried oxide and increases interface chargers. Both of these effects can cause a shift in drain current, but once the gate oxide thickness is thin, the influence of gate oxide chargers is small. Furthermore in Ω – Gate Nanowire devices the interface area is high, resulting in more interface chargers created by irradiation.

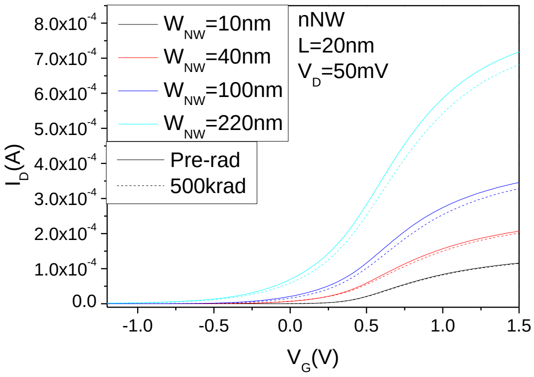

Fig. 2. Drain current as a function of gate voltage for four different width (20nm, 40nm, 100nm and 220nm) to n-channel devices.

Fig. 3 shows the transconductance as a function of gate voltage for the n-channel nanowire devices. It is possible to observe that the maximum value of transconductance is degraded after proton irradiation. Proton radiation can cause damage in devices structure, resulting in lower electron mobility in the channel region. Therefore, the maximum transconductance value is reduced.

It is possible to observe that large devices suffer more with the radiation than the narrow devices. This occurs because the narrow devices active area are smaller and the gate electrostatic control is more effective than the large devices.

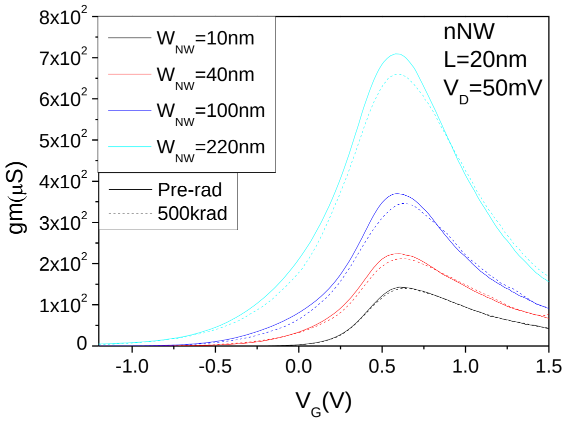

Fig. 3. The transconductance as a function of gate voltage for four different width (20nm, 40nm, 100nm and 220nm) to n-channel devices.

In Fig. 4 it is possible to see the maximum transconductance values as a function of the fin width, before and after irradiation. As can be seen in previous analyzes, the maximum of the transconductance for irradiation devices are lower than standard ones, due to the electron mobility degradation.

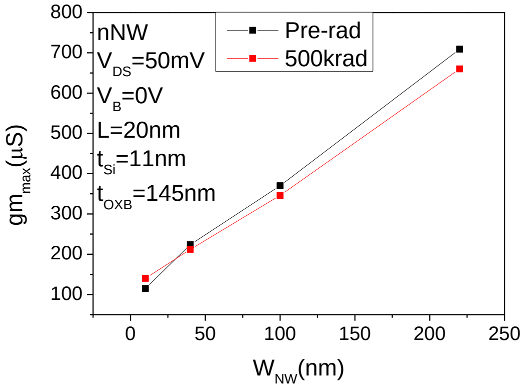

Fig. 4. The value of the maximum transconductance as a function of width for the devices, before and after proton radiation.

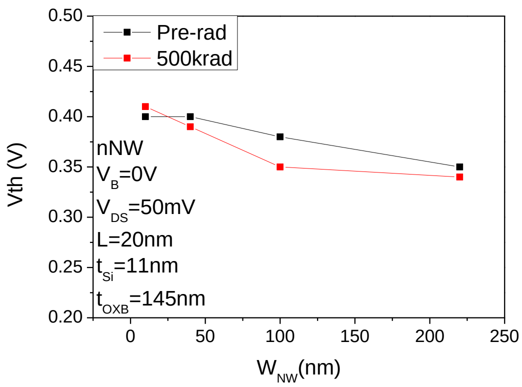

Fig. 5. The value of the threshold voltage as a function of width for the devices, before and after proton radiation.

In Fig. 5 it is possible to see the threshold voltage as a function of fin width, before and after irradiation. No significant variation can be observed in threshold voltage after irradiation for total ionization dose studied in this work.

5. Conclusions

In this work the proton irradiation influence in n-channel SOI Ω – Gate Nanowire were investigated. For narrow devices (W_{NW}=10nm and W_{NW}=40nm) no influence can be observed once these devices present better gate electrostatic control for channel chargers and lower active area. In case of wide devices, were noticed a reduction on maximum transconductance, indicating an electron mobility degradation, and a shift in drain current due to the increase of interface trap chargers.

Acknowledgments

The authors acknowledge CNPq, CAPES and FAPESP for financial support and .LAMFI.

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