Nonlinear transport regime in lateral field effect devices based on SOI

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Using the TCAD-Medici simulator, we have studied the electrical transport in several lateral field effect devices, commonly called Self-switching devices (SSDs) essentially based on SOI. This new type of nanometer-scale, rectifying devices, is realised by tailoring the boundary of a narrow semiconductor channel to break its longitudinal symmetry [1]. Our first goal was to adjust our experimental data measured at 300K with Medici simulated ones obtained in the same conditions. As shown on figure 01, we obtain an excellent agreement between the simulated and the experimental current-voltage characteristics measured at room temperature on a p-type SOI based SSD shown in the inset of figure 01. The width of the channel and the etched grooves are 230nm and 200nm respectively. More details about the fabrication process and the experimental results are reported in [2]. The simulated results take into account the presence of a uniform surface charge density $Q_{ss}$, between the insulating etched grooves and the semiconductor [4] and is deduced by fitting experimental data with medici I-V curves. The best agreement is obtained for $Q_{ss} = 3.4 \times 10^{11}$ cm$^{-2}$. The adjustment of the experimental data shown in figure 01 requires to take into account the existence of a non-negligible leakage current through the etched grooves and a series resistance due to the current leads. These results suggest that in order to prevent the leakage current and the effect of parasitic resistances to optimize the electrical performance of the device, it is preferable to increase the width of the etched grooves far enough from the active device and of course to decrease the length of the current leads. We have also studied the effect of the small size of the device on the hole transport inside the channel of the SSD. In fact, even an applied voltage as small as 1V induces sufficiently high electric field in the nanochannel to be in presence of hot carriers and nonlinear transport. This fact is proven by the simulation results which shows that both the hole density and velocity in the channel vary in a nontrivial manner versus the applied voltage due to the nonsymmetrical geometry of the studied device. In particular, we show that the breakdown in reverse appears more gradually than in a pn junction. In figure 02, we represent the variation of the hole velocity all along the simulated device. The channel is situated between the abscissas 0µm and 1.2 µm. We can see that the value of the hole velocity drops quickly under the limit value of $3 \times 10^6$ cm/s (the approximate value beyond of which the carriers are considered hot carriers) even if we apply voltage biases up to $+10$V. For reverse biases up to $-10$V, the hot holes need to go about 300nm away from the exit of the channel to relax their energy. These results illustrate the importance to take into account the distance needed for hot holes to relax in the eventuality of the integration of such devices for circuit applications.