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Effect of Dopants in Tunnel Barriers of Selectively Doped SOI-FETs

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Introduction

In the past decade, several experiments have been reported for single electron tunneling through single dopant atom in nanoscale transistors [1-4]. We have recently shown that nanoscale selective doping of nano-channel FETs can be realized with conventional CMOS processes [5], where the formation of a cluster of donors has been observed. For high temperature operation, it is important to understand the impact of donors located in the tunnel barriers [6]. In this work, we study this effect by monitoring the behavior of selectively doped devices after large bias application.

Dopant-atom based selectively doped SOI-FETs:

A schematic bird's eye view of a nano-channel SOI-FET is shown in Fig. 1(a). Selective doping of the channel was done by opening of a fine (~10-30 nm-wide) doping window by electron-beam (EB) lithography processes. Then, doping with phosphorus (P) donors is performed by thermal-diffusion doping. Doping concentration is high ($N_D > 1\times 10^{19}$ cm^{-3}), which ensures, with high probability, the formation of multiple-P-donor clusters (Fig. 1). Here, we present the observation of transport through deeper states from such cluster donors by depletion of donor located in the tunneling barrier region.

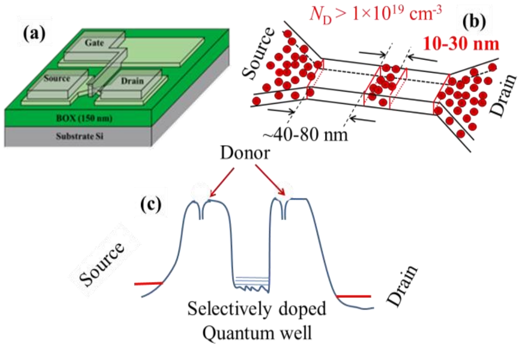

Fig. 1. **(a)** Bird's eye view of a SOI-FET. **(b)** Selectively doped nanoscale transistors **(c)** Possible potential landscape of the device.

Low temperature I_D-V_G characteristics and excitation effect:

Figure 2 (a) shows I_D-V_G characteristics at 15K of one typical selectively doped devices. At this temperature, we are probably unable to see the transport through the deepest states. To check the really deepest states transport path, we systematically excite the device by applying various bias condition before the I_D-V_G measurement. After applying a softer bias (called Init. 1 with V_g= -5V and V_d = 0.5V), we didn't observe any new current peak, as shown in Fig. 2(b). However, for a relatively higher excitation bias condition (Init. 2 with V_g= -5V and V_d = 2.0), we observed a new set of current peaks appears at the lower gate voltage, as shown in Fig. 2(c). After further increasing of excitation bias (Init. 3 with V_g= -5V and V_d = 5V), another new current peak appeared at additionally lower voltage at ~ -0.5 V, as presented in Fig. 2(d).

The appearance of new peaks due to excitation is most likely due to lowering of the barrier height by the depletion of donors situated in the tunnel barrier region. This process may give some direction for the operation of the devices at higher temperature. Further investigation is under way to understand the phenomena.

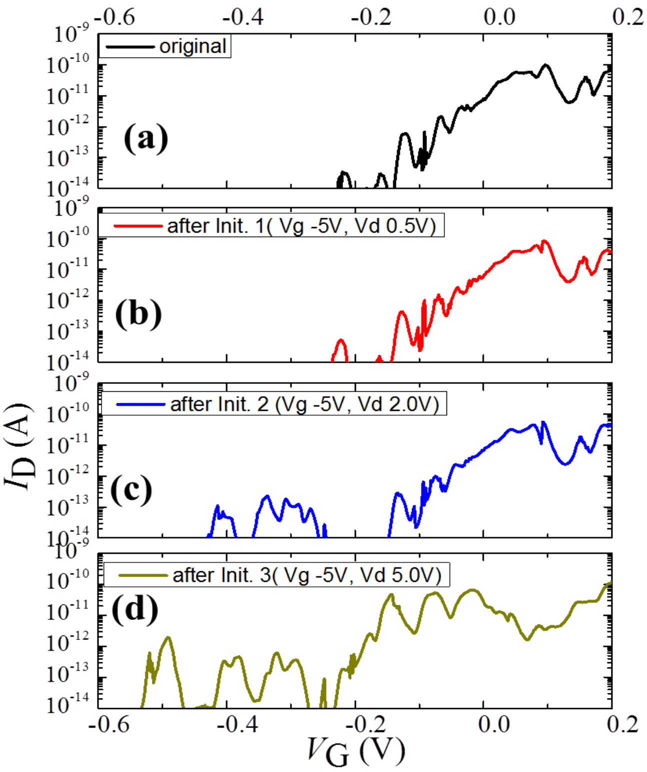

Fig. 2. I_D-V_G characteristics for different excitation condition of the selectively doped SOI-FETs at 15K.

References: [1]H. Sellier *et al.*, Phys. Rev. Lett. **97,** 206805 (2006). [2]M. Pierre *et al.*, Nature Nanotechnol. **5,** 133 (2010). [3]M. Tabe *et al.*, Phys. Rev. Lett. **105,** 016803 (2010). [4]E. Hamid *et al.*, Phys. Rev. B **87,** 085420 (2013). [5]D. Moraru et al., Silicon Nanoelectronics Workshop (2013). [6]M. Hofheinz et al., Eur. Phys. J. B 54, 299–307 (2006).