High-temperature single-electron tunneling transport through dopant-cluster in narrow channel SOI-FETs

Arup Samanta[1*], Daniel Moraru[2], Yuki Takasu[1], Takeshi Mizuno[1], Michiharu Tabe[1]

[1]Research Institute of Electronics, Shizuoka University, 3-5-1 Johoku, Hamamatsu

[2]Faculty of Engineering, Shizuoka University, 3-5-1 Johoku, Hamamatsu

[*]E-mail: rarup@rie.shizuoka.ac.jp

Introduction

In the past decade, several experiments have reported on single-electron tunneling (SET) transport through single dopant in nanoscale transistors [1-6]. Recently, we reported SET transport through dopant-cluster at low temperature [7]. In this report, we show SET through dopant-cluster at high temperature (> 150 K) in narrow-channel transistors.

Results and Discussion

We fabricated nondoped and selectively doped channel nanoscale SOI-FETs as schematically presented in Fig. 1(a-b). We used P-donors for doping. Doping concentration in both selectively doped regions and leads is $N_D \sim 2\times10^{-19}$ cm^{-3}. Width of the devices is varied as a parameter. In Fig. 1(c), we presented temperature (T) dependence of I-V characteristics for one of the narrowest-channel nondoped device. This device shows quasiperiodic current peaks at low temperature. With increasing T, new current peaks appear, which persist up to T > 150 K. The stability diagrams of this device at T = 80 K and 140 K presented in Fig. 1(e) and (f), respectively, indicate the presence of SET transport at high temperature. The origin of the tunneling current of this type of devices could be dopant-cluster formed with diffused P-donors near the source and drain leads. Persistence of the SET current at high temperature is due to combined effect of deeper transport states in the dopant-cluster and the suppression of FET current due to transport through narrow channel.

The temperature dependence of I-V characteristics of one of the selectively doped narrowest-channel device is shown in Fig. 1(d). This device also indicates the presence of SET current at T > 150 K. In this device, SET transport occurs most likely through a dopant-cluster formed in the selectively doped channel region.

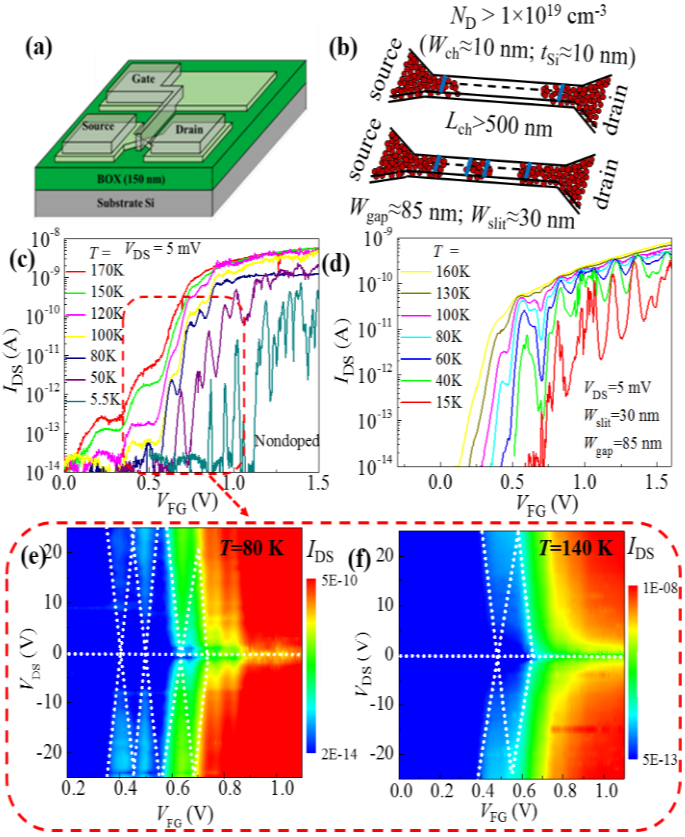

Figure 1 (a) Bird's eye view of an SOI-FET. **(b)** Schematic doping distribution in the nondoped and selectively doped devices. **(c)-(d)** Temperature dependence of I-V characteristics of nondoped and selectively doped devices, respectively. **(e)-(f)** Stability diagrams at T = 80 K and 140 K, respectively, for one of narrow-channel device.

Conclusion

We report for the first time high temperature (~150 K) single-electron tunneling transport through dopant- cluster. This is achieved by optimizing channel width to suppress the FET current and taking the advantage of deeper transport states in a closely-packed P-donor-cluster.

References [1]H. Sellier *et al.*, Phys. Rev. Lett. **97**, 206805 (2006). [2]G. P. Lansbergen *et al.*, Nat. Phys. **4**, 656-661 (2008). [3]Y. Ono *et al.*, Appl. Phys. Lett. **90**, 102106 (2007). [4]M. Pierre *et al.*, Nat. Nanotechnol. **5**, 133 (2010). [5]M. Tabe *et al.*, Phys. Rev. Lett. **105**, 016803 (2010). [6]E. Hamid *et al.*, Phys. Rev. B, **87**, 085420 (2013). [7]D. Moraru *et al.*, Sci. Rep, 4, pp. 6219 (2014).