Comparative Analysis of Threshold Voltage and On-current Variability in 65nm Bulk and FDSOI MOSFETs at Cryogenic Temperature

[1]IIS, Univ. of Tokyo, [2]AIST ○Zihao Liu[1], Tomoko Mizutani[1], Kiyoshi Takeuchi[1], Takuya Saraya[1],
Hiroshi Oka[2], Takahiro Mori[2], Masaharu Kobayashi[1], and Toshiro Hiramoto[1]
E-mail: zh-liu@nano.iis.u-tokyo.ac.jp

[Introduction] Cryogenic application of traditional silicon-based devices is getting more and more relevant with increasingly higher interest of quantum computation. This work therefore compares the cryogenic variability of bulk and FDSOI MOSFETs fabricated at the same fab, which is missing in previous studies [1]. **[Fabrication]** The number of both bulk and FDSOI devices is 256, and the devices are prepared using 65nm process node with W/L=140nm/60nm. Cryogenic Temperature (CT) is set to be 1.5K for both device types, while the room temperature (RT) is set to be 300K. **[Results and Discussion]** I_{on} is defined as drain current at V_g=1.2V, while overdrive current I_{ov} is set at 0.5V above $V_{thc.}$ The threshold voltage quantile plot is shown in Fig.1. Results showed that V_{thc} increases at CT due to fermi level shift, and V_{thc} variability also increases for bulk due to increase of depletion charge and for FDSOI due to freeze out effect [2-3]. FDSOI showed consistently smaller variability, however. Meanwhile, FDSOI also showed smaller drain induced barrier lowering (DIBL) value due to better electrostatic control advantage. The same quantile plots analysis was carried out on $I_{on,}$ and the results showed that when the linear region analysis results are compared to the saturation region, it can be noticed that the at saturation region, FDSOI showed noticeably smaller variability as compared to bulk, and moreover, there is no degradation at CT in FDSOI compared with RT. The degradation in bulk at CT is also limited. To look into this phenomena, I_{ov} quantile plots are analyzed in Fig. 2. The plot indicated that the I_{ov} at same overdrive voltage shows reduced variability than I_{on}. Additionally, the variability increase at linear region still exists due to freeze out [4]. When comparing devices, FDSOI is more likely to have increased variability. Additionally, since the difference in variability between I_{ov} and I_{on} plots reflects how much threshold voltage affects the current variability, if we see from the specific value of standard deviation, it can be said that FDSOI suffers more from the variability induced by threshold voltage. **[Conclusion]** FDSOI showed consistently smaller variability even under CT as compared to bulk and smaller RDF advantage is also present. Nevertheless, its variability still increases due to freezeout effect. Linear region device operation may pose a challenge in cryogenic environment. **[References]** [1] Z. Liu et al., JJAP 63, 2024. [2] D. S. Maria et al., IEEE WOLTE 2021. [3] Z. Liu et al., JJAP 61, 2022. [4] A. Beckers et al., IEEE TED 67, 2020.

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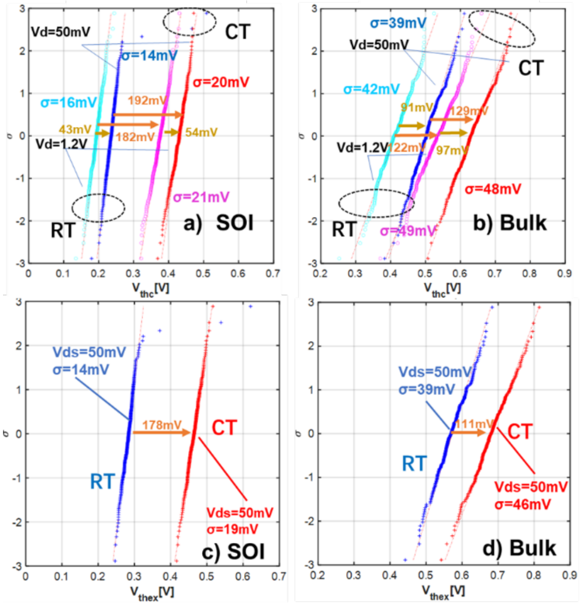

Fig.1. V_{thc} and V_{thex} quantile plots. CT results are shown in red and pink color, while RT results are shown in blue and cyan colors.

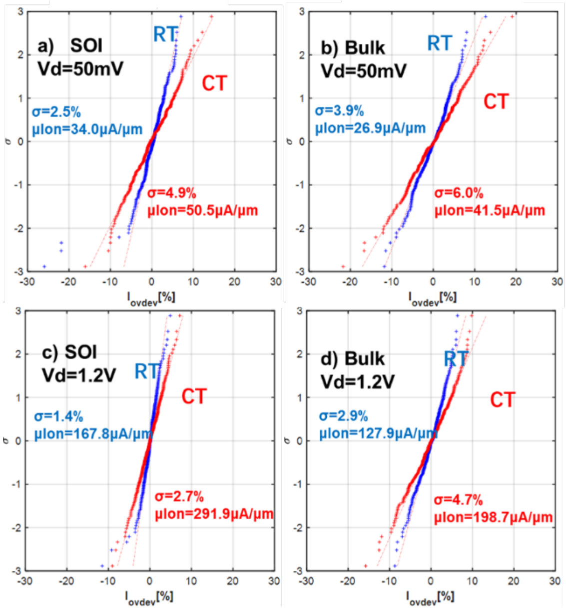

Fig.2. I_{ov} quantile plots for bulk and FDSOI FETs.