Analysis of Width-Dependent Drain Current Variability in Extremely Narrow GAA Silicon Nanowire MOSFETs

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[Introduction] Silicon nanowire MOSFET (Si-NWFET) is one of the most promising candidates for ultimate scaling. In our previous work, the on-current (I_{on}) variability of Si-NWFETs with 4nm effective width (W_e) was studied and compared with traditional bulk and FDSOI MOSFETs [1]. In this work, the analysis is extended to W_e=2-7 nm Si-NWFETs, and also to saturation region [2]. **[Fabrication]** The number of Si-NWFETs measured is 170. The fabrication process is based on [3]. The nanowire length (L) is 100nm, and the estimated width ranges from 2nm to 7nm. The height (H) is 3nm. **[Results and Discussion]** I_{on} is defined as drain current at V_g=1.2V. The variability decomposition is carried out in the linear region following the same method in [1]. Constant current threshold voltage (V_{thc}), transconductance (G_m), and current onset voltage (COV) are considered to be the most important influencers. The decomposition results are as shown in Fig.1. The absolute variability increases with decreasing nanowire width, and COV always has a negligible impact. Nevertheless, the G_m component remains dominant due to the silicon-thickness-fluctuation-induced mobility fluctuation ($\mu_{fluctuation}$). The V_{thc} component began to increase below 4nm but is still smaller than the G_m component even in 2nm Si-NWFETs. In the saturation region, due to high correlation between the components, the Pelgrom plot is used instead to evaluate the variability. The results for I_{on} and I_{ov} in linear and saturation region are as in Fig. 2 with previous bulk and FDSOI results also included [4], where I_{ov} is the drain current at fixed overdrive voltage (0.8V). I_{on} variability rapidly increases and deviates from straight line below 4nm, indicating the presence of systematic sources of variability. V_{thc}'s impact is negligibly small in 3-7nm range. The huge variation of both V_{thc} and I_{on}, as well as $\mu_{fluctuation}$ are essentially caused by the quantum confinement effects, in which fluctuations of nanowire width caused significant fluctuation of quantum levels [5]. **[Conclusion]** In very narrow nanowire FETs, I_{on} variability increases rapidly and $\mu_{fluctuation}$ dominates Ion fluctuation, which is further severely influenced by quantum confinement effects. **[References]**

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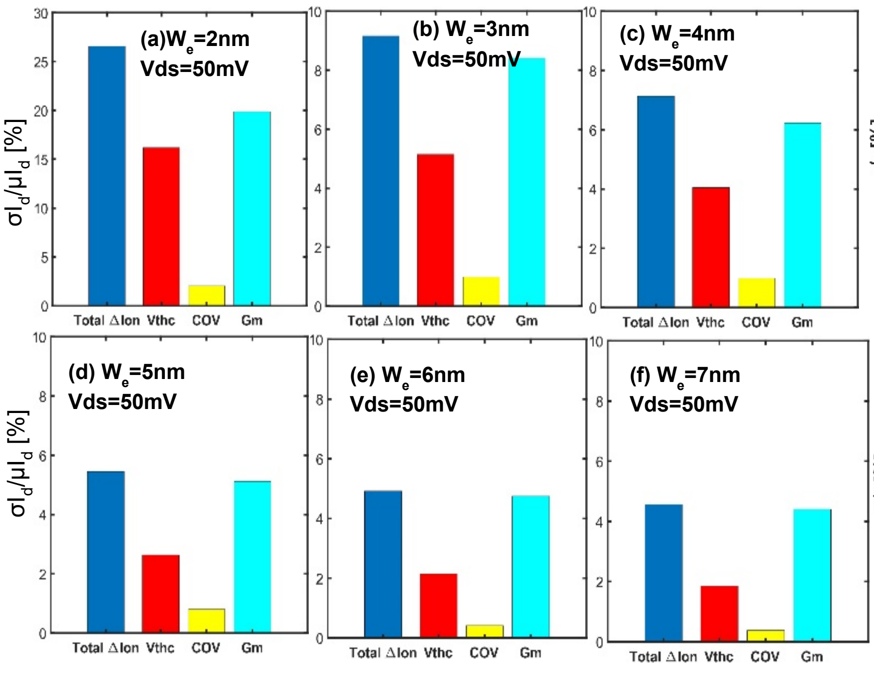

Fig.1. I_{on} variability decomposition results for different W_e. The variability is normalized to average I_d. The total I_{on} variability, V_{thc} component, COV component, and G_m component are shown for each W_e. Note that the scale of the y-axis is different in (a).

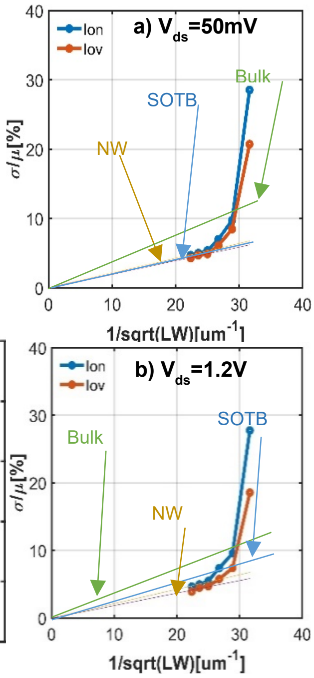

Fig.2. Pelgrom plot for I_{on} and I_{ov} in (a) linear and (b) saturation regions.