Temperature-Dependent Electronic Transport in Reconfigurable Transistors based on Ge on SOI and Strained SOI Platforms

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Reconfigurable field-effect transistors (RFETs) allow the dynamic switching between n- and p-type operation during run-time. RFETs have been identified as add-on technologies to CMOS, that can efficiently map XOR and majority gate logic, provide hardware security primitives and analog circuits for sensor front-end.

To boost performance and switching power efficiency vs. Si, Ge has been predicted as the RFET channel material of choice. However, the complex junction and oxide interface formation have so far hindered hysteresis-free operability and providing high as well as the necessary symmetric on-state- with reasonable off-state currents between both n-/ p-type IV characteristics [1],[2]. Here we bypass these aspects, [3] first by growing Ge on top of a <110> SOI substrate by low-temperature molecular-beam epitaxy, constituting our Ge on SOI (GeSOI) platform. To obtain thicker and more relaxed Ge layers, a strained-Si on insulator (s-SOI) platform was established (see Fig. 1a,b). As evident in the transfer characteristic shown in Fig. 1, the GesSOI platform exhibits higher on-state currents normalized to the cross-section, lower threshold voltage (V_{th}) but also relatively slightly higher on-state asymmetries compared to the GeSOI platform, while both retain a neglectable off-state current. Nevertheless, both platforms provide stable regimes of operability, as outlined in Fig. 2 for the GesSOI RFET, considering the gate-voltage-dependent switching capabilities. Consequently, the elaborated operational stability of these device platforms allows to investigate temperature-dependent IV characteristics, from which the transport regimes and activation energy for the RFETs can be extracted. In this respect, to give a comprehensive picture of the influence of the different parameters on the transport mechanisms, temperature-dependent gate- and bias-dependent current-voltage data was evaluated constructing 2-D colormap representations, as shown in Fig. 3 und Fig. 4 for the GeSOI and GesSOI platform, respectively.

References

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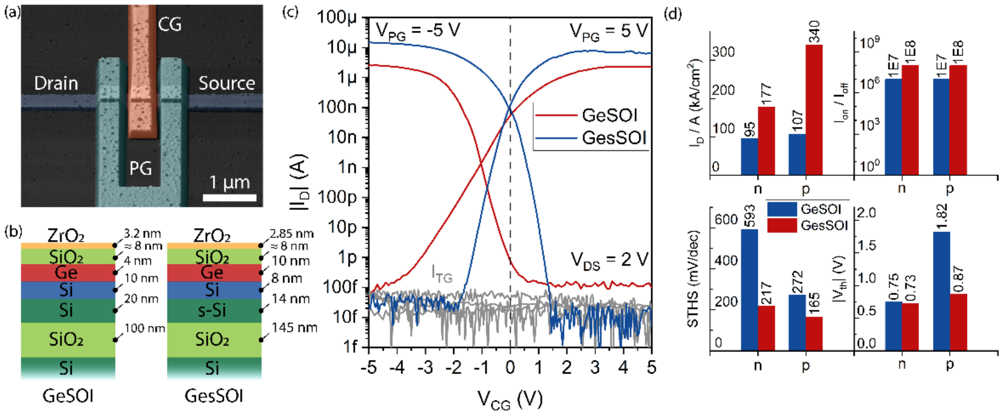

Fig. 1: (a) False-color AFM scan of the triple-gated RFET. (b) Schematic of GeSOI and GesSOI platform stacks. (c) Corresponding transfer characteristic of the RFET devices for both platforms, where the mode is set with a PG voltage V_{PG} of 5V for n-type and -5V for p-type operation and a symmetrically applied bias V_{DS} of 2V (V_D = 1V, V_S = -1V) (d) Transistor parameter evaluated for the shown devices of both platforms.

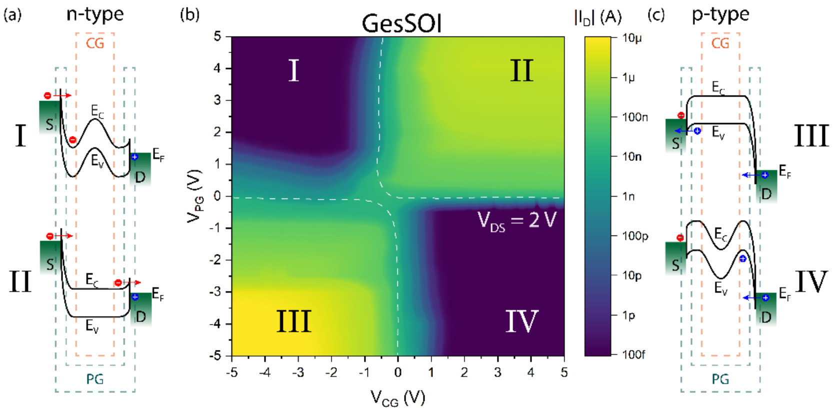

Fig. 2: Gate-voltage-dependent switching capabilities of the GesSOI platform (b) with the corresponding band diagrams and the related band bending situation for both operation modes, for n-type (a) and p-type (c).

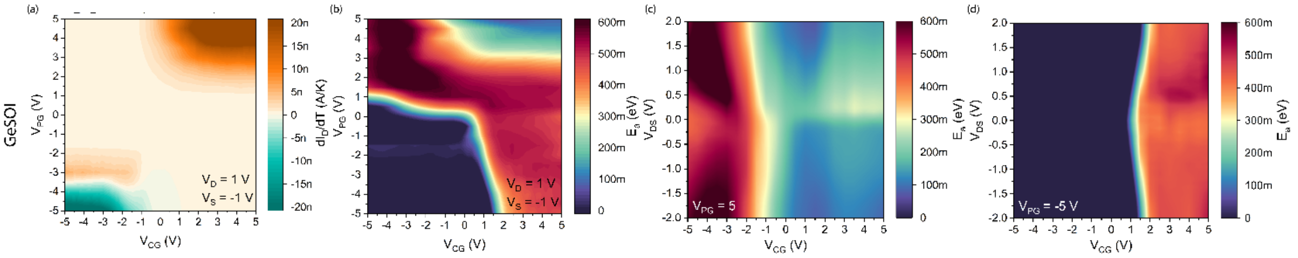

Fig. 3: Gate-voltage-related (a) temperature gradient for GeSOI RFETs and (b) activation energy for GeSOI RFETs for a constant bias. Bias-related and CG-dependent activation energy for n-type (c) and p-type operation (d) for the GeSOI platform.

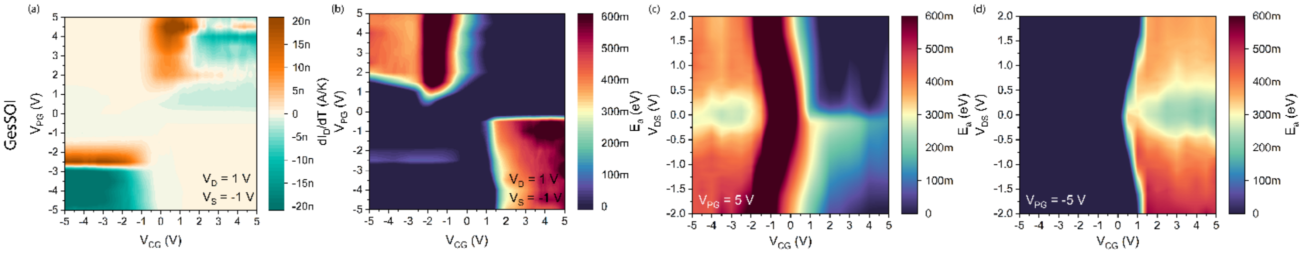

Fig. 4: Gate-voltage-related (a) temperature gradient for GesSOI RFETs and (b) Gate-voltage-related activation energy for GesSOI RFETs for a constant bias. Bias-related and CG-dependent activation energy for n-type (c) and p-type operation (d) for the GesSOI platform.