Modeling GaN Nanowire and Nanofin FETs Electrostatics using Fast 2D/3D Schrödinger-Poisson Solver.

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Gallium Nitride is a material of extreme interest for high-frequency and high-power applications. This has led to the development of GaN HEMTs and GaN nanowires. Computing carrier densities in such devices requires generic, accurate and fast solution of the coupled Schrödinger-Poisson problem to describe formation of the Q2DEG and Q1DEG, respectively. In this work, PETSc linear solver and SLEPc eigenvalue solver packages are used to achieve this goal.

GaN HEMTs retain the same topology as their GaAs counterparts. Split-gate nanostructures (Fig. 1a) and 3D Nanofin (NF) FETs [1] (Fig. 1b), realized by etching parallel mesa channels under the gate of AlGaN/GaN HEMTs [2], offer an alternative technology. A variant of the 3D NF FETs is the AlGaN/GaN MISFET (Fig. 1c), wherein a layer of Al_2O_3 surrounds the AlGaN/GaN fin [3]. Vertical confinement for the split-gate structure and the corresponding wavefunctions are shown in Fig. 2a. In Fig. 2b, we show the lateral confinement in the Schottky NF FET and the MISFET. Variation of the subband energies with fin width for the MISFET is shown in Fig. 2c. Carrier density in the center of the fin, as a function of gate bias, is shown in Fig. 3a, from where we can extract the threshold voltage of the MISFET. We find that under positive bias, AlGaN/GaN MISFET has two conduction channels: (1) due to the confined 2DEG at the hetero-interface, and (2) due to the formation of side-wall channels under the vertical gates (Fig. 3b). These two conduction pathways exhibit different transport characteristics, and, consequently, differently affect the I-V characteristics. As an example, we will show confined systems that exhibit enhanced electron mobilities [4], which will be computed from the self-consistent solution of the Schrödinger-Poisson-Boltzmann problem.

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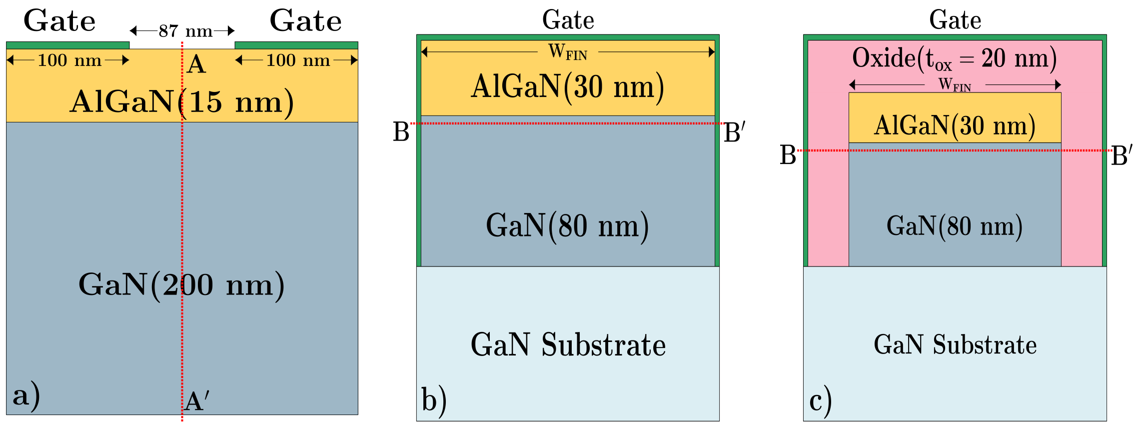

Figure 1: Cross section of different AlGaN/GaN FET variants. **a)** Split-Gate AlGaN/GaN nanowire. **b)** AlGaN/GaN FinFET with Schottky gate. **c)** AlGaN/GaN MISFET with Al_2O_3.

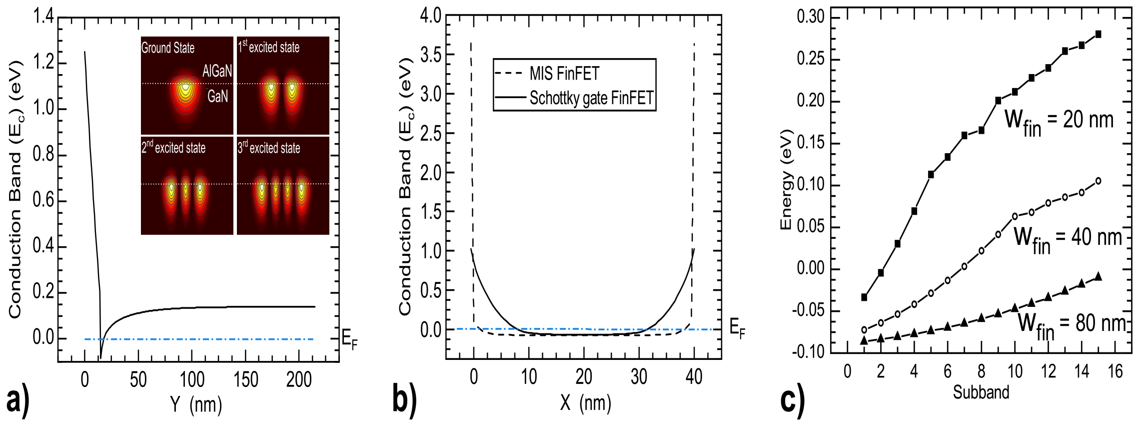

Figure 2: **a)** Conduction band (CB) profile along cutline A-A′ of the split-gate nanowire (figure 1a). Inset shows the probability density functions of the first four eigenvalues. **b)** The CB profile along the cutline B-B′ of the FinFETs shown in figure 1b) and 1c). **c)** The lowest 15 subband energies for FinFET structure from figure 1c) and for three different values of the fin widths.

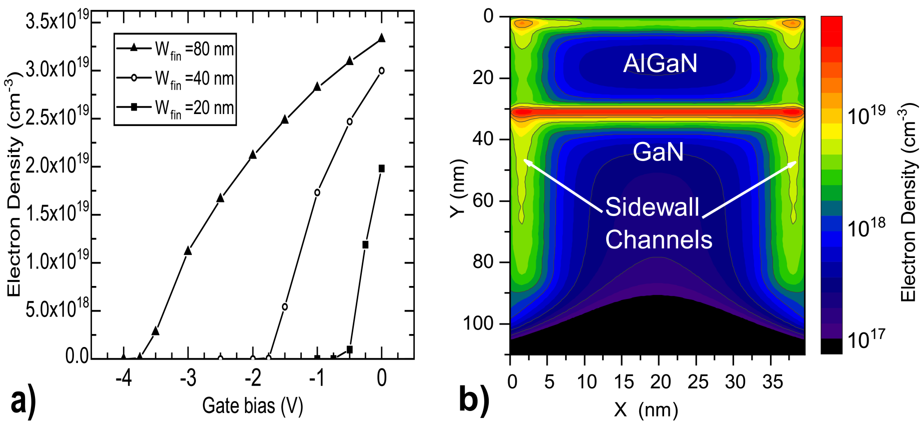

Figure 3: **a)** The electron density at the center of the fin in the MISFET from figure 1c) as a function of gate bias, for three different fin widths. The threshold voltage is less negative as the fin width reduces. **b)** Electron density in the MISFET at a positive gate bias of 2.0 V. Sidewall MOS like channels form along the vertical gates.