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Article

Fabrication of Silicon Nanowire Metal-Oxide-Semiconductor Capacitors with $Al_2O_3/TiO_2/Al_2O_3$ Stacked Dielectric Films for the Application to Energy Storage Devices

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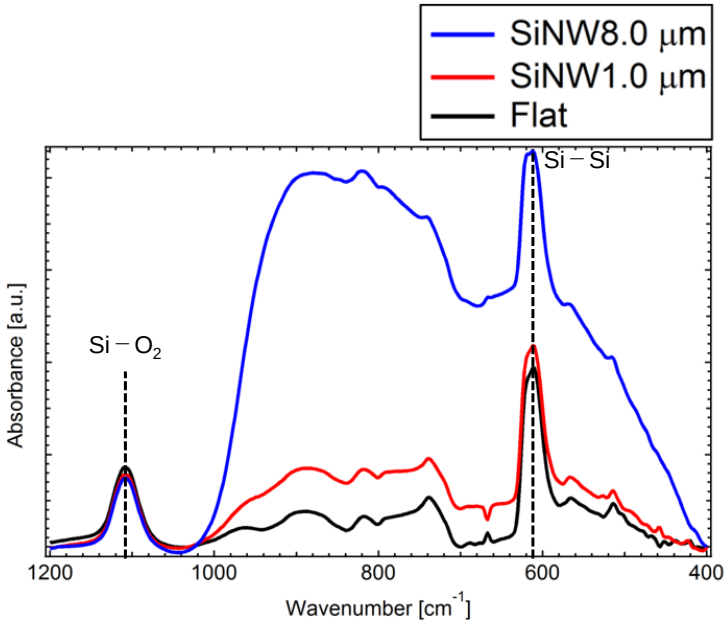

Figure S1. FT-IR spectra of SiNW arrays and a flat Si wafer coated by ATA. Two pronounced bands are attributed to IR absorption by Si–O_2 complexes (at ~1107 cm^{-1}) and by Si lattice phonons (at ~610 cm^{-1}), respectively. An Al_2O_3 broad band (500~1000 cm^{-1}) can be seen. If TiO_2 was crystallized, strong TiO_2 anatase band at 435 cm^{-1} could be observed. However, since there is no strong band at 435 cm^{-1}, TiO_2 is amorphous.

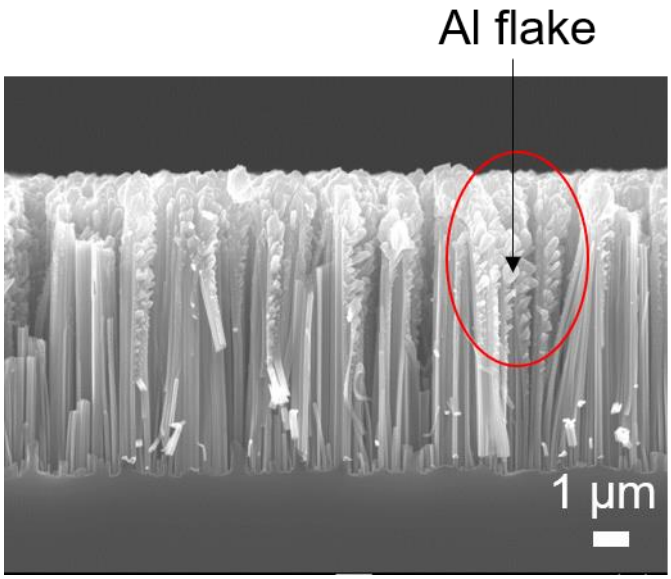

Figure S2. Cross-sectional SEM image of a SiNW MOS capacitor after Al evaporation. Flakes of Al crystals can be seen from the top to middle of SiNWs. Since Al electrodes were deposited by thermal evaporation, SiNWs were not perfectly coated with Al.

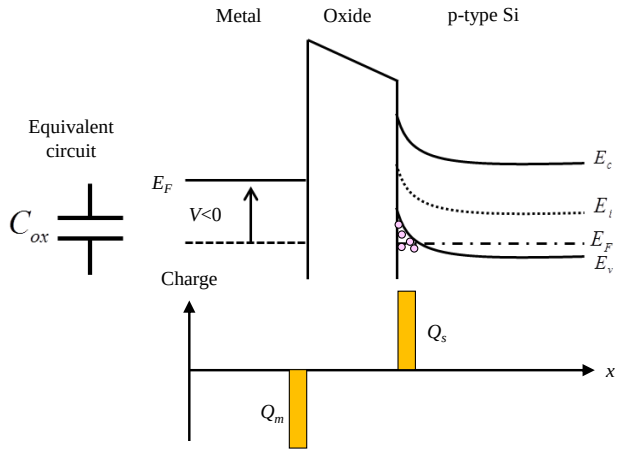

Figure S3. Energy band diagram and equivalent circuit of a MOS capacitor in the range of V < 0.

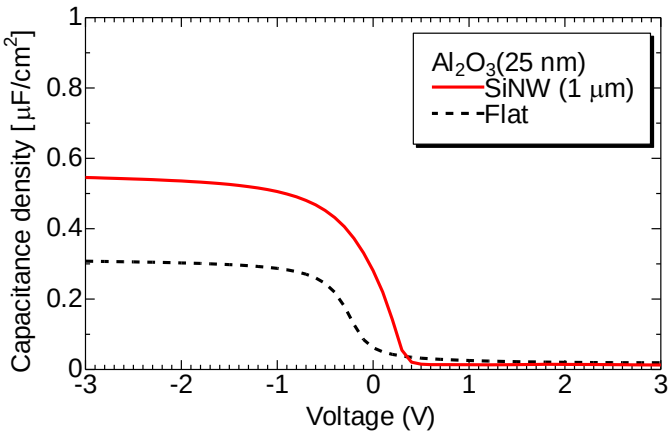

Figure S4. *C-V* characteristics of (Dashed line) a flat MOS capacitor and (Solid line) a SiNW MOS capacitor using 25-nm-thick Al_2O_3 as an insulator. The length of SiNWs is 1.0 μm.

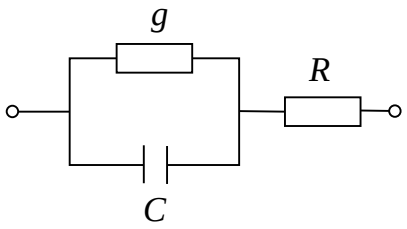

Figure S5. Equivalent circuit approximation of a leaky MOS capacitor.

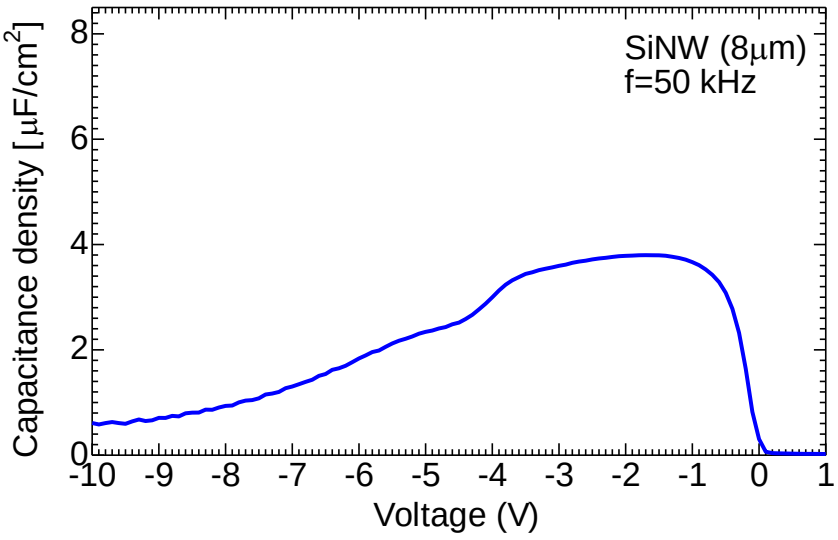

Figure S6. *C-V* characteristics of the SiNW MOS capacitor with the length of 8 μm measured at 50 kHz.

In this experiment, a total impedance was measured as an equivalent parallel RC combination. The capacitance density was decreased with increasing the absolute value of applied voltage. This trend is different from the Figure 3a. As mentioned before, *C-V* measurement at low frequency is not reliable due to the large influence of leakage current. To keep $Q_f > 1$, the frequency should be enough higher than around 50 kHz. Moreover, Choi *et al*. reported sharp decrease in capacitance density at acceleration region due to tunnel leakage current [42]. Therefore, the decrease in capacitance density in Figure S5 is also due to the leakage current density. To avoid this, higher measurement frequency is necessary.