Electrical Characterization of NWFETs with an EBL-defined Nafion Gate

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Humidity and Atmospheric Dependence

The Nafion gating effect is highly dependent on the humidity and the time spent in a humid atmosphere. This attributed to three main effects: (1) dissociation of water into H\textsuperscript{+}/OH\textsuperscript{-} ions (2) ions move more easily when they are solvated (3) protons move though the Nafion pores which are bigger when the Nafion is hydrated. Adding hydrogen in the carrier gas lead to a better drain current response due to the Pd gate contact that injects H\textsuperscript{+} ions into the Nafion.

RC Equivalent Circuit Fitting

A voltage applied on the Nafion-metal interface is not instantaneous applied on the Nafion-nanowire interface due to the finite ionic conductivity. A mathematical expression for the time dependent drain current response can be deduced by modeling the EDL as a resistor and capacitor in series: \( I(t) = I_o \cdot (1-e^{-t/\tau}) + I_p \).

Gate Voltage Range

The drain current shape is influenced by the gate voltage range. This depends on the \( I \) vs \( V \) shape; i.e. if the gate voltage is included in the subthreshold, linear or saturated regime. The displacement speed of the protons inside the Nafion also has an important influence. The protons move faster at the beginning of the sweep than at the end.

Conclusion

Functional Nafion-gated NWFET was developed with optimistic results in terms of operation speed. Complex electro-chemistry and high humidity dependence were demonstrated. Influence of hydrogen and gate voltage range was studied.

References


Solid Polymer Electrolyte

A solid polymer electrolyte (SPE) is an ionic conductor commonly synthesized by dissolving a salt in polymer gel. SPE can be used as a gate in a nanowire field-effect transistor (NWFET) without any current leakage due to the difference of carrier types. The electric double layer (EDL) formation induces a high gate capacitance. Moreover, the ionic conductivity makes SPE-gated NWFETs good candidate for ion-to-electron transducer; a key task of bioelectronics.

Nafion

- High protonic conductivity due to the sulfonic acid groups
- Can be patterned by EBL exposure
- Already used in batteries and super-capacitors.

Device Fabrication

First a nanowire is deposited on a Si/SiO\textsubscript{2} substrate. Second the gate metal lead is deposited by evaporation. Nafion is then spin-coated on the substrate and exposed in an EBL system. Finally the source/drain contacts are deposited by evaporation.

Transfer Characterization

- DC voltage (i.e. quasi-static variation, frequency close to 0) was applied on the gate of our device to deduce the transfer characteristics and prove their functionality. The on/off ratio and the subthreshold swing were deduced and \( V_{sd} \) sweeps were performed to confirm that we stay in the \( V_{gs} \) linear region.

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