Ebola biosensing with a gate controlled memristor mode

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Nanowire-based field-effect transistors (FETs) are currently attracting a strong attention due to their potential to deliver promising miniaturized diagnostic tools with a high and label-free sensitivity [1,2]. Recently, the use of their memristor property was demonstrated as biosensing principle, showing that the binding of charged biomolecules bring a violation of its zero-crossing signature by opening a voltage gap V_{GAP} in the current minima when the source-to-drain voltage V_{SD} was swept [3]. The demonstration was done in dry conditions to get rid of the screening effect caused by the excess of nonspecific ions.

In this work, we demonstrate the biosensing in the memristor mode directly in a liquid environment using a FET based on a pattern of honeycomb shaped silicon nanowires (Figure 1a). We engineer the gap opening process by applying a gate voltage V_G through the reference electrode that mimics the presence of surrounding charged species of the desired sign (Figure 1b). An initially opened gap V_{GAP} allows to detect the biomolecules carrying arbitrary, positive or negative charge that results in either further increasing or closing the V_{GAP}, respectively. The VP40 matrix protein from Ebola virus is detected in a miniaturized electronic nanobiosensor for the first time, in femtomolar levels, by analyzing the needed V_G to maintain a constant value of V_{GAP}=1.5V (Figure 1c). We finally compare the same device performance in terms of its detection range and sensitivity to the results obtained in the already known field-effect transistor (FET) mode (Figure 1d), showing that the memristor mode is sensitive at the same concentration levels as the FETs.

References

[1] Patolsky, F.; Zheng, G. F.; Lieber, C. M. Nat. Protoc. 1 (2006), 1711–1724.
[2] Karnaushenko, D.; Ibarlucea, B.; Lee, S.; Lin, G.; Baraban, L.; Pregl, S.; Melzer, M.; Makarov, D.; Weber, W. M.; Mikolajick, T.; Schmidt, O. G.; Cuniberti, G. Adv. Healthc. Mater. 4(10) (2015), 1517–1525.
[3] Tzouvadaki, I.; Jolly, P.; Lu, X.; Ingebrandt, S.; De Micheli, G.; Estrela, P.; Carrara, S. Nano Lett. 16(7) (2016), 4472–4476.

Figures

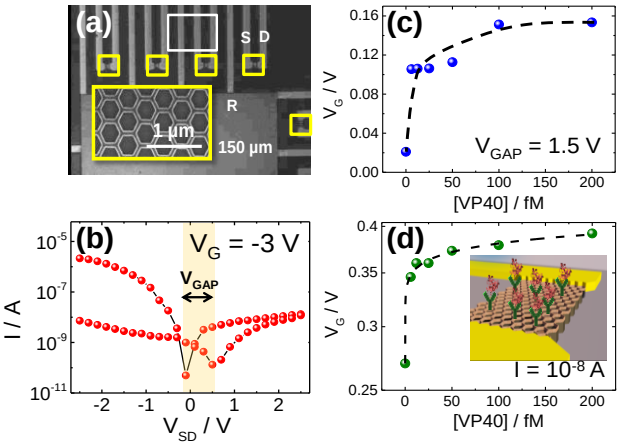

Figure 1. (a) Nanosensor where S=source, D=drain, and R=reference denote the electrodes. The inset shows silicon nanowires located at yellow areas. (b) A V_{GAP} opening (orange area) appears by applying a negative V_G. (c) The biosensing in the memristor mode. At increasing protein concentrations, V_G needs to be increased in order to maintain a constant V_{GAP}=1.5V. (d) The biosensing in the FET mode. The inset depicts the device modified with antibodies that catch the target protein.