Self aligned fabrication process for carbon nanotube based field-effect devices: transistors, memory cells and bio-sensors.

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Carbon nanotube field-effect transistors (CNTFETs) are well recognized to become a possible replacement of the traditional MOSFET in the CMOS technology to develop logic circuits, so that Moore´s law can still be followed in the future [1]. However, mass production should be possible for integration on a very large scale, i.e., billions of transistors on one wafer. We present in this work our new fabrication process for single-walled carbon nanotube (SWNTs) based devices. The process is based on chemical vapor deposition growth of the nanotubes using a sacrificial catalyst (Figure 1). SWNTs are grown directly on their final place avoiding any manipulations. Furthermore, only one-step lithography is necessary, not only in order to contact the devices but also to passivated them simultaneously. Polymethyl methacrylate (PMMA) is used as a passivation layer to protect the SWNTs from ambient air and increase the life time. Thanks to this suitable process, we have already fabricated around 15.000 passivated devices. Moreover, we show that our CNTFETs are suitable for memory applications. They can be used as non-volatile memory cells operating at room temperature. The memory function is obtained by the threshold voltage shift due to the highly reproducible hysteresis in the transfer characteristics (Figure 2). The ratio of the current levels between a logical "1" and a "0" is about 10^6. Lastly, CNTFETs are ideally suitable for biomedical sensor applications due to their excellent inherent properties such as ultra small size, high specific surface area, extremely high sensitivity and the above mentioned hysteresis effect. For example, the detection and identification of single viral particles may be possible using functionalized CNTFETs as sensors: The binding of a virus to a suitably functionalized semiconducting SWNT will measurably affect the gate-dependent electrical current-voltage characteristics of the transistor via charge transfer between the SWNT and the virus (Figure 3).

[1] W. Hoenlein, F. Kreupl, G. S. Duesberg, A. P. Graham, M. Liebau, R. Seidel, and E. Unger, "Carbon nanotubes for microelectronics: status and future prospects," Mater. Sci. Eng. C, vol. 23, pp. 663-670, 2003.

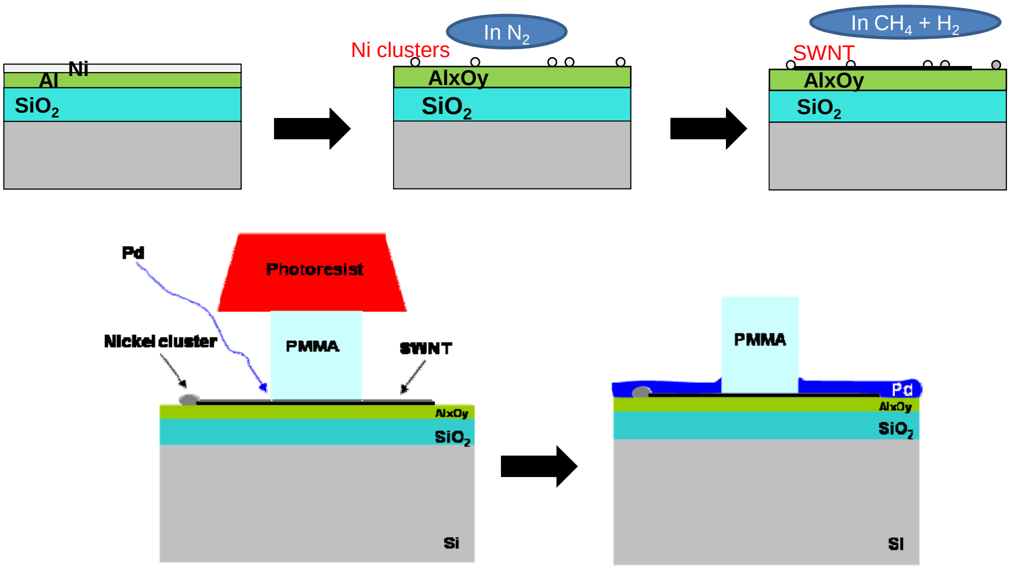

Figure 1. Schematic of the fabrication process for CNTFETs reported in this work.

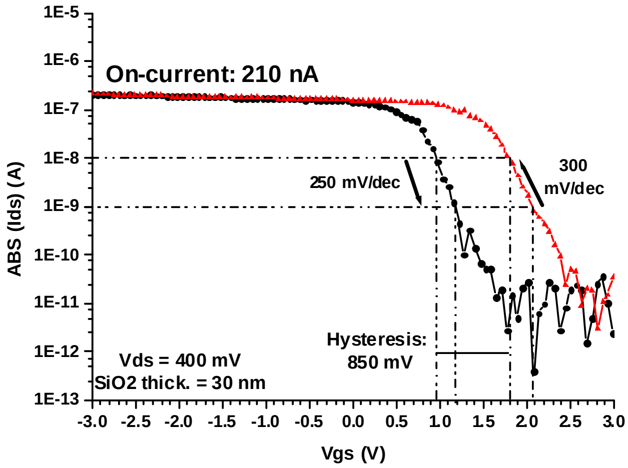

Figure 2. Transfer characteristics of CNTFETs with 30 nm gate oxide thickness.

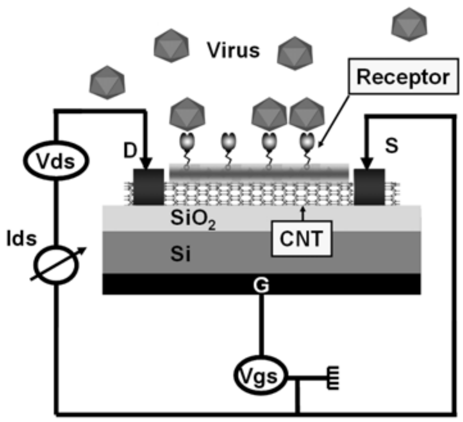

Figure 3. Illustration of proposed CNT sensor for virus detection.