Realization and characterization of vertical self-both-ends-bonded SW nanotubes grown at 550°C in a via-like metal/insulator/metal structure by in situ PECVD

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Single Walled Carbon Nanotubes (SWCNTs) have focused a considerable research effort due to their outstanding properties and potential large application area. They are promising candidates to be integrated in future nanoelectronic devices [1], high sensitivity sensors [2] or used for heat removal in chips [3]. Many studies on SWCNTs devices fabrication are based on a SWCNT ex situ growth at high temperature (>700°C) and a second assembling step is needed. Some studies also report vertical interconnects with in-situ growth [4] but they require a post growth top contact realization. To be compatible with CMOS technology and to achieve manufacturable devices, CNT growth and integration processes have to comply both with low thermal budgets and large scale integration on silicon wafers.

In the following work, SWCNTs are grown and both-ends self connected in situ by a Plasma Enhanced Chemical Vapor Deposition (PECVD) at a low temperature of 550°C. We have developed a vertical via-like metal/insulator/metal structure on 200mm silicon wafers that allows bottom to top metal-to-metal nanotube self interconnections during growth. Morphological and electrical investigations of these interconnects are presented.

The structures used are described on Figure 1**.** A first metal layer is deposited on a highly doped Si wafer as a bottom electrode. A 200nm insulator layer of TEOS-SiO_2 is then deposited by PECVD and covered by a metal layer as a top electrode. Vertical 300-500nm diameter via-hole etching is then performed and stopped on the bottom metal surface. After sub-layer SiO_2 recessing, a Fe based catalyst is sputtered through a shadow mask. The CNT growth is then performed using an Electron Cyclotron Resonance (ECR) PECVD method. After a reduction step, a low pressure CH_4 gas mixture is introduced at 550°C. The final nanotube-connected structure is shown on Figure 2**.**

The process has been optimized to selectively grow single wall CNT. TEM image on Figure 3 shows the high quality structure of as grown 1.4nm diameter SWCNTs. Some SWCNTs bundles are also observed. In order to investigate their electrical behaviour we have performed I(V) and I(time) measurements by applying a sweep bias voltage between the two metal electrodes. Electrical characteristics of the tested devices do not give evidence of any hysteresis or instability which show the structure stability. The breakdown behaviour of such device has been tested by increasing bias voltage up to 40V. Preliminary measurements, as shown on Figure 4, have exhibited very high current density around 10^9 A/cm^2 followed by a sequential current drop until reaching zero with increasing voltage. Each drop can be attributed to a breakdown of one of the SWCNTs that interconnects the metal layers. These results are consistent with those of Dai team [5] who has performed similar measurements on horizontal SWCNTs between two planar electrodes.

Additional electrical measurements are on-going. They will be carried out at different temperatures to investigate the semi-conducting versus metallic behaviour of self interconnected SWCNTs.

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References:

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Figures:

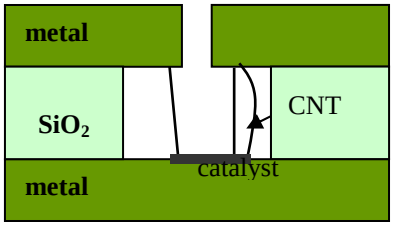

Figure 1: metal/SiO_2/metal structure in which base-growth SWCNTs self interconnect the bottom and top metal electrodes during growth

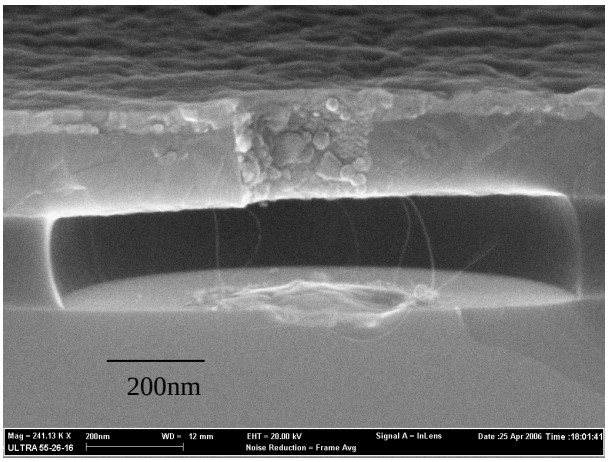

Figure 2: SEM image SWCNTs vertically self interconnected between two metal layers. The SWCNT array is grown at 550°C by an ECR-PECVD method from a CH_4 mixture

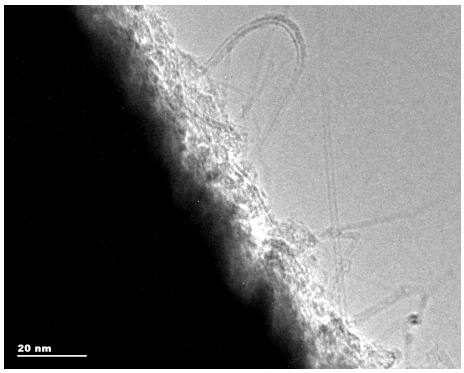

Figure 3: TEM image of SWCNTs grown in the same run as the previous structure. Straight 1.4nm diameter SWCNTs and some bundles (curved) are observed

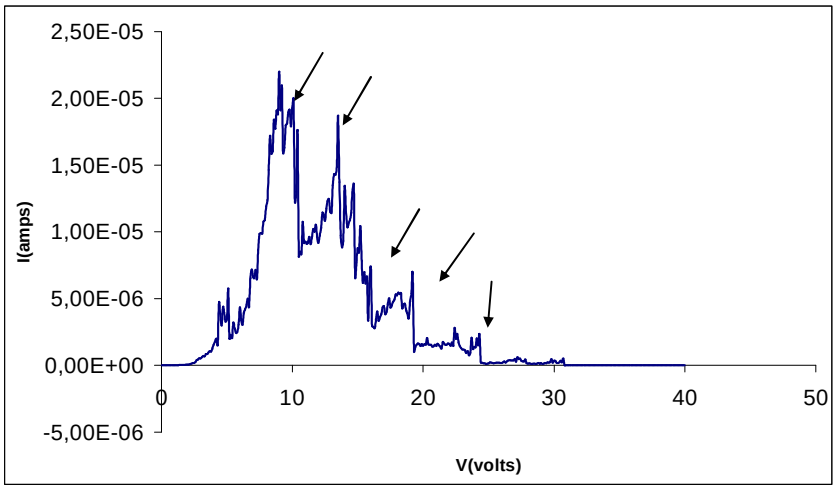

Figure 4: Electrical I(V) measured on the device described in figure 2 with increasing bias voltage between the two metal electrodes. Each arrow points up a current drop which could be related to a single SWCNT breakdown. After all SWCNT has been disconnected the current reaches zero. Considering that only a few SWCNT participate to the current conduction, the maximum current density is estimated to be around10^9A/cm^2