CARBON NANOTUBES FILMS FOR THE DETECTION OF MID-INFRARED LIGHT

*Sylvain Maine, C. Koechlin, R. Haidar, B. Tretout, J. Deschamps, A. Loiseau, and J.-L. Pelouard**
ONERA, Chemin de la Hunière, F-91761 Palaiseau, France
**LPN-CNRS, Route de Nozay, F-91461 Marcoussis, France*
sylvain.maine@onera.fr

Carbone nanotubes CNT behave as a direct gap semiconductor, with a band-gap energy depending on their structure (single or multi-wall) and geometry (diameter, chirality). Typically, single-walled CNT present a bandgap energy between 0.1eV and 1.5eV, thus they are well suited for opto-electronic applications in visible to the infrared range, such as bolometric light detectors [1] or phototransistors [2].

Following these pioneering works, we propose to study bolometers based on CNT films with extended detection range to the mid-infrared spectrum (8-12µm), in band III of atmospheric transparency. As shown in Figure 1, thin CNT films may present constant and highly efficient absorption in this spectral range, demonstrating their high potential for band III applications.

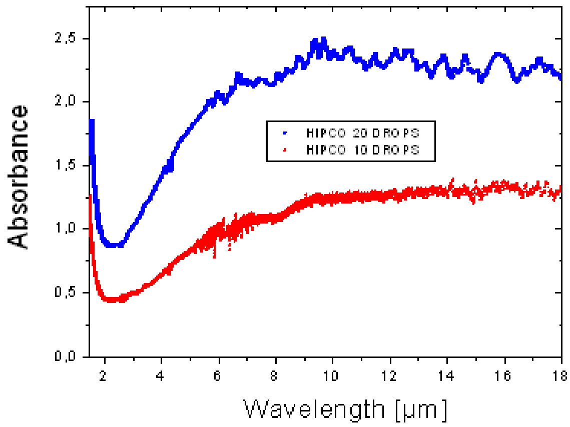

Figure 1 : absorption spectra of thin HiPCO CNT films (density expressed in drops, corresponding to typical thicknesses of 100nm and 200nm).

Studied devices are made of a suspended CNT film over platinum interdigit electrodes (Figure 2), using a technique based on cellulose filters [3]. The electrode interdigital pitch can be of 1µm, 2µm, 5µm or 10µm.

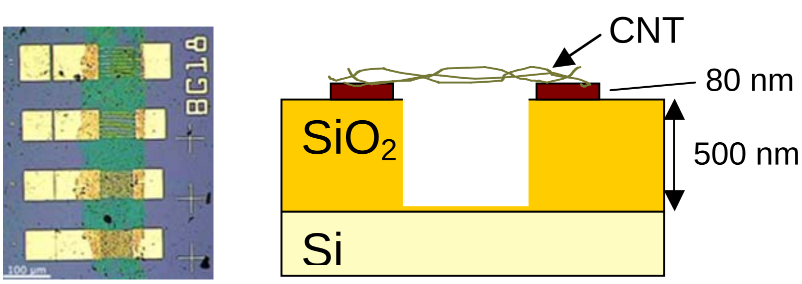

Figure 2 : Photo and Schematic diagram of the CNT films suspended on 80nm thick platinum electrodes.

In the 100-300K temperature range, measured *I-V* characteristics denotes a slight nonlinearity for bias voltages larger than 0.5V as already been noted for thin CNT films [4]. Measurements of the low voltage resistance of various geometry devices give reach to the resistance square which proves to follow a quadratic temperature law (Figure 3a):

$$R_{square} = \frac{R_0}{T^2} \text{ where } R_0 \approx 10^{12}\ \Omega$$

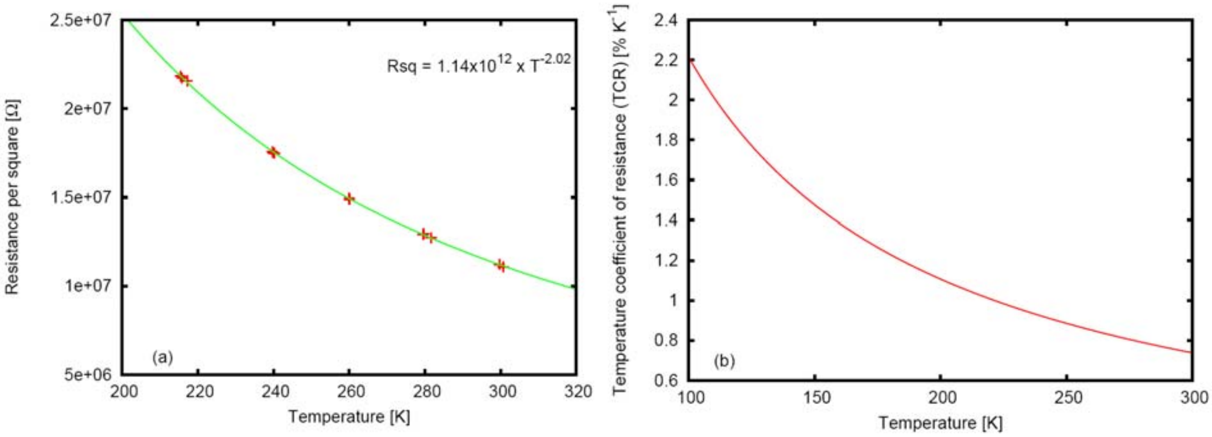

Figure 3 : (a) Resistance per square of the CNT film versus temperature for various geometry devices ; (b) TCR as a function of temperature.

One can also extract the temperature coefficient of resistance *TCR* which is a sizing parameter for bolometric devices based on semiconductor material (Figure 3b):

$$TCR = -\frac{\Delta R}{R \Delta T}$$

We find out a *TCR* of ~1% at ambient temperature, which is slightly below the usual value of materials used for bolometric applications (2.5% in amorphous silicon). Let us point out that this promising value is obtained on non-optimised structures: indeed, scanning electron microscope (SEM) images show that the CNT films presents textural defects and/or embeds remaining cellulose impurities. Work is in progress to address this specific matter as well as the architecture of the devices, in order to achieve the best possible electrical contact on the CNT.

References:

[1] M.E. Itkis et al., "Bolometric Infrared Photoresponse of Suspended Single-Walled Carbon Nanotube Films", Science **312,** p 413 (2006)
[2] M. Freitag et al., "Photoconductivity of Single Carbon Nanotubes", NanoLetters **3**, 8 (2003)
[3] Z. Wu et al., "Transparent, Conductive Nanotube Films", Science 305, p 1273 (2004).
[4] V. Skalavova et al., "Electronic transport in carbon nanotubes: From individual nanotubes to thin and thick networks", Phys. Rev. B 74, 085403 (2006).