ELECTRICAL CONDUCTIVITY OF THE GRAPHENE FOR NANO-ELECTRONICS: MODELING AND CHARACTERIZATION

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Due to their outstanding physical properties, graphene and its allotropes, Carbon Nanotubes (CNTs), Graphene Nanoibbons (GNRs) or Graphene NanoPlatelets (GNPs), are the major candidates to become the silicon of the 21st century and open the era of so-called carbon electronics [1].

The low electrical resistivity, high thermal conductivity, high current carrying capability, besides other excellent mechanical properties, make graphene a serious candidate to replace conventional materials in realizing VLSI nano-interconnects [2]. A carbon-based VLSI technology is not yet a pure theoretical wish, since in the last few years, the rapid progress in graphene fabrication made possible the first examples of real-world applications [3-4].

The present paper reports a resume of the ingoing activities carried out in the frame of a collaboration between the Units of Naples Federico II and Cassino, along with the INFN in Frascati. The collaboration is aimed at investigating the behavior of such a new material in nanoelectronic applications, either with modeling and experimental characterization.

The modeling activity is carried out in the frame of the electrodynamical models already developed by these Units (*e.g.*, [5]-[8]). A self-consistent transport model, based on the tight-binding model and the semi-classical Boltzmann equation, provides the constitutive relation for the graphene materials, written in terms of a generalized non-local Ohm's law in the frequency and wave-number domain:

$$\hat{\mathbf{J}} = \ddot{\boldsymbol{\sigma}}(\omega,\boldsymbol{\beta})\hat{\mathbf{E}}_t \ , \tag{1}$$

where, in principle, the conductivity is a symmetric dyad. By coupling (1) to Maxwell equations, a clear analytical relation between the circuit model parameters and the physical and geometrical properties of the nanostructures is obtained [5]-[8]

In the long wavelength limit, the conductivity of an infinite sheet of graphene does not show spatial dispersion, but only frequency dispersion, being the generic entry of the dyad:

$$\sigma(\omega) = \frac{\sigma_c}{1 + i\omega/\nu} \ , \ \ \sigma_c = \frac{2\ln 2}{\pi\hbar^2\nu} e^2 K_B T, \tag{2}$$

where ν is the collision frequency. A similar behavior is obtained for a GNR, where the (2) holds, but replacing the constant σ_c with a value σ_0 which is modulated by the GNR chirality, size and temperature, through the equivalent number of conducting channels. Note that $\sigma_0 \to \sigma_c$ as the GNR width *W* tends to infinity, regardless of the chirality [8].

In the general case, we must take into account the dyadic nature of the conductivity. For the sake of simplicity, let us refer to the components of any vector to the parallel and orthogonal directions with respect to the vector, **β**, denoted with the symbols "∥" and "⊥", respectively. Figure 1 shows the dispersion introduced in such a case.

An experiment is currently building, to investigate the above effects foreseen by the models: dependence on the chirality and size of GNR, spatial and frequency dispersion in graphene sheets of finite size. Figure 2 shows the realized setup, where a graphene layer (for now, GNPs) is deposited on a substrate and contacted to two copper electrodes.

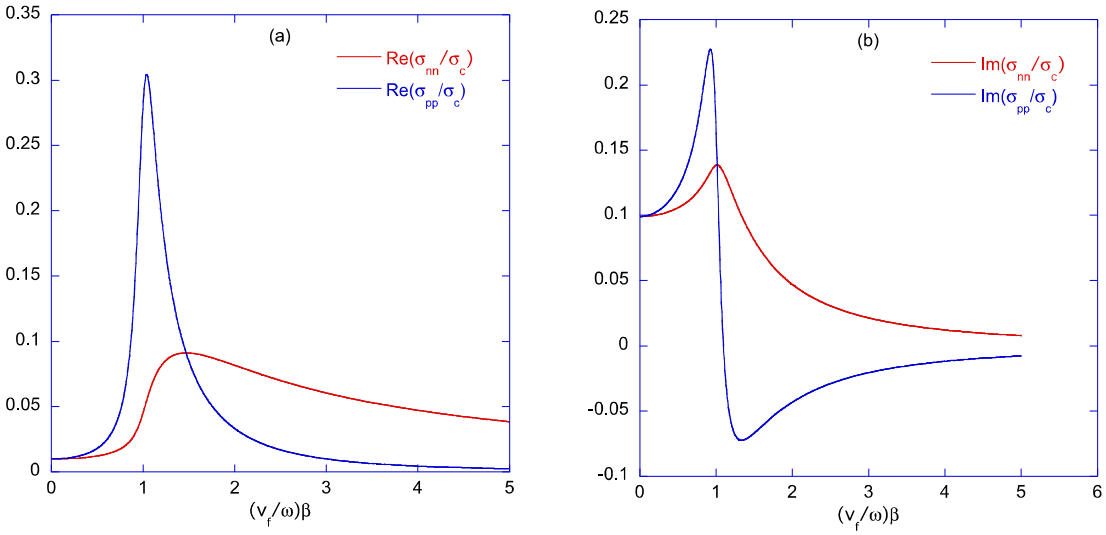

Figure 1. (a) real and (b) imaginary parts of $\sigma_{\parallel\parallel}$ and $\sigma_{\perp\perp}$, normalized to σ_c, vs $(v_F/\omega)\beta$ for $\nu/\omega = 0.1$

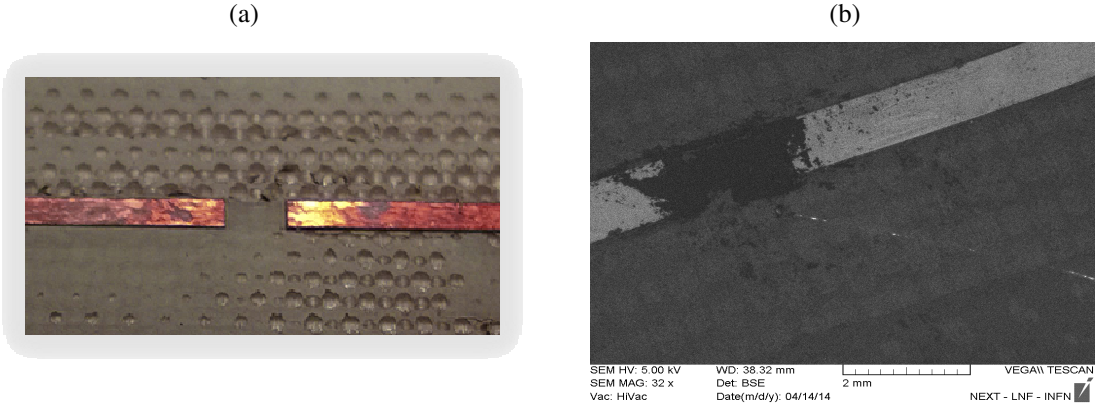

Figure 2. Experimental setup: (a) substrate and electrodes; (b) the deposited GNP layer.

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