Nano carbon hybrids: new materials for electronics

Nuno Santos[1], Alexandre Carvalho[1], Tiago Holz[1], António Fernandes[1], Florinda Costa[1]

1 — Department of Physics & I3N, University of Aveiro

The intensive research efforts put in carbon based materials resulted in major scientific and technological breakthroughs awarded with two Nobel prizes in the last two decades. The wide range of carbon allotropes (eg. graphite, fibres, diamond, buckyballs, nanotubes, graphene) possessing distinct physical and chemical properties allowed innovative solutions in areas spanning from structural reinforcement to biomedical or electronic applications. Nowadays, a strong challenge consists on the combined synthesis of different allotropes in a single hybrid material in order to tailor the desired properties towards a specific application.

In fact, nano-carbon hybrid structures are very stimulating materials not only due to the recognized excellent individual properties of each carbon allotrope but also to the synergistic combination possibility of sp2 and sp3 bonded forms. Particularly, both sp2 (graphene, graphite) and sp3 (diamond) phases of carbon exhibit outstanding mechanical, thermal and complementary electronic properties, being graphene a superior electrical conductor and diamond an excellent electrical insulator. Our group has been studying the resulting properties of multi-phased carbon forms produced by Microwave Plasma Chemical Vapour Deposition (MPCVD). The latest focus has been put on graphenediamond hybrids (GDH) and diamond-graphite nano-platelets (DNP).

The simultaneous synthesis of graphene-diamond hybrids is highly desirable in order to explore the synergistic effects of these complementary materials. Although being a hard task since the thermodynamic conditions to synthesize one phase are unfavourable to the other, it was successfully accomplished for the first time [1]. These hybrids consist in few-layer graphene sheets sprinkled by nanocrystalline diamond (NCD) hemispherical clusters (Figure 1). A strong covalent bond between both phases was found, foreseeing applications in field effect transistors (FETs) and electron field emission in cold cathode devices.

Diamond-graphite nanoplatelets consist on vertically aligned diamond nanoblades (~ 5-10 nm thick) encapsulated by a nanographite thin layer (Figure 2). This hybrid outperforms standard NCD coatings in convective heat dissipation due to the enhanced surface area provided by its particular high aspect ratio structure [2]. Thus, DNP enable effective heat transfer at low production cost, weight, and thickness, which are crucial characteristics when developing thermal management solutions for the increasingly miniaturized, yet powerful, new generations of microelectronics.

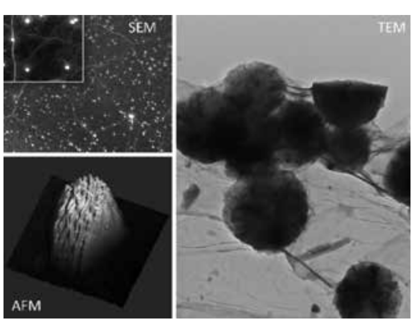

FIGURE 1
The GDH hybrids, as displayed by three different techniques: scanning electron microscopy (SEM), transmission electron microscopy (TEM) and atomic force microscopy (AFM). The bright spots seen in SEM correspond to the NCD clusters, whose hemispherical morphology is clearly depicted in TEM and AFM images. Graphene sheets wrapping the NCD clusters are visible in TEM.

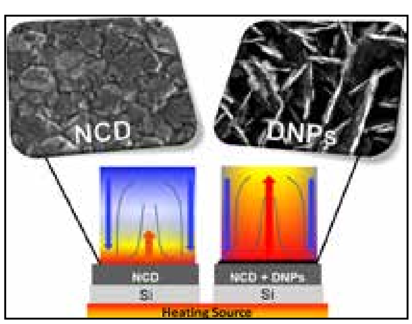

FIGURE 2
Schematic representation of the experiment used to demonstrate the increased convective heat dissipation performance of the DNPs hybrids compared to NCD. This behavior arises from the distinct materials' morphologies, as depicted in the SEM micrographs.