NANODIAMONDS: HINTS FOR BIO-TECHNICAL APPLICATIONS

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ABSTRACT

Thanks to its extreme chemical inertness, optical transparency, exceptional hardness and minimal toxicity, diamond is widely considered as one of the most promising and intriguing materials for a large variety of bio-applications. The recent progresses in the production of nanodiamond have now boosted the interest for its application as a multifunctional bio-technological material.
In this paper we present some relevant strategies that are being developed in our labs towards enabling nanodiamond-based bio-applications.

1. INTRODUCTION

Among the large number of nanoparticles that are being investigated for their feasibility to interact with biological entities at the nano-scale, nanodiamond crystallites are widely considered at present the more promising. It has been proven that nanodiamond is an excellent substrate for the adhesion and growth of several types of cells in vitro, and can advantageously and selectively bind various biological molecules. Therefore, the nanodiamond can be considered as an ideal surface for sensing, detecting, separating and purifying biological systems. Other remarkable application deals with the photophysical properties of systems characterized by bright photoluminescence in the extended red region and by the absence of photobleaching and photoblinking.

In our labs a variety of different strategies are being explored to prepare specific platforms based on nanodiamonds. In particular, we are developing different methodologies and testing technologies devoted to possible applications for sensing, imaging, and drug-delivery.

In such a framework we shortly describe here some under-developing synthetic strategies dealing with bio-related applications of nanodiamond are shortly described in the follow.

2. EXPERIMENTAL

The nanodiamond samples are prepared by CVD from CH_4/H_2 gas mixtures, or by self-assembling of colloidal dispersions of nanodiamond particles produced by dynamical synthesis. In this last case specific protocols are followed to avoid re-aggregation of the primary nanoparticles. The decoration by metal nanoparticles is achieved by electrochemical methods (Au, Ag, Ni) and also by electroless procedures (Au).
The surface modifications of the diamond surfaces are obtained by surface adsorption, electrostatic linking or covalent bonding.

3. RESULTS AND DISCUSSION

Fluorescent nanodiamond (FND) is emerging as a new type of nanomaterial that holds great promise for biological applications. FND exhibits several remarkable features, including emission of bright photoluminescence in the extended red region, no photobleaching and photoblinking, and easiness of surface functionalization for specific or nonspecific binding with nucleic acids and proteins,etc. These excellent photophysical properties, together with the good biocompatibility may open up new frontier in biosensing.
A technology based on the use of metallic nanostructures that interact with fluorophores to increase their emission intensity has long been recognized since its discovery in 1980.
Typically, a 2- to 10-fold enhancement in the fluorescence intensity is observed for fluorophores with low quantum yields. A number of biotechnological applications taking advantage of this so-called metal-enhanced fluorescence (MEF) have been developed, such as, to improve the sensitivity of DNA hybridization assays.
To bring together the appealing advantages of FND and MEF in our laboratory we prepare nanometric diamonds in form of particles (Figure 1-a) and films with fluorescent properties and couple them with plasmonic metals nanoparticles for the production of interesting systems for photonic applications.
In this contest we investigated the color centers genereted by N or by the insertion of semiconductive species, as Si, inside the diamond lattice that maintained their structural properties (Figure 2-b) [1].

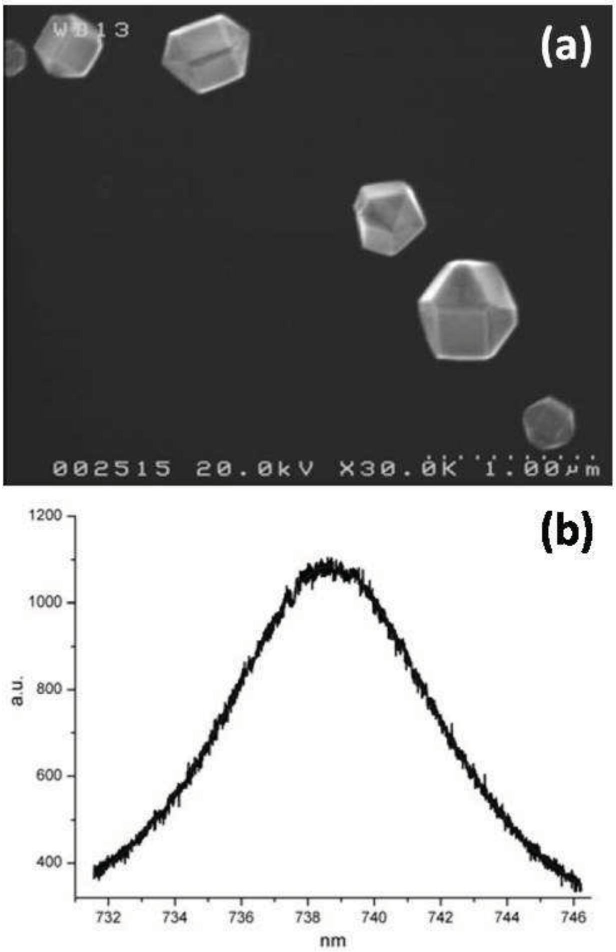

FIGURE 1: (a) FE-SEM image of nanocrystalline diamond; and (b) photoluminescence of silicon colour centre in nanocrystalline diamond

Figure 2 shows the FE-SEM images of nanodiamond partcles decorated by Au nanoparticles. These hybrid samples are prepared for optical sensing of organic and bio-molecules.

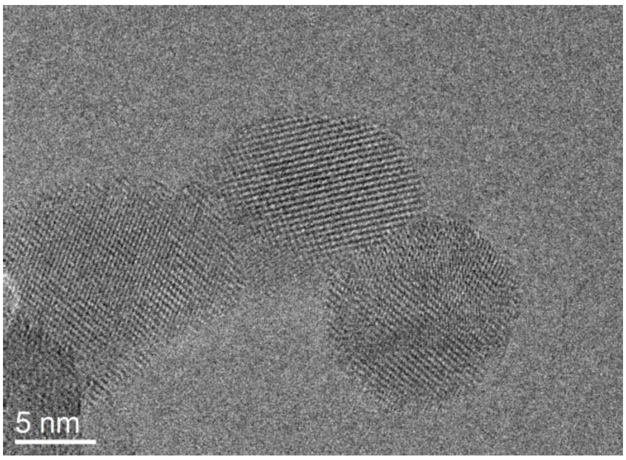

FIGURE 2: HR-TEM image of diamond nanoparticles decorated with Au particles

As regards the surface modifications of the diamond phase, the relationship between the conditions of the chemical processes inducing the various functionalizations and the optical responses is also deeply investigated (Figure 3).

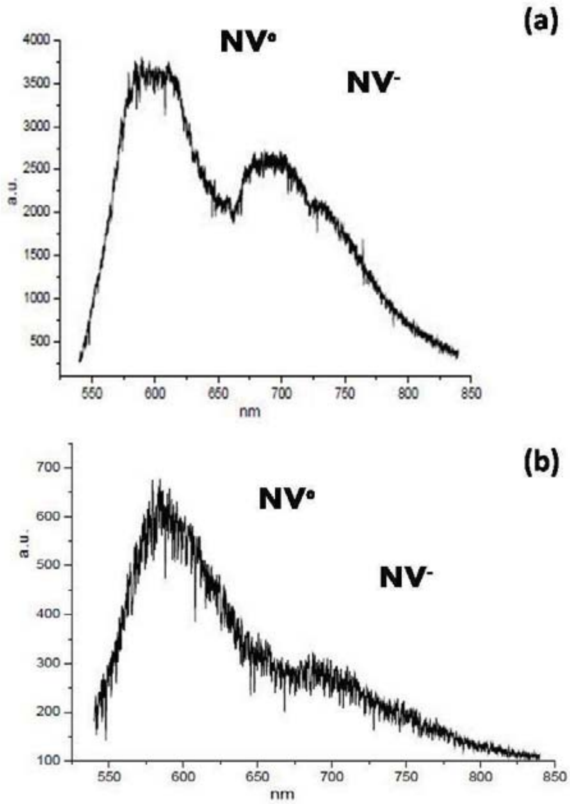

FIGURE 3: Photoluminescence of nitrogen-vacancy colour centre Silicon of nanodiamond before (a) and after (b) surface functionalization with acyl chloride.

A series of differently bonded nanodiamond-molecule systems are produced in order to test the chemical/physical interactions and to define the binding forces acting between functionalized DND surfaces and linked or adsorbed moieties. These materials represents a proof-of-principle for the development of drug-delivery systems. Moreover preparation of materials suitable in perspective for imaging is addressed by linking fluorophores to the nanodiamond surfaces (Figure 4).

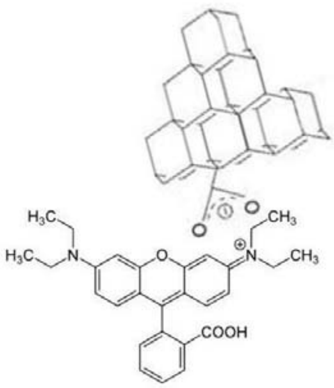

FIGURE 4: Example of a dye-nanodiamond particle conjugate

Different functionalizations of nanodiamond crystallites are under consideration for their application to diamond enhanced thickness shear mode resonator for selective bio-sensing (Figure 5).

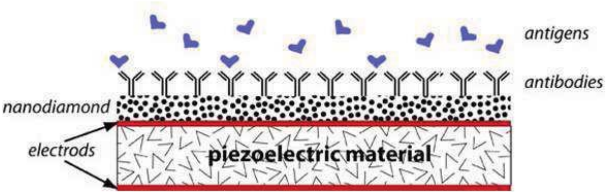

FIGURE 5: Scheme of a diamond-based enhanced thickness shear mode resonator

This kind of devices, assembled by nanoparticles or by differently shaped nanostructures obtained by diamond films nanosculpuring, can be used also for electrochemical microgravity and visco-elastic monitoring of molecule/diamond surface interactions.
Last but not least, nanocomposite layers formed by nanodiamond grains embedded in conductive polymer matrices (Figure 6) are being produced for bioelectrodes and sensors assembling [2].

FIGURE 6: TEM image of a polyaniline-nanodiamond film composite

4. CONCLUSIONS

The objective of the present research is to extend and finalize results and competences up-to-now acquired by our group in the field of carbon nanomaterials to the realization of diamond-based devices for bio-related applications.

5. REFERENCES

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