

Surface chemistry, substrate electronic structure, and surface-bound water effect on surface potential of detonation nanodiamonds

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1. Introduction

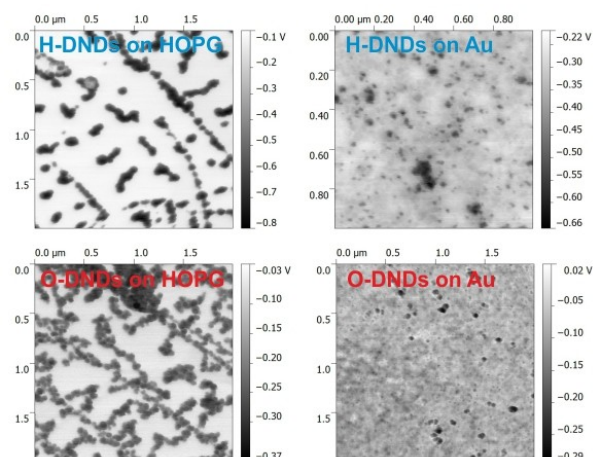
Detonation nanodiamonds (DNDs) belong to family of carbon nanomaterials with great application potential in spintronic, biological as well as industrial applications. Due to their typical size of 4-5 nm with ~15% of a DND particle atoms residing on its surface their surface properties are extremely important. The possibility to tailor their initial surface chemistry and to subsequently build up rather complex covalent or non-covalent organic functionalization is their great advantage over the other non-carbon nanomaterials. However, despite certain progress in the last years their surface electronic properties remain largely unknown. From this point of view the local measurement of surface potential on individual nanoparticles by means of Kelvin probe force microscopy (KPFM) may resolve some fundamental physical properties of the DNDs. It was shown recently that the surface potential of DNDs at ambient conditions is not stable but depends on the workfunction of surrounding materials, i.e. certain charge can be trapped on DNDs (*Langmuir* 29, (2013) 1634). Here we use single pass KPFM technique with amplitude modulation to study surface potentials of hydrogenated and oxidized DNDs as “standard” diamond surface terminations on highly oriented pyrolytic graphite (HOPG) and sputtered Au substrates. The measurements were performed in a glove box under dry, inert nitrogen atmosphere to avoid the surface water layer impact on the KPFM data.

2. Experimental

Detonation nanodiamonds were synthesized from trinitrotoluene (TNT) and hexogen (RDX) precursors in a detonation chamber. Purification of the DNDs includes an air-oxidation treatment at 390°C during several hours. A first part was kept as obtained while the second part was hydrogenated by annealing of the DNDs under hydrogen atmosphere at 700°C for 3 hours. From such treated DNDs colloidal solutions were then prepared by means of ultrasonication and centrifugation and then used for electrophoretic deposition of the DNDs on HOPG and Au substrates for KPFM measurements (*Appl. Phys. Lett.* 101, (2012) 253111).

3. Results

The obtained KPFM data revealed important role of the surface water layer present both on H-DNDs and O-DNDs even under water-free glove box environment. Until the adsorbed water is not removed by sample annealing at ~150°C the precise measurement of the



surface potentials of DNDs is problematic. On the other hand once the adsorbed water layer is removed from the DNDs the clear difference between H-DNDs and O-DNDs on both HOPG and Au substrate becomes obvious. The results are in agreement with those obtained on hydrogenated and oxidized bulk diamond, i.e. the workfunction of H-DNDs is lower than that of O-DNDs. This signalizes successful hydrogen and oxygen surface termination of DNDs by above mentioned approaches. Moreover the AFM/KPFM data show noticeable differences in surface morphology of the deposits as well as of the surface potentials of DNDs on HOPG and Au substrates despite of the similar workfunctions of the two substrates. According to our KPFM data the DNDs on HOPG have lower surface potential than on Au which indicates different charge transfer between a nanoparticle and semi-metallic (HOPG) or metallic (Au) substrates.