Surface Modification of Nanodiamond Powders for Advanced Composites and Biomedical Applications

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Nanosized diamond powders (nanodiamond - ND), which are produced by detonation synthesis in large quantities, represent a novel relatively inexpensive carbon nanomaterial with a broad range of potential applications. The process of detonation synthesis of ND was discovered in the former USSR in the 1960s. However it has remained essentially unknown to the rest of the world until recently. Starting from the 1990s, ND has been used as a component of sorbents, lubricating and polishing compositions and as an additive to electrolytic and electroless deposition bathes. Still, many potential applications of this exciting nanomaterial, including those in the biomedical and composite fields, remain unexplored.

In the as-produced detonation soot, the diamond core is surrounded by graphene shells and amorphous carbon. Acid purified ND is composed of particles of ~5nm in diameter combining an inert diamond core with covalently bonded surface functional groups, such as C=O, COOH, OH, CH_2, CH_3, C=C etc.

The failure to use consistent ND material with precise control of its carbon composition and surface chemistry could be one of the reasons for contradicting reports regarding the properties of ND-polymer matrix composites. There are both examples of improvement in mechanical strength, wear resistance and ageing characteristics of polymer matrices (mainly natural and synthetic rubbers) upon ND addition, and decrease in strength of epoxies filled with diamond. Taking into account a strong dependence of composite properties on the interface between the components, these discrepancies can be attributed to different interactions of the nanoparticles with the matrix. The interactions between the components of a composite can be adjusted by surface modification of the nanoparticle filler. Recently we have developed a techniques for selective conversion of functional groups on the surface of ND into C=O and COOH, and NH_2.

In this study we report on the techniques for ND surface modification, properties of the resulting functionalized materials, and the use of functionalized ND powders in advanced polymer-matrix composites with the improved nanoparticle-matrix interface.

Composites of epoxy polymers with amino-terminated ND covalently incorporated into the epoxy network were produced. Nanoindentation shows an increase in the Young's modulus, hardness and recovery rate for the composites with a 5 % wt. aminated nanodiamond addition as compared to pure epoxy and epoxy with a 5 % wt. non-aminated material. Especially notable are almost a two-fold decrease in creep rate and a significant increase in hardness which were only observed for composites containing amino– terminated nanodiamond.

PAN and PA-11 polymer nanofibers with diameters of 20-1000 nm containing up to 60 wt.% of COOH-terminated nanodiamond were produced by electrospinning. The electrospun nanofiber mats were further heat treated at moderate temperatures to produce optically transparent ND-polymer films. This technique can be used to introduce high concentrations of well dispersed ND into a polymer matrix. Due to the presence of ND, the coatings provide improved mechanical and thermal properties and can be used for wear, scratch and UV protection of various surfaces.

We will also briefly discuss biomedical applications of the aminated ND as a material for drug delivery systems and as non-toxic quantum dots.