Diamond nanoparticles: purification, deagglomeration and functionalization

Pentecost A., Neitzel I., Mochalin V.*, Gogotsi Y.

A.J. Drexel Nanotechnology Institute and Department of Materials Science and Engineering, Drexel University, 19104, Philadelphia, U.S.A.
**e-mail: vadym@coe.drexel.edu*

Diamond nanoparticles (nanodiamond, ND) have outstanding mechanical, optical, thermal, and electrical properties in combination with biocompatibility, low toxicity, and tuneable, highly stable surface structure and chemistry. The unique feature of ND as compared to carbon nanotubes, graphene, and other carbon nanomaterials with sp^2 bonding is that its surface chemistry can be fully controlled without compromising the structure and useful properties of the material. However, ND has not been used to its full potential because of as yet unsatisfactory control of the particle size, surface chemistry and interior structure, as well as particle agglomeration. Our ability to address these issues will lead to breakthroughs in using ND in biomedical and other applications.

A set of techniques was developed for de-agglomeration, purification and surface modification aimed at large scale production of high quality ND with precisely controlled characteristics for advanced composites and biomedical applications. Dry milling of ND with sodium chloride, sugar, and other inexpensive, non-toxic, non-contaminating media allows for reduction of ND agglomerates from micron-size down to 10-15 nm (2-3 single ND particles). Controlled oxidation of ND in air followed by treatment with diluted aqueous acids yields high purity ND with 95-97 % wt. sp^3 carbon and sub-ppm levels of heavy metals. It also results in changes of surface chemistry, uniformly converting different functional groups present on the surface of non-purified ND into carboxylic groups. In this way various grades of ND from different manufacturers are brought to the same standardized stage. Further functionalization of this material can be done in numerous ways using gas annealing or wet chemistry techniques based on the chemistry of carboxylic groups, yielding ND powders finely tuned for specific purposes.

Applications of de-agglomerated, purified, and functionalized ND including reinforcement of polymers, biodegradable tissue engineering scaffolds, drug delivery systems, and biomedical imaging will be discussed.