Recent Developments in the Application of Dispersed Single-Nano Diamond Particles

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In the past 40+ years, R&D in detonation nanodiamond has long suffered from the overlook of covalent aggregation among primary particles. Although the nature of tight assembly has not yet been thoroughly understood, it is most likely that, as in all other nanocarbons including soot (carbon black) and carbon nanohorns formed by the bottom-up processes, primary particles of nanodiamond were glued to each other through C-C bonding as they are formed under high-temperature conditions to form tight assembly of 60-200 nm in size. It was impossible to disintegrate the covalent aggregates until 2002, when we applied wet stirred-media milling with ceramic beads to disperse them into primary particles. The resulting colloid is diaphanous, although pitch black in high concentration, but surprisingly stable. Dried residue from the milled colloid *van der Waals* aggregates of primary particles, and can be readily re-dispersed in water and also in a few organic solvents by sonication.

Dispersed single-nano diamond (DSND) particles, as we temporarily call them, have a narrow size-distribution of 4.6±0.7nm irrespective of its origin, and methods of determination. They are distinctly different from the previously commercialized covalent aggregates and exhibit long-dreamed size-dependent behavior of semi-quantum particles, a new breed in science and technology. Here we report some of our recent results obtained during preliminary scanning on the applicative possibilities of DSND particles.

1. *Gelation.* Pristine DSND particles have large surface carrying complex oxygenated functional groups (Rozhkova) and this feature is the origin of high affinity to water, several alcohols and DMSO. Colloidal solutions in these solvent can hold up to 10% of DSND particles without forming any visible precipitates turbidity for months. Removal of solvent from these concentrated colloids lead to soft and then hard gel. In the hard hydrogel, each particle of DSND is surrounded by its 42 wt.% of highly oriented water layer that freezes at -8°C according to DSC analysis (Korobov). Ionic drug molecules such as Doxorubicin and Dexomethasone are likewise absorbed onto DSND surface, and inactivated. However, this complex gel penetrates cell membranes. The drugs can be slowly released from the gel by adding chloride ions, thus the gel provides a novel drug delivery system (Huang/Ho).
2. *Single-layer coating.* DSND colloid in high-viscosity solvent like ethylene glycol+water can be applied evenly by means of an ink-jet patterning device from micron-sized nozzles onto a smooth surface to leave a densely packed single-layer coating after evaporating solvent. Such a surface can serve as highly effective nucleation sites for CVD diamond film growth (Williams, Inaba).
3. *Lubricating property.* A big surprise is the discovery of high lubricating (not polishing) effect of DSND colloids in water (Mori) and also in oil. This observation should exert considerable impact on various branches of industry.