Dispersion and Fractionation of Polydispersed Detonation Nanodiamond at an Industrial Scale

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While primary particles of detonation nanodiamond (DND) are within the 2-10nm size range, during the synthesis and purification processes DND aggregates up to several microns are typically formed. Tightly- and loosely-bond aggregates originate from chemical and Van-der-Waals types of bonding between primary particles. In this paper, industrial methods of disaggregating DND product using cavitation-inducing treatment followed by fractioning (size separation) will be discussed.

Reduction of the average aggregate size can be achieved, for example, through ball milling [1], fractionation of modified DND forming stable suspensions using centrifugation [2, 3], or by a combined graphitization/oxidation gas-phase method [4]. While the ball milling method [1] is capable to reduce particle size down to the sizes of primary particles, contamination from the balls and increased content of the sp^2 carbon phase requires further purification processing of the particles. Combination of the ultrasonic method of desaggregation of DND in combination with fractionation using centrifugation allows to obtain suspensions of DND with small fraction size with high yield of 20-30 nm particles [2]. Importantly, the demonstrated approach of combining ultrasonic treatment with centrifugation avoids contamination of the final DND product.

It will be demonstrated that an important requirement for the successful ultrasonic DND desaggregation is ultrasonic treatment in a regime of cavitation – the production of microbubbles in a liquid that are formed when a large negative pressure is applied to it. We will demonstrate results of the DND treatment in a cavitation regime produced by ultrasound system (acoustic cavitation) and by fluid flow (hydrodynamic cavitation) in a apparatus where a system of rotating disks creates hydrodymanic cavitation. The inter-disks distance can be adjusted depending on the DND aggregate size to achive maximum size reduction. The ultrasound system specifically designed for the dispersion of DND consists of a magnetostrictor transducer and a water-cooled ultrasound horn that is directly immersed in the sample. The ultrasound frequency is 20-22 kHz; the output power from the horn can be varied between 100 W and 400 W. The optimum regime is obtained by frequency tuning using a resonance regulator for each sample, since the sample volume and characteristics of every suspension to be treated vary. A modified version of the ultrasound system contains an option of sonication under additional external pressure on the suspension, which significantly reduce noise level from the sonicator. Comparable characteristics of the DND fractions (size and yield) from the three types of treatment in the cavitation regime (ultrasound, ultrasound under pressure and hydrodynamic cavitation) in combination with ultracentrifugation realized at an industrial scale will be presented. Regimes with negative effect of the treatment will be discussed. The role of fractioning for different applications will be also outlined.

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