Characterization of Detonation Nanodiamonds and Analysis of Deagglomeration Processes

1. Introduction

This poster presents the results of a study on the characterization of detonation nanodiamonds (DNDs) and the analysis of their deagglomeration processes using mechanical treatment.

Detonation nanodiamonds are carbon nanoparticles with a diamond crystal structure, produced through the controlled detonation of carbon-containing explosives. The size of a single particle investigated in this study is approximately 30 nm. Due to their high specific surface area, exceptional hardness, biocompatibility, and the possibility of surface functionalization, detonation nanodiamonds have found applications in fields such as biomedicine, electronics, tribology, and composite materials.

A significant limitation of their application is their natural tendency to agglomerate, resulting from the presence of functional groups on the particle surface and intermolecular interactions. The resulting agglomerates may reach sizes ranging from several to several dozen micrometers, making it difficult to achieve a homogeneous dispersion in composite materials and negatively affecting their performance.

2. Research Objective

The main objective of this study was to develop an effective deagglomeration procedure for detonation nanodiamonds and to determine the influence of process parameters on particle size distribution. Achieving a homogeneous dispersion is essential for improving the mechanical properties, wear resistance, thermal conductivity, and structural stability of nanodiamond-containing materials.

3. Experimental Methodology

The deagglomeration process was carried out using a Retsch PM100 planetary ball mill. The method is based on the impact and shear forces generated during the rotational movement of the milling chamber.

The milling mixture consisted of detonation nanodiamonds, sodium chloride, and zirconia milling beads with diameters ranging from 45 µm to 3 mm. The mass ratio of NaCl to DND was 1:5, while the ratio of the NaCl–DND mixture to zirconia beads was 1:60. After the deagglomeration process, the zirconia beads were separated from the powder using a sieve with a mesh size of 200 µm, assisted by vibrations at a frequency of 50 Hz.

Sodium chloride acted as a process additive, reducing particle re-agglomeration during milling, whereas the zirconia beads ensured efficient transfer of mechanical energy to the material.

4. Particle Size Distribution Analysis

The first set of results presented on the poster concerns particle size distribution for different milling configurations. The histograms indicate that the initial material exhibits a broad particle size distribution and a significant fraction of large agglomerates.

As the milling process progresses, the particle size distribution shifts toward smaller diameters, accompanied by a gradual reduction in the fraction of the largest particles. This demonstrates the effective breakdown of agglomerates under the influence of the mechanical energy supplied during milling. At the same time, the proportion of finer fractions increases, indicating an improvement in the degree of particle dispersion.

5. Equivalent Particle Diameter Analysis

The second set of results presents the distribution of equivalent particle diameters, providing a more accurate assessment of the deagglomeration efficiency.

The analysis revealed that appropriately selected milling conditions lead to a narrower particle size distribution and improved material homogeneity. The reduction in distribution width indicates a lower number of large agglomerates and a more uniform dispersion of particles throughout the sample.

6. Influence of Process Parameters

Particularly favorable results were obtained when zirconia beads of different diameters were used. Larger beads were responsible for breaking down large agglomerates, while smaller beads enabled further size reduction and homogenization of the material. This approach resulted in more efficient deagglomeration compared to the use of beads with a single diameter.

In addition, the presence of sodium chloride contributed to a more uniform particle size distribution and reduced the tendency of particles to re-agglomerate during milling.

7. Conclusions

The conducted analyses demonstrated that the proper selection of milling parameters is crucial for effective deagglomeration of detonation nanodiamonds. Insufficient milling energy does not ensure complete agglomerate breakdown, whereas an adequately high energy input significantly reduces particle size and improves dispersion homogeneity.

The results also indicate the need for further optimization of process parameters to achieve stable and reproducible material properties.

The development of effective deagglomeration methods for detonation nanodiamonds may contribute to improving the quality of polymer composites, ceramic materials, and functional coatings. Improved nanoparticle dispersion directly enhances material performance, thereby expanding the potential applications of detonation nanodiamonds in advanced engineering and biomedical technologies.