Characteristics of Detonation Nanodiamonds and Analysis of Their Aggregation and Deagglomeration Process

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Introduction

Detonation nanodiamonds (DNDs) are characterized by nanoscale particle sizes and a relatively narrow size distribution. Despite these advantages, they exhibit a strong tendency to form agglomerates because of van der Waals interactions and moisture adsorption on their highly developed surface. The presence of agglomerates can negatively affect the structure and properties of polymer films, leading to the formation of defects and reduced material performance. Therefore, different deagglomeration parameters were applied using a planetary ball mill to enhance nanoparticle dispersion and minimize agglomeration.

Material and method

Detonation nanodiamonds (DNDs) obtained from Adamas were employed in this study. The material occurred as micrometer-sized agglomerates with an oval morphology and a smooth surface. Deagglomeration was performed using a Retsch PM 100 planetary ball mill to reduce the size of the agglomerates. The efficiency of the deagglomeration process was assessed through particle size distribution measurements conducted with a Fritsch Analysette 22 MicroTec Plus particle size analyzer. All figures presented in this study were generated using MATLAB R2024b.

Objective of research

The aim of this study was to deagglomerate detonation nanodiamonds and minimize the presence of agglomerates. Effective deagglomeration is a crucial prerequisite for the successful fabrication of polymer films modified with detonation nanodiamonds, as it promotes a more uniform distribution of nanoparticles within the polymer matrix.

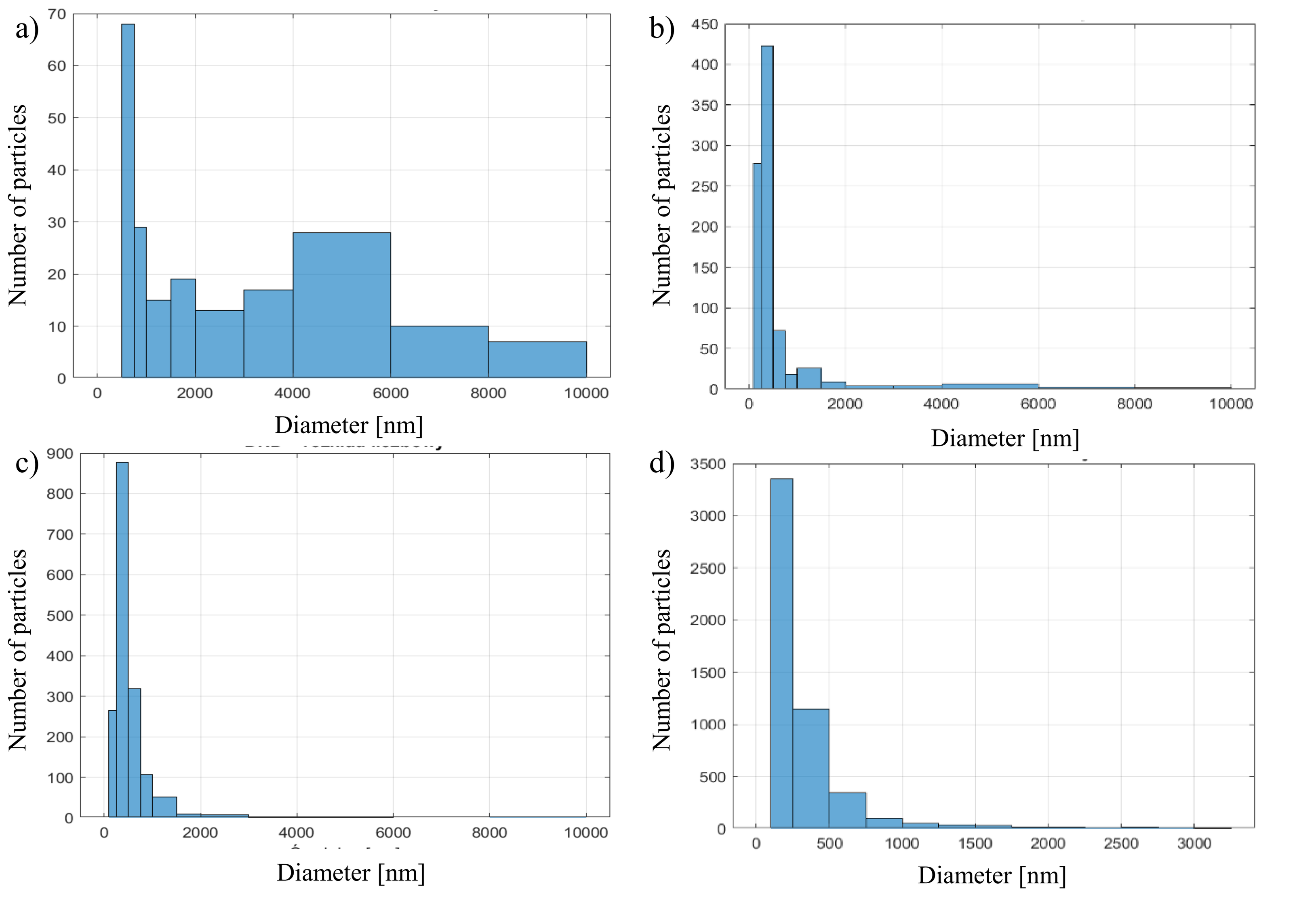

Fig. 1. Particle size distribution of detonation nanodiamonds (DNDs): (a) a mixture of salt, nanodiamonds, and zirconia balls after 2 min of mixing at 100 rpm; (b) a mixture of salt, nanodiamonds, and zirconia balls after 2 min of mixing at 100 rpm; (c) a mixture of salt, nanodiamonds, and zirconia balls after 10 min of mixing at 100 rpm; (d) a mixture processed in an impact blade mill for 15 s at a rotational speed of 24,000 rpm

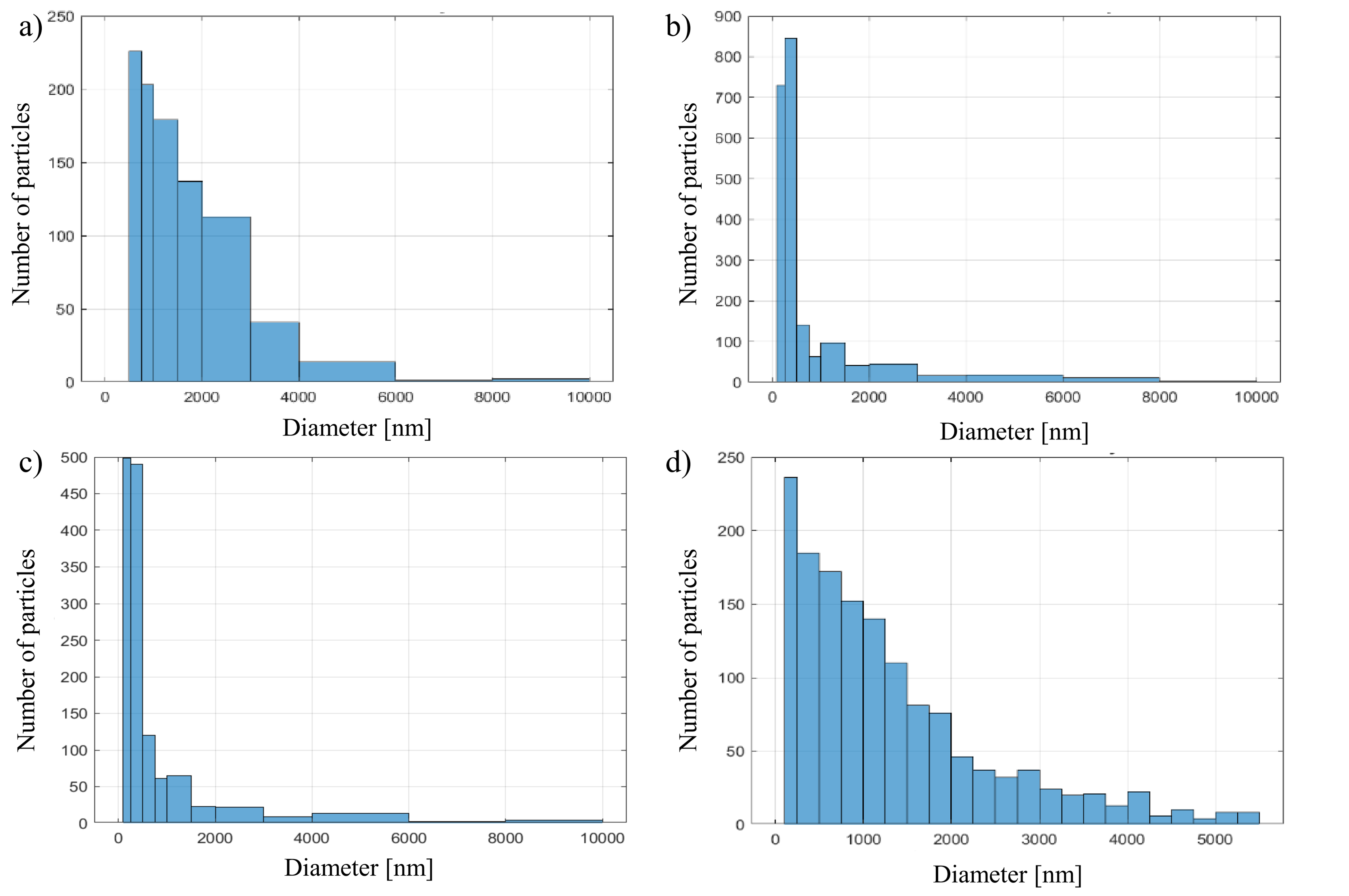

Fig. 2. Particle size distribution of sodium chloride (NaCl): (a) a mixture of salt, nanodiamonds, and zirconia balls after 2 min of mixing at 100 rpm; (b) a mixture of salt, nanodiamonds, and zirconia balls after 2 min of mixing at 100 rpm; (c) a mixture of salt, nanodiamonds, and zirconia balls after 10 min of mixing at 100 rpm; (d) a mixture processed in an impact blade mill for 15 s at a rotational speed of 24,000 rpm

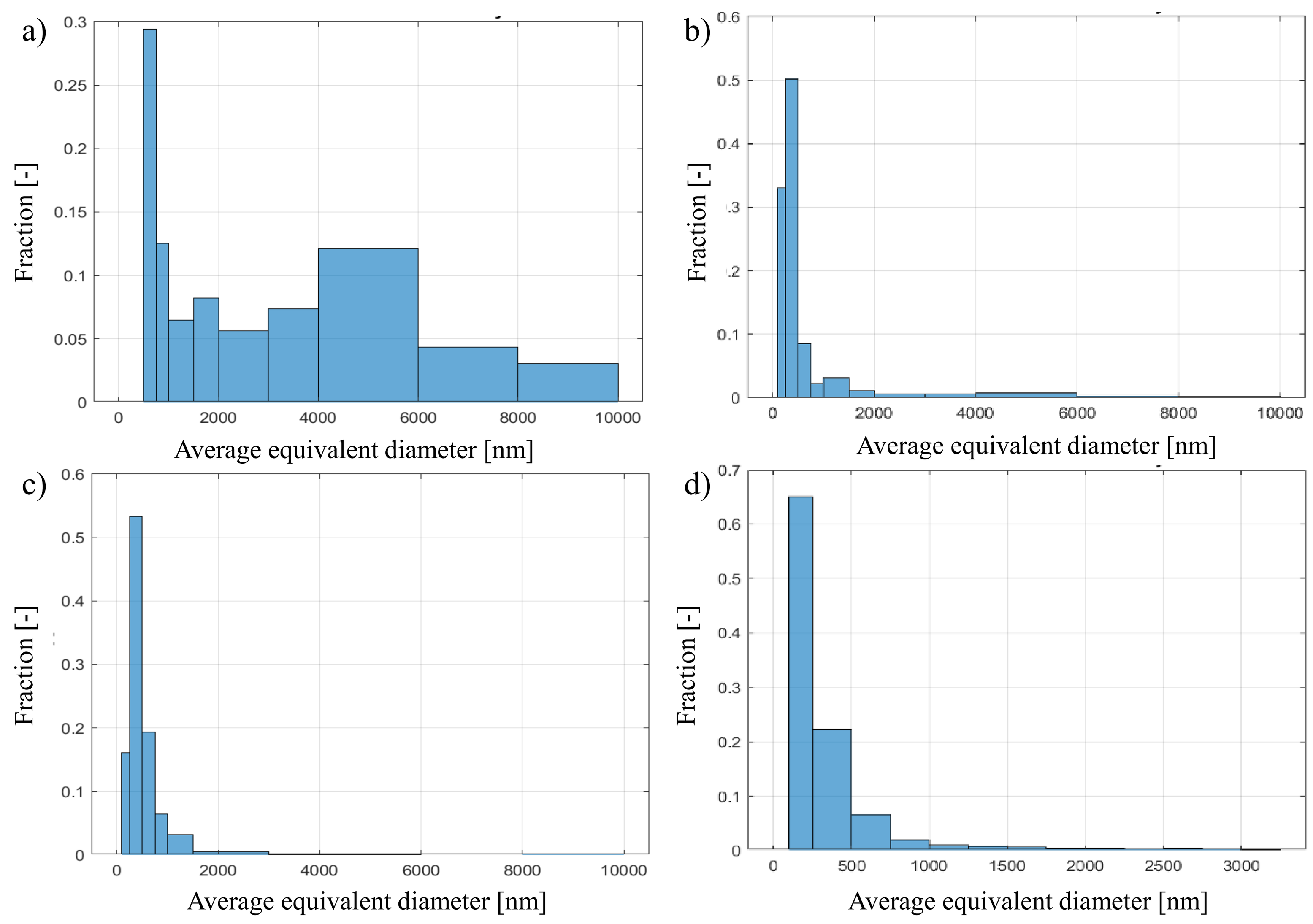

Fig. 3. Normalized particle size distribution of detonation nanodiamonds (DNDs): (a) a mixture of salt, nanodiamonds, and zirconia balls after 2 min of mixing at 100 rpm; (b) a mixture of salt, nanodiamonds, and zirconia balls after 2 min of mixing at 100 rpm; (c) a mixture of salt, nanodiamonds, and zirconia balls after 10 min of mixing at 100 rpm; (d) a mixture processed in an impact blade mill for 15 s at a rotational speed of 24,000 rpm

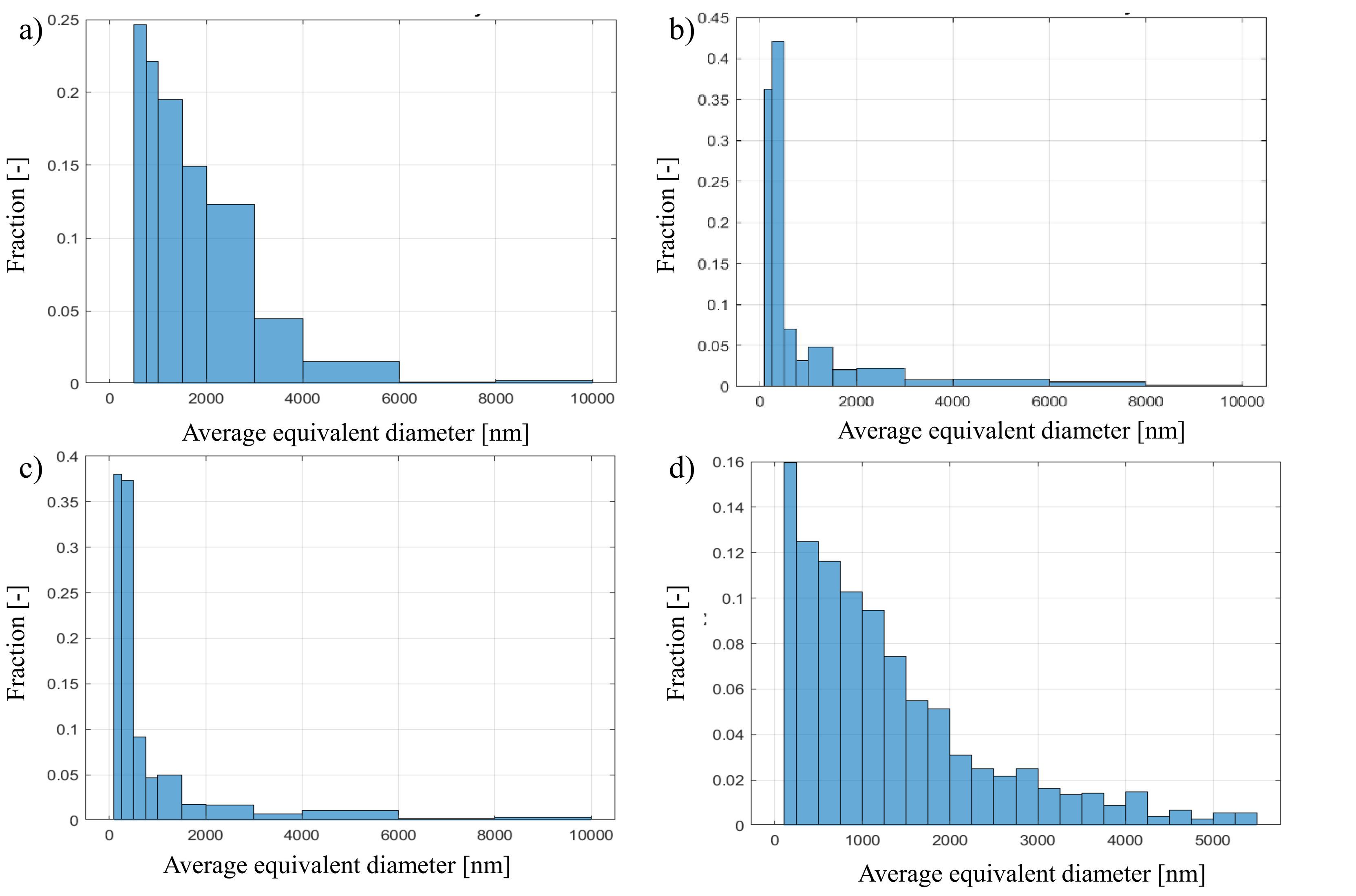

Fig. 4. Normalized particle size distribution of sodium chloride (NaCl): (a) a mixture of salt, nanodiamonds, and zirconia balls after 2 min of mixing at 100 rpm; (b) a mixture of salt, nanodiamonds, and zirconia balls after 2 min of mixing at 100 rpm; (c) a mixture of salt, nanodiamonds, and zirconia balls after 10 min of mixing at 100 rpm; (d) a mixture processed in an impact blade mill for 15 s at a rotational speed of 24,000 rpm

Conclusion

In summary, the comparative analysis demonstrated that the key factor determining the particle size distribution of nanodiamonds is the energy input into the system during mechanical processing. An increase in mechanical intensity, achieved either by extending the mixing time or by applying a high-energy process, led to more effective deagglomeration, a shift in the particle size distribution toward smaller diameters, a reduction in the fraction of large agglomerates, and improved system homogeneity. The most efficient homogenization and the narrowest particle size distribution were obtained using high-energy treatment, confirming the necessity of applying intensive mechanical methods to achieve a stable and uniform nanodiamond dispersion. The results clearly indicate that processing parameters have a decisive influence on the degree of deagglomeration and the properties of the NaCl/DND dispersion system. These findings may serve as a basis for optimizing the preparation conditions of nanodiamonds for composite applications, where uniform particle distribution is crucial. Moreover, they confirm that appropriate selection of process parameters enables control over the microstructure of the system and, consequently, its functional properties. Furthermore, the results highlight the importance of tailoring mechanical processing conditions to achieve reproducible and application-relevant dispersion characteristics.

References

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