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Interaction of Nanodiamonds with Water: Impact of Surface Chemistry on Hydrophilicity, Aggregation and Electrical Properties

Pietro Aprà [1,2,3], Lorenzo Mino [2,4,*], Alfio Battiato [3], Paolo Olivero [1,2,3], Sofia Sturari [1], Maria Carmen Valsania [2], Veronica Varzi [1,2,3] and Federico Picollo [1,2,3]

1 Physics Department, University of Torino, Via Pietro Giuria 1, 10125 Torino, Italy; pietro.apra@unito.it (P.A.); paolo.olivero@unito.it (P.O.); sofia.sturari@edu.unito.it (S.S.); veronica.varzi@unito.it (V.V.); federico.picollo@unito.it (F.P.)
2 "Nanostructured Interfaces and Surfaces" (NIS) Inter-Departmental Centre, University of Torino, Via Quarello 15/a, 10135 Torino, Italy; mariacarmen.valsania@unito.it
3 National Institute of Nuclear Physics, Section of Torino, Via Pietro Giuria 1, 10125 Torino, Italy; battiato@to.infn.it
4 Department of Chemistry, University of Torino, Via Pietro Giuria 7, 10125 Torino, Italy
* Correspondence: lorenzo.mino@unito.it

Abstract: In recent decades, nanodiamonds (NDs) have earned increasing interest in a wide variety of research fields, thanks to their excellent mechanical, chemical, and optical properties, together with the possibility of easily tuning their surface chemistry for the desired purpose. According to the application context, it is essential to acquire an extensive understanding of their interaction with water in terms of hydrophilicity, environmental adsorption, stability in solution, and impact on electrical properties. In this paper, we report on a systematic study of the effects of reducing and oxidizing thermal processes on ND surface water adsorption. Both detonation and milled NDs were analyzed by combining different techniques. Temperature-dependent infrared spectroscopy was employed to study ND surface chemistry and water adsorption, while dynamic light scattering allowed the evaluation of their behavior in solution. The influence of water adsorption on their electrical properties was also investigated and correlated with structural and optical information obtained via Raman/photoluminescence spectroscopy. In general, higher oxygen-containing surfaces exhibited higher hydrophilicity, better stability in solution, and higher electrical conduction, although for the latter the surface graphitic contribution was also crucial. Our results provide in-depth information on the hydrophilicity of NDs in relation to their surface chemical and physical properties, by also evaluating the impacts on their aggregation and electrical conductance.

Keywords: nanodiamonds; surface chemistry; hydrophilicity; IR spectroscopy; Raman spectroscopy; nanoparticle aggregation

Citation: Aprà, P.; Mino, L.; Battiato, A.; Olivero, P.; Sturari, S.; Valsania, M.C.; Varzi, V.; Picollo, F. Interaction of Nanodiamonds with Water: Impact of Surface Chemistry on Hydrophilicity, Aggregation and Electrical Properties. *Nanomaterials* **2021**, *11*, 2740. https://doi.org/10.3390/nano11102740

Academic Editor: Jean-Charles Arnault

Received: 26 September 2021
Accepted: 13 October 2021
Published: 16 October 2021

1. Introduction

Nanodiamonds (NDs) are attracting ever-increasing interest for their appealing physical, chemical, and optical properties for a broad range of technological applications. The most widely employed techniques for their synthesis are represented by the detonation of explosive carbon-based compounds (e.g., trinitrotoluene and hexogen) [1], laser ablation [2], milling of high-pressure high-temperature (HPHT) diamond microcrystals [3], and chemical vapor deposition (CVD) [4]. Initially, due to the extreme hardness and the low friction coefficient of diamond, NDs were mainly employed in tribology [5]. Over time, they turned out to be interesting for a much wider variety of applications, particularly in the context of nanocomposites, sensing, quantum emitters, and energy storage and conversion [6]. Moreover, their low toxicity, biocompatibility, and the possibility of tailoring their surface chemistry make NDs good candidates for biomedical applications—such as