J Mater Sci: Mater Electron **(2025) 36:1150**

Comparative analysis of diamond graphitization approaches for 3D electrode fabrication

Adam Britel[1,2,*], Akhil Kuriakose[3,4], Elena Nieto Hernández[1,2], Emilio Corte[1,2], Sviatoslav Ditalia Tchernij[1,2], Pietro Aprà[2], Sofia Sturari[1,2], Nour-Hanne Amine[1,2], Vanna Pugliese[1,2], Elisa Redolfi[1,2], Jacopo Forneris[1,2], Paolo Olivero[1,2], Ottavia Jedrkiewicz[3], and Federico Picollo[1,2]

[1] *Department of Physics and "NIS" Inter-Departmental Centre, University of Torino, Via Pietro Giuria 1, 10125 Turin, Italy*
[2] *National Institute of Nuclear Physics, Sect. Torino, Via Pietro Giuria 1, 10125 Turin, Italy*
[3] *Istituto Di Fotonica e Nanotecnologie (IFN)-CNR, and Como Lake Institute of Photonics, Università dell'Insubria, Via Valleggio 11, 22100 Como, Italy*
[4] *Dipartimento di Scienza e Alta Tecnologia, Università dell'Insubria, Via Valleggio 11, 22100 Como, Italy*

Received: 26 February 2025
Accepted: 16 June 2025

ABSTRACT

This work presents a comprehensive comparative study of different methods to induce graphitization in diamond, with a focus on their impact on the material properties and potential applications. The employed graphitization methods vary between laser writing-based strategies using Bessel beams and irradiation-based methods incorporating keV broad beam implantation, focused Gallium ion beam lithography, and a thermal-based graphitization method. The study emphasizes the effects of annealing time in the thermal method and the influence of the induced graphite on the material electrical properties for all the employed methods. A key highlight of this work is the exploration of easy and innovative approaches to create 3D conductive patterns within diamonds. This is achieved through combining laser-based and ion beam methods, as well as optimizing ion beam parameters to enable the creation of 3D conductive patterns. Each method presents unique advantages: thermal annealing enables simple surface graphitization, ion implantation allows precise depth control for sub-surface structures, and Bessel beam laser writing facilitates direct 3D in-bulk modification without mechanical movement or masking. This comparative insight helps to identify the most suitable technique depending on the required electrode geometry and device integration constraints. The outcomes of each graphitization approach showcase unique benefits and limitations, giving various possibilities to employ diamonds in electrical applications. By building on prior research, this study offers an extended perspective on integrating advanced fabrication techniques to expand the use of diamonds in emerging technologies.

Address correspondence to E-mail: a.britel@unito.it

https://doi.org/10.1007/s10854-025-15232-w
Published online: 02 July 2025