Processing single crystal diamond with N_2-GCIB: on the understanding of irradiation angles dependence on the machined surface

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Single crystal diamond (SCD), renowned for its exceptional mechanical, thermal, and optical properties, occupies a pivotal position in diverse applications. Its unparalleled hardness and superior thermal conductivity render it indispensable for precision cutting tools and semiconductor devices. Recent strides in single crystal diamond synthesis and polishing methodologies have catalyzed breakthroughs in quantum computing and biomedical devices, elevating performance across scientific and industrial realms. In our investigation, we scrutinized the influence of gas cluster ion beam (GCIB) irradiation angles on the machined surface of diamond under 20 keV acceleration energy with a dose of 5×10^{16} ions/cm^2. Employing a White Light Interferometer (WLI), we assessed material removal rates by selectively masking half of the diamond surface. Remarkably, N_2-GCIB exhibited maximal material removal efficiency at normal incidence angles, with diminishing rates as the angle deviated from the perpendicular. Intriguingly, minimal material ablation occurred when the incidence angle surpassed 80 degrees. Furthermore, we delved into the angle-dependent surface roughness (Ra and Rq) on both machined and non-machined surfaces. Leveraging White Light Interferometer (WLI) measurements and Atomic Force Microscopy (AFM), we observed reductions in both Ra and Rq following irradiation at varying angles. Notably, Rq exhibited less sensitivity to incidence angle variations, while Ra displayed a significant decline. These findings enhance our comprehension of single crystal diamond behavior under controlled irradiation conditions, yielding valuable insights for practical applications. The interplay between irradiation angles and material removal rates provides a foundation for optimizing diamond machining processes, paving the way for continued advancements in cutting-edge technologies.