Advancements in Defect-Engineered Material Characterization: A TERS Analysis of Black Diamond

Eleonora Bolli[1]

[1]Institute of Structure of Matter, DiaTHEMALab, ISM-CNR, Rome, Italy

Abstract: Conventional Scanning Probe Microscopy (SPM) methodologies, such as Atomic Force Microscopy (AFM), are foundational in mapping the topographic properties of samples. Advanced techniques like Conductive AFM (C-AFM) and Kelvin Probe Force Microscopy (KPFM) extend these capabilities, enabling the mapping of electronic properties and work function information on a nanometric scale. One of the most innovative advancements in material characterization integrates AFM with Raman spectroscopy, resulting in Tip-Enhanced Raman Spectroscopy (TERS).

TERS amplifies the Raman signal, achieving imaging and spectroscopic characterization of nanoscale materials with spatial resolutions beyond the diffraction limit of light. The methodology encompasses precise alignment of laser excitation with the SPM tip, optimization of the enhancement factor, and strategies to mitigate thermal effects and tip degradation. Although this technique is primarily explored with 2D materials, careful experimental procedures can also provide valuable information on materials that are not strictly two-dimensional. From this perspective, TERS offers an innovative approach to analyzing materials modified to improve their properties through defect engineering. Defect engineering is a strategic approach in materials science that intentionally introduces and manages defects to manipulate and control material properties.

In our studies we demonstrate the application of the combined SPM-TERS methodology in identifying and characterizing defects in various nanostructured materials, including fs-laser treated diamond known as black diamond. This innovative characterization method enables detailed studies of materials produced with defect engineering, achieving resolutions never before obtained optimizing material properties for advanced technological applications.