ABSTRACT

Nano-structured Diamond Sensors for Extreme Environments: Taking SERS from the laboratory to the Ocean

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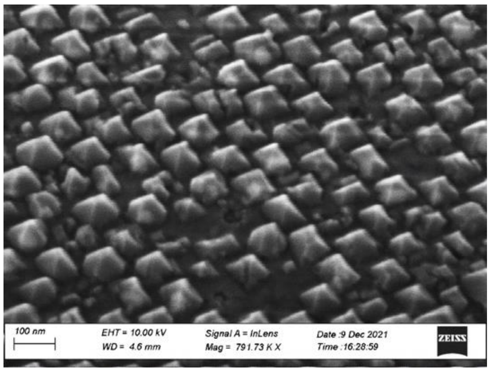
The treasures within the pyramids of ancient Egypt contained much that was gold. In this work, diamond nanopyramids with a base dimension of ~60nm have been fabricated which encase gold nanoparticles (NPs) with a diameter of ~20nm. The plasmonic nature of the gold NPs, along with the optical properties of the diamond host matrix make these nanostructures of great interest in numerous applications; here we will discuss the realisation of robust sensors for marine applications.



Diamond, a wide band gap semiconductor with superlative electronic properties. Further, diamond is chemically resilient, and is transparent at optical wavelengths. Diamond has also been shown to resist biofouling in marine environments. This leads to the idea that diamond may be an ideal platform for sensors destined for use in extreme environments, including ocean deployment. Surface plasmon excitations in NPs lead to electromagnetic field enhancement near the metal surface. The NPs effectively act like small antennae, capturing and amplifying the incident light. Their plasmonic natures offers opportunities for Surface Enhanced Raman spectroscopy (SERS) enabling trace levels of chemical detection, being up to 109 times more sensitive than conventional Raman spectroscopy. This is of great interest for use within the marine environment where trace chemical sensing is important for pollution control and, of growing importance, for climate change studies. However, SERS substrates tend to degrade over time and are not suitable for re-use. Moreover, they are simply too fragile for use in environmentally challenging situations such as ocean analysis.

As a robust substrate for SERS, diamond has near-to ideal optical properties displaying only a single intense peak at 1332cm-1 enabling the Raman signal from many organic species to be detected with little interference. However, the typical reliance of van-der-Waals forces for NP adhesion to the diamond offers little improvement over other substrates in terms of marine applications. A possible solution is the inclusion of the NPs in diamond, sufficiently near the surface of the diamond to retain their plasmonic enhancement of the SERS signal.

This paper will outline how simulation methods have allowed us to predict optimal Au/Ag NP sizes and distribution within diamond substrates for the realisation of highly effective and robust SERS sensors. Methods, including nano-imprint-lithography (NIL) and anisotropic etching approaches will be discussed for the realisation of these optimised structures. High performance diamond-based SERS sensing will be reported and the prospects for this technology within extreme environments discussed.