World Academy of Science, Engineering and Technology
International Journal of Electronics and Communication Engineering
Vol:10, No:07, 2016

Carbon Nanotubes (CNTs) as Multiplex Surface Enhanced Raman Scattering Sensing Platforms

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Abstract : Owing to its fingerprint molecular specificity and high sensitivity, surface-enhanced Raman scattering (SERS) is an established analytical tool for chemical and biological sensing capable of single-molecule detection. A strong Raman signal can be generated from SERS-active platforms given the analyte is within the enhanced plasmon field generated near a noble-metal nanostructured substrate. The key requirement for generating strong plasmon resonances to provide this electromagnetic enhancement is an appropriate metal surface roughness. Controlling nanoscale features for generating these regions of high electromagnetic enhancement, the so-called SERS 'hot-spots', is still a challenge. Significant advances have been made in SERS research, with wide-ranging techniques to generate substrates with tunable size and shape of the nanoscale roughness features. Nevertheless, the development and application of SERS has been inhibited by the irreproducibility and complexity of fabrication routes. The ability to generate straightforward, cost-effective, multiplex-able and addressable SERS substrates with high enhancements is of profound interest for miniaturised sensing devices. Carbon nanotubes (CNTs) have been concurrently, a topic of extensive research however, their applications for plasmonics has been only recently beginning to gain interest. CNTs can provide low-cost, large-active-area patternable substrates which, coupled with appropriate functionalization capable to provide advanced SERS-platforms. Herein, advanced methods to generate CNT-based SERS active detection platforms will be discussed. First, a novel electrohydrodynamic (EHD) lithographic technique will be introduced for patterning CNT-polymer composites, providing a straightforward, single-step approach for generating high-fidelity sub-micron-sized nanocomposite structures within which anisotropic CNTs are vertically aligned. The created structures are readily fine-tuned, which is an important requirement for optimizing SERS to obtain the highest enhancements with each of the EHD-CNTs individual structural units functioning as an isolated sensor. Further, gold-functionalized VACNTFs are fabricated as SERS micro-platforms. The dependence on the VACNTs' diameters and density play an important role in the Raman signal strength, thus highlighting the importance of structural parameters, previously overlooked in designing and fabricating optimized CNTs-based SERS nanoprobes. VACNTs forests patterned into predesigned pillar structures are further utilized for multiplex detection of bio-analytes. Since CNTs exhibit electrical conductivity and unique adsorption properties, these are further harnessed in the development of novel chemical and bio-sensing platforms.

Keywords : carbon nanotubes (CNTs), EHD patterning, SERS, vertically aligned carbon nanotube forests (VACNTF)
Conference Title : ICOP 2016 : International Conference on Optics and Photonics
Conference Location : Stockholm, Sweden
Conference Dates : July 11-12, 2016