Seminar

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Institute for Plasma Research

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Title: Development of SERS substrates based on self-organized nanoparticles for the molecular sensing applications

Speaker: Mr. Sebin Augustine
Institute for Plasma Research, Gandhinagar

Date: 31st May 2024 (Friday)

Time: 09.35 AM

Venue: Seminar Hall, IPR

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Abstract

Surface-Enhanced Raman Spectroscopy (SERS) is a widely used sensing method in chemistry, forensics, food, agriculture, and in the biological field for detecting trace quantities of molecules. In this method, the localized near-field induced by metal nanoparticles, enhanced the vibrational modes of trace molecule and increases the sensitivity manifold. Researchers worldwide are continually working on improving the sensitivity and uniformity of SERS. Nanoparticles arrays grown over ion-induced ripple nanopatterns have shown great potential as SERS templates. The ion irradiation parameters provide the ability to adjust the ripple wavelength at the nanoscale, which affects the growth of nanoparticles and helps to produce compact nanoparticle arrays. Our work presents a two-stage process for growing nanoparticles on nano-rippled templates. Initially, low-energy ion beam irradiation is used to fabricate self-organized ripple patterns on silicon and glass surfaces. In the next step, metal nanoparticles were grown at glancing angles using physical vapor deposition (PVD), resulting in aligned nanoparticle arrays. The wavelength of the ripple patterns determines the shape and interparticle gap of the deposited nanoparticles. The Localized Surface Plasmon Resonance (LSPR) response of silver grown on these nanoscale ripple patterns is studied to develop an optimized substrate for 532 nm laser excitation. To demonstrate the SERS properties of the produced substrate, we used crystal violet dye molecules concentrated at 10^{-6} to 10^{-10} M. Using these SERS substrates, we successfully detected the dichlorvos pesticide at concentrations as low as 1 ppm, which is below its recommended level [1].

To make the substrate sensitive to border excitation regions at 532 nm and 785 nm, self-organized bimetal Au/Ag nanoparticles were created. A systematic investigation was carried out to examine the impact of Au nano capping layers on the morphological and optical properties of Ag nanoparticles. The experimental results were compared with FDTD simulations to explore the effect of interparticle gap and Au/Ag layer thicknesses on the LSPR position and SERS enhancement [2]. It was demonstrated that adding an Au capping layer to Ag nanoparticles redshift the LSPR wavelength. The SERS properties of the developed substrate were investigated, and it was found that the growth of Au/Ag nanoparticles allowed for the detection of analyte molecules using both 532 nm and 785 nm laser excitation wavelengths.[2].

To make the SERS substrate more sensitive and economical, the possibility of creating low-amplitude ripples on the glass was investigated. It has been found that ripples with amplitudes similar to silicon but with higher wavelengths can be produced using low-energy ion beam irradiation [3]. This method serves as a low-cost alternative to growing self-organized ordered nanoparticles. The SERS and LSPR

properties of the ordered silver nanoparticles grown on the glass substrate were investigated and showed better SERS sensitivity. The substrate was used to detect the food adulterant Metanil yellow in a turmeric solution. The resulting SERS substrate was then used to distinguish cancerous patient saliva from saliva of tobacco users. PCA-LDA-based multivariate analysis of the saliva samples demonstrates the potential applicability of such a substrate in cancer detection [4]. Overall, this study can be useful in the SERS-based detection of ultralow concentrations of analytes molecules.

Reference :

[1] Sebin Augustine, K.P. Sooraj, Vivek Pachchigar, C. Murali Krishna, Mukesh Ranjan *Applied Surface Science* 544 (**2021**) 148878.

[2] Sebin Augustine, Mahesh Saini, Sooraj K.P., Sukriti Hans, Vivek Pachchigar, Mukesh Ranjan *Optical Materials* 135 (**2023**) 113319.

[3] Sebin Augustine, Sooraj K.P., Mahesh Saini, Sukriti Hans, Vivek Pachchigar, Mukesh Ranjan, *Photonics and Nanostructures - Fundamentals and Applications* 56 (**2023**) 101166.

[4] Sebin Augustine, Arti Hole, Sooraj K P, Mahesh Saini, Mukesh Ranjan, C. Murali Krishna *Radiation Effects and Defects in Solids* (**2024**)