Numerical study of photonic nanojet effect on metal nanopillars SERS substrate

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1. Introduction

The surface-enhanced Raman scattering (SERS) has been used for many applications such as chemical analysis and biological detection. Therefore, the structure of SERS substrates plays an important role for the inspection effect. Several studies are devoted to design complex nanostructures on the surface of SERS substrates. There is also an enhancement method by applying the photonic nanojets which can be generated by the microspheres attached on the SERS substrates [1]. The photonic nanojet is a narrow light beam in the shadow side of microstructure. The core-shell microspheres have been proposed to get tunable high intensity, and the combination of Klarite SERS substrate and biocompatible microsphere also indicate the potential of Raman enhancement [2]. In addition, the microspheres can be coated flatly by air/water interface self-assembly technology [3].

Herein, we consider to use the commercial metal nanopillars SERS substrate which is coated with polystyrene microspheres. The field intensities and enhancements by the micro/nano structure can be analyzed by the finite-difference time-domain method. We also simulate the case of SERS substrate without microspheres in order to compare the electric field enhancement effect from adding photonic nanojet being generated by microspheres.

2. Methodology and Results

To study the effects of the metal nanopillars SERS substrate with and without microsphere, the polystyrene microspheres with diameter as 4.26 μm that can be successfully manufactured by dispersion polymerization are considered. Fig. 1 shows the simulated structure which is the case of SERS substrate with microsphere. The height of metal pillar is 440 nm with a layer of 10 nm gold film on the surface. The uniform meshes were applied in the simulation domain and the mesh spacing was determined to be 4 nm to ensure that the simulation results can be numerically converged to the reasonable numerical errors.

Fig. 2 shows the simulation results of the electric field intensity distribution for the incident light with wavelength 632.8 nm. The results show that the maximum electric field intensity locates in the center of the red dashed circle, which indicates one microsphere. It is obvious that the electric field intensities in the center of the contact surface between SERS substrate and microsphere are much stronger than the electric field intensities in the area of SERS substrate not covered by the microsphere.

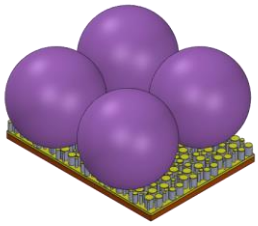

Fig. 1. Polystyrene microspheres coated on metal pillars SERS substrate

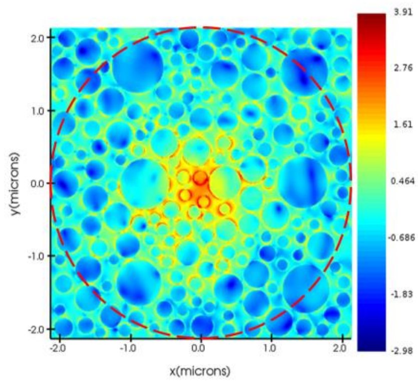

Fig. 2. Electric field intensity distribution for the top view of SERS with microsphere in log scale.

3. Conclusion

The metal nanopillars SERS substrate with and without microsphere is established to investigate the electric field enhancement effect. It is found that the electric field intensity is effectively increased by photonic nanojet generated by adding microspheres. The results show that this composite structure of SERS substrate can provide better sensing sensitivity for Raman spectra measurement.

Acknowledgements

This work was supported by the Ministry of Science and Technology (107-2221-E-002-188-MY3) and NTU Project (109L7829). We are grateful to the National Center for High-Performance Computing, Taiwan, for providing us with the computation time and facilities.

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