SERS-active substrate based on gap surface plasmon polaritons

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Since the first observation of single-molecule surface-enhanced Raman scattering (SERS) from aggregates of colloidal particles and deposited metallic nanoparticles,[1-2] SERS has become a powerful and sensitive technique for the detection and identification of chemical and biological molecules. Metallic nanoparticles and roughened electrodes have been used as SERS-active substrates in which the enhancement factor (EF) can be 10^6 (average value for conventional SERS) and around 10^{12} (maximum value for single-molecule SERS).[3] It is well established that the SERS enhancement arises from optical excitation of surface plasmon resonances at the metal nanoparticles, which leads to a gigantic increase in the electromagnetic field strength at the particle surface.

For practical applications, it is indispensable to produce SERS-active substrate with reproducible and tunable SERS enhancement. The key to obtain strong and robust SERS enhancement is to excite the localized surface plasmon (LSP) resonance in nanostructured substrate, which is determined by the properties of the metals, the size and shape of the nanostructures, the inter-particle spacing, and the dielectric environment. Recently, there has considerable attention on the electromagnetic field enhancement in gap surface plasmon polaritons (GSPPs),[4-6] which is excited at the narrow gap of the dielectric layer between two metal surfaces.

In this work, we numerically investigate the optical field enhancement supported by GSPPs on a thin SiO_2 spacer and a thick bottom silver layer (Fig. 1). The optical field enhancement at the edge of the nanostructures originates not only from LSP resonance but also from multiple scattering and coupling of GSPPs in the spacer region between two metal plates. By calculating field enhancement, we predict SERS enhancement factors (EFs) of up to 10^{11} for equilateral triangular nanostructures (Fig. 2). The SERS EFs as a function of the geometry and dimension of the nanostructures are also obtained by simulation. The effect of the surrounding medium on the SERS EFs is also investigated. Coupled with easy fabrication, those nanostructures are expected to find important applications in optical sensing as a SERS-active substrate.

References

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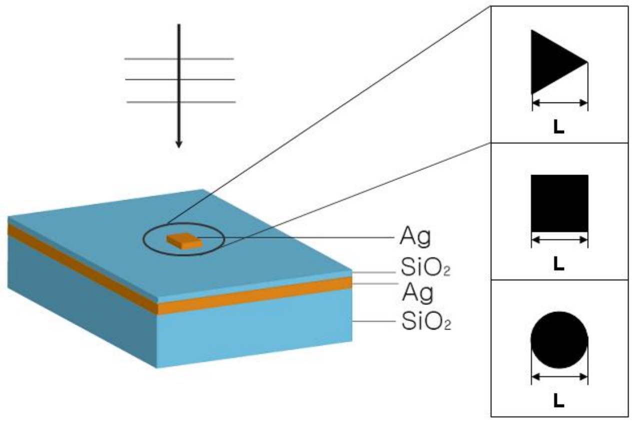

Fig. 1. A schematic of the proposed structures for gap surface plasmon polaritons.

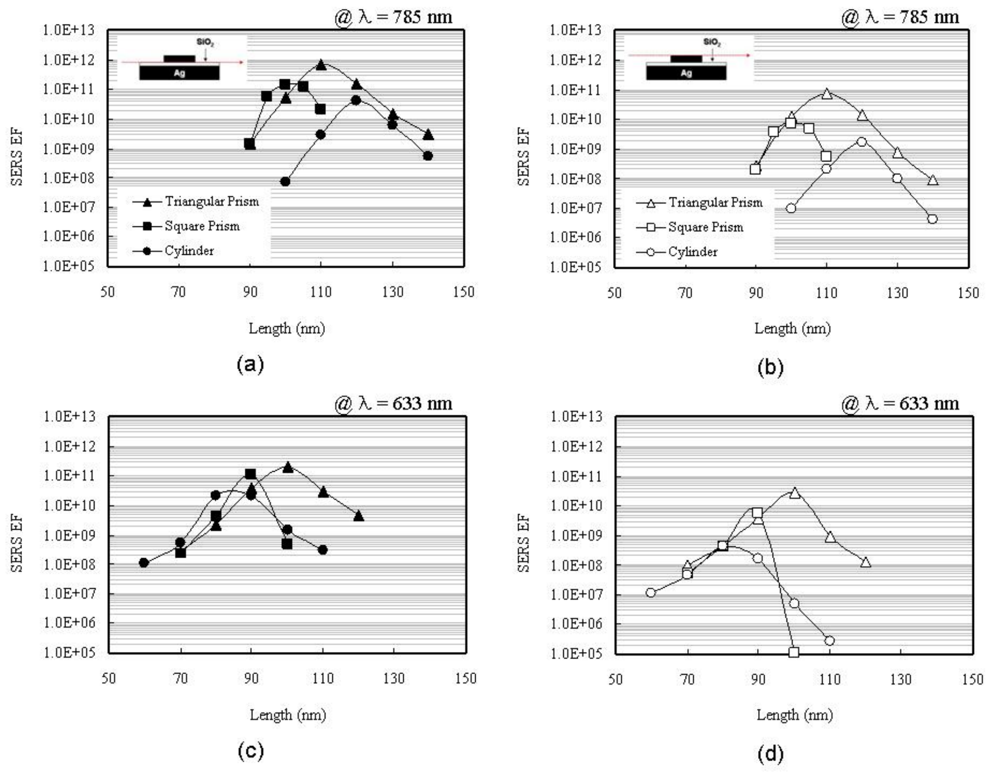

Fig. 2. Comparison of SERS EFs for different incident wavelengths and nanostructure dimensions. The incident wavelength is 785 nm in (a) and (b), and 633 nm in (c) and (d). (a) and (c) show the EFs at the bottom region of the nanostructure and (b) and (d) show the EFs at the top region of the nanostructure.