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Surface-Enhanced Raman Scattering of Free-standing Gold Ellipse Nanoantenna

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1. Introduction

Localized surface plasmon has been widely used on surface-enhanced Raman scattering (SERS) spectroscopy. Coupling between two metal surfaces that are separated only few nanometers bring localized surface plasmon to resonant at the gap and induce large electromagnetic field (E) enhancement. This work is to present a SERS amplifying antenna for the near infrared region. Instead of the visible-light range amplifying antenna such as a bowtie, the simulation results indicate that ellipse antenna could provide large E enhancement at near infrared wavelength by combing the free-standing magnifying property with large aspect ratios of the ellipse geometry. The resonance wavelength shows red shift as the aspect ratio of ellipse disk increases which is in agreement with both the simulation result and analytical result based on Lorentz-Mie theory.

2. Method and Result

The free-standing gold ellipse nanoantenna was fabricated using semiconductor process such as e-beam lithography, e-beam evaporator and reactive ion etching process. The antenna was designed with three kinds of row-to-row distance and different aspect ratios of ellipse disks. Fig. 1a shows the SEM image of free-standing ellipse disks with 3:1 aspect ratios and 785 nm row-to-row distance. The enhancement property of fabricated sample was characterized by the SERS spectrum at the wavelength of 785 nm. Fig. 1b shows the band area of Raman enhancement peak measured from the pMA analyst with three kinds of row-to-row distance, 100, 400 and 785 nm. The result reveals that the designed antenna with 400 nm row-to-row distance has the largest band area, whereas the band area drops as the aspect ratio increases but rises slightly for the aspect ratio of 7. Recently the enhancement factor has shown the dependency on the column and row distances due to the long range resonance between each bowtie antenna [1].

Then the finite-difference-time-domain (FDTD) simulation was performed to find the relation between the enhancement factor, the row-to-row distance, and the aspect ratio of disk. The FDTD result shows the same trend of the variation of E enhancement with the row-to-row distance and aspect ratio which agrees well with the experimental result. The effect of post height was also simulated showing that the shifting of resonance wavelength behaves stronger with post.

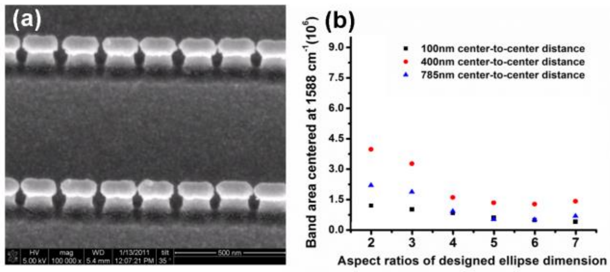

Figure 1 (a) SEM image of free-standing gold ellipse antenna (b) The band area of SERS peak with different aspect ratios.

Finally, the analytical solution of two ellipsoid particles with a nanogap was derived using the Lorentz-Mie theory and electric dipole theory. The resonance wavelength of two ellipsoid particles with a nanogap was calculated from the analytical solution which was then compared with the FDTD simulation result for the two particles system and free-standing system. The analytical solution of sensitivity for the two ellipsoid particles system was also derived to investigate the shifting of resonance wavelength with respect to the environment dielectric constant.

3. Conclusions

The free-standing gold ellipse antenna has been designed and fabricated for the SERS application. The enhancement factor is featured by the band area of SERS peak, and FDTD simulation results showed the same trend as the experimental data measured at the wavelength of 785 nm. This result is due to the linear dependency between the resonance wavelength and the aspect ratio of the disk. By properly designing the aspect ratio of ellipse disk, the free-standing ellipse antenna could be suitable for the application in near infrared region.

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References

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