Localized Surface Plasmon Resonance and Plasmon Hybridization in Contour Bowtie Nanoantenna

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1. Introduction

Single molecule detection via surface-enhanced Raman scattering (SERS) technique with the help of enhanced electromagnetic field near the metallic nanostructure has attracted much attention recently. A large electric field enhancement can be produced in the gap of a bowtie-shaped antenna by exciting the localized surface plasmon resonance (LSPR) [1]. Also, core-shell particles, tunable plasmonic spheres consist of multilayer metallic shells, have been studied widely due to the extraordinary sensing abilities [2]. However, there are few works on the advantage of combining the enhanced electric field in bowtie antenna gap with the great sensitivity of core-shell structure. The purpose of this work is to perform simulations on a model system of contour bowtie antenna to investigate the critical dimension to induce the additional enhancement by examining the resonance wavelength and the local electromagnetic field enhancement dependence on bowtie size and contour thickness. In addition, a plasmon hybridization model was proposed to explain the simulation results.

2. Theoretical Methods and Results

Lumerical FDTD Solutions, a commercial electromagnetic software based on the finite-difference time-domain method (FDTD), was used to perform the simulation of the gold contour bowtie antenna, which consisted of the solid bowtie defined by the circumradius of the equilateral triangle, *R*, with various contour thicknesses, *t*, as shown in the inset of Figure 1. By systematically varying the contour thickness at a fixed antenna dimension, we could elucidate the essential trends of how the contour thickness affects the plasmon resonance. First, the local electromagnetic field (*E*) enhancement and the resonance wavelength of three bowtie antennas (NCB150, NCB100, and NCB60 which corresponded to the side length of the triangle of about 259.8 nm, 173.2 nm, and 103.9 nm, respectively) with various contour thicknesses were examined. Then, the mechanism of the contour thickness dependence of the field enhancement was explored. Finally, we developed the plasmon hybridization model to analyze the coupling effect in the contour bowtie antenna.

From Figure 1, the maximum *E* intensity enhancement for NCB150 becomes larger initially as the contour thickness decreases. As the contour thickness decreases to a critical value, the *E* intensity enhancement reaches a maximum and then decreases to a value which is even smaller than that of the solid bowtie antenna. On the other hand, there are no obvious *E* intensity enhancements for NCB100 and NCB60 with decreasing contour thickness. The above phenomena resulted from the polarizability and the coupling effect between the solid bowtie and the cavity structure.

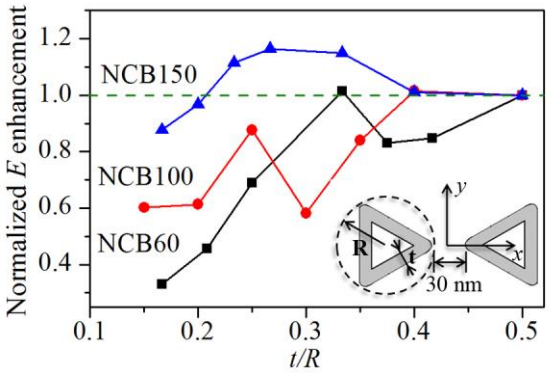

Figure 1. The *E* enhancements of NCB150, NCB100, and NCB60 normalized by the maximum *E* intensity enhancement of each solid bowtie antenna. The inset shows the schematics drawing of a contour bowtie on the *x*-*y* plane.

3. Conclusions

In conclusion, we use FDTD method to simulate the plasmon behaviors of gold bowtie nanostructures with different contour thicknesses. As the dimension of contour bowtie antenna decreases to the critical case NCB100 (bowtie triangle side length of about 173 nm) or the contour thickness decreases to a certain value, the contour bowtie antenna can no longer exhibit the additional local electromagnetic field enhancement compared to the solid bowtie.

Acknowledgements

The work was jointly supported by the National Science Council, Taiwan under Contract no. NSC 103-2221-E-002-076-MY3 and Excellent Research Projects of National Taiwan University under Project no. 103R8918. We also thank the staff of the Nano-Electro-Mechanical-Systems (NEMS) Research Center, National Taiwan University for their support and valuable advice.

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