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Optimization of Sensitivity and Electric Field Enhancement for Bowtie Nanoring Nanoantenna Arrays

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1. Introduction

The resonant oscillation of the conduction electrons excited by light interacting with a sub-wavelength metallic nanostructure is called localized surface plasmon resonance (LSPR). It has been shown that a large electromagnetic field can be excited in the gap of a bowtie-shaped nanoantenna [1]. Also, investigations of nanoring structures have exhibited better electric field enhancement and sensitivity compared to solid nanodisk structures [2]. However, there are few reports on the advantages of combining the great electromagnetic field enhancement produced in the bowtie-shaped antenna gap with the enhanced sensitivity characteristic of the nanoring structure. The purpose of the present work is to perform numerical studies on a model system of bowtie nanoring antenna array to examine the dependence of resonance wavelength, local electromagnetic field enhancement, and sensitivity on the nanohole size inside the bowtie nanoring antenna.

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 bowtie nanoring antenna array, which consisted of the solid bowtie and the nanohole structure inside the bowtie. By systematically varying the nanohole size, *r*, we could examine the trends of how the nanohole size inside the bowtie antenna affects the plasmon resonance. First, the local electromagnetic field (*E*) enhancements and the resonance wavelengths of bowtie nanoring antennas were examined. Then, the properties of surface sensitivity and bulk sensitivity obtained from the transmission spectra dependence on the nanohole size were explored. Finally, we utilized the charge and the electric field intensity distributions to analyze the effects of nanohole size on LSPR of the bowtie nanoring antenna array.

Figure 1 shows red shift of the maximum resonance wavelengths of bowtie nanoring antennas compared to the solid bowtie antenna regardless the nanohole size. Also, the maximum electric field intensity enhancement becomes larger compared to the solid bowtie antenna as the nanohole size increases. On the other hand, the maximum resonance wavelengths of bowtie nanoring antennas exhibit a linearly shift for the surrounding refractive index in the range of 1.00–1.76. The bulk sensitivity increases from 538 to 881 nm/RIU, about 63% enhancement compared to the solid bowtie, as the nanohole size increases to 40 nm radius.

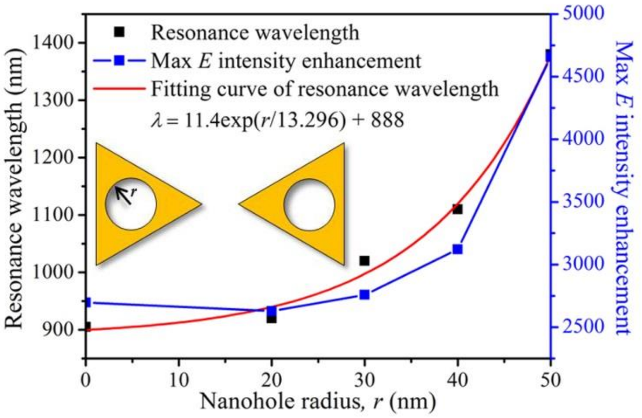

Figure 1. Maximum *E* intensity enhancement and resonance wavelength as functions of the nanohole size inside the bowtie, *r*, for bowtie nanorings.

3. Conclusions

In conclusion, we used the FDTD method to simulate the surface plasmon resonances of gold bowtie nanoring nanoantenna arrays with different nanohole sizes. Both the local electromagnetic field intensity enhancement and the resonance wavelength increase with the increasing nanohole size of bowtie nanoring. The bulk sensitivity of the optimized bowtie nanoring has better performance than the solid bowtie due to the switch of the major sensing peak from mode I to mode II, for which mode II shows a stronger response of the resonance wavelength shift to the change of surrounding refractive index.

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References

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