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Concentric Corrugations Enhanced Optical Antenna for Raman Scattering

Yi-Han Huang[1], Bo-Kai Chao[2], Chun-Hway Hsueh[2], Jia-Han Li[1,*],

[1] Department of Engineering Science and Ocean Engineering and [2] Department of Materials Science and Engineering
National Taiwan University, Taipei, 10617, Taiwan
*E-mail : jiahan@ntu.edu.tw

1. Introduction

Optical antenna or nanoantenna, which can control the optical signal radiation and manipulate the light energy at the tiny region, has attracted more attentions for various applications during these years [1, 2]. For example, the nanoplasmonic structures were used to enhance the surface enhanced Raman scattering (SERS) signals for biological or chemical sensing application [3, 4]. A. Ahmed and R. Gordon put a circular reflector around the optical dipole antenna to boost the Raman signals and studied the emission pattern of the radiated signal from the directive optical antenna [5, 6]. Because the spot size of the exciting source is usually larger than the nanoantenna area, the surrounding light energy could not be all focused on the gap of the optical antenna. On the other hand, the bull's eye structures can be used for collecting light energy into the center of the rings [7]. Thus, we propose to study a structure which combines the bull's eye structure and optical antenna with a reflective layer beneath it.

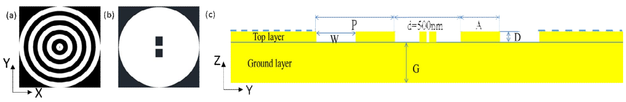

Figure 1. Schematic illustration of top view of (a) optical dipole antenna located at the center of bull's eye structure, (b) zoom-in plot of (a), and (c) the cross section plot of structure we studied.

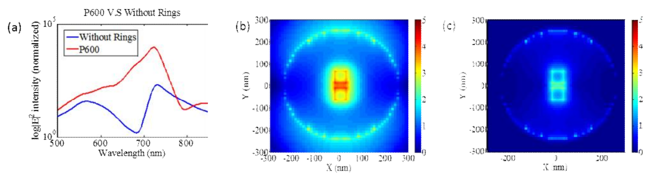

Figure 2. (a) Comparisons of $|E|^2$ intensity spectrum for the structures with and without concentric corrugations, where the periodicity was chosen to be 600 nm. (b) and (c) are for $|E|^2$ intensity around the optical dipole antenna for the structure with and without the concentric corrugations, respectively.

2. Simulation Setup and Results

The schematic plot of our proposed structure is shown in Figure 1. The period of the concentric corrugation can be decided by the bull's eye design [7]. To avoid complications, we set the length, width, and height of each rectangular structure of optical dipole antenna in Fig. 1 as 55 nm, 45 nm, and 50 nm, respectively. The gap between two rectangular structures is 20 nm. The simulations of various structures were performed using the Lumerical FDTD Solutions [8], the commercial software based on the finite-difference time-domain method. The optical properties of gold are taken from the experimental measurements by Johnson and Christy [9]. Figure 2(a) shows the comparisons of the electric field intensities verse wavelength for the structures with and without concentric corrugations, where the periodicity was chosen to be 600 nm. It is found that the electric field intensity at the gap of nanoantenna is enhanced when the period rings are added around the optical dipole antenna. Figures 2(b) and 2(c) shows the electric field intensity distributions of structures with and without the rings respectively at the resonant wavelength of each structure in Fig. 2(a). As a result, the corresponding electric field intensity at the gap of structure with rings is boosted by a factor of 45 as compared to the structure without the rings.

3. Conclusions

The concentric corrugated rings can be used to improve the localized electric intensities of the optical dipole antenna. The maximum enhancement can be achieved by proper design of the period and parameters of rings according to the properties of optical dipole antenna. The structure we studied in this paper can be fabricated by current semiconductor fabrication processes. It can be used to improve the Raman signal of the SERS substrate, and the concept can also be used on the other applications of nanoantennas.

Acknowledgements

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