Controlling Gap-Mode Plasmonic Fields via Silver Nanocubes on a Silver Thin Film

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1. Introduction

Localized Surface Plasmon Resonance (LSPR) induces enhanced electric fields that are confined near metallic nanoparticles. These regions of strong local fields, known as hotspots, are crucial for applications such as biosensing and imaging. We previously demonstrated that nanocube structures with narrow gaps exhibited large-area hotspots throughout the gap regions [1]. However, coupling between adjacent nanocubes caused peak broadening and redshift, limiting applications in the visible range. We recently showed that interaction with a silver thin film can overcome this limitation [2]. Based on this approach, in this study, we aimed to control LSPR spectra and localized electric fields by placing silver nanocubes on a 10-nm-thick silver thin film.

2. Methods

Finite difference time domain (FDTD) simulations were performed using Fujitsu Poynting for Optics. Fig. 1 shows the schematic of the nanocube structures on a silver thin film. The film thickness d was fixed at 10 nm, while cube side length L, height h, gap distance G, and spacer thickness sp were varied to tune the LSPR response. Periodic boundary conditions were applied in X and Y direction, and absorbing boundaries in Z direction. An X-polarized pulsed light was incident from the backside of the structures.

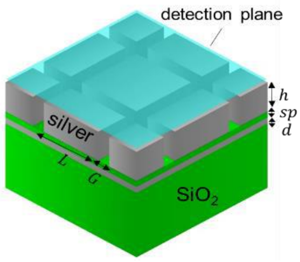

Fig. 1 schematic of the nanocube structures on thin film.

3. Results and discussions

Fig. 2 shows reflectance spectra and electric field distributions for structures with L=100 nm, h=50 nm, G =20 nm, d=10 nm, and sp =3–10 nm. Two sharp peaks appeared in the visible range, attributed to the interaction between nanocube dipole oscillations and standing waves in the spacer layer. These peaks are tunable by adjusting spacer thickness. Fig. 3 presents reflectance spectra and electric field distributions for structures with L=100 nm, h=30 nm, G=20 nm, sp=0 nm, and d=10 nm, under different surrounding refractive indices. When the nanocubes were in direct contact with the silver thin film, the enhanced electric field shifted toward the upper side of the gap region, resulting in increased overlap with the surrounding medium. Consequently, a high refractive index sensitivity of 546 nm/RIU was achieved. We are planning to begin the fabrication of the proposed structures.

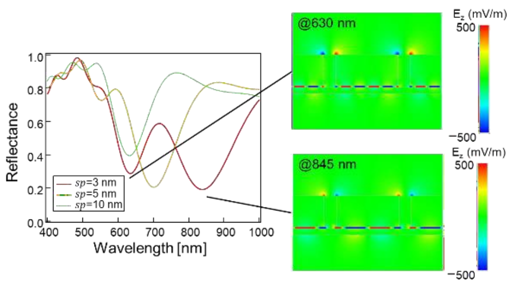

Fig. 2 Reflectance spectra and electric field distributions varying spacer thickness.

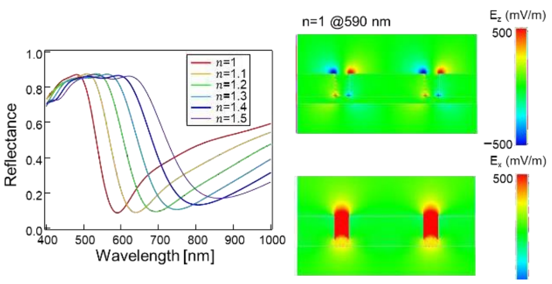

Fig. 3 Reflectance spectra and electric field distributions varying surrounding refractive indices.

References

[1] K. Okamoto et al., Photonics, 11, 292 (2024). [2] K. Yamasaki et al., Photonics, 12, 439 (2025).