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Fabrication of plasmonic cavity and indefinite metamaterial by laser-induced forward transfer

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1. Introduction

Optical cavity has found many applications in integrated photonics [1-2], micro/nano-laser [3-4], luminescence enhancement [5], and nonlinear optics [6]. To achieve high performances on the applications, an optical cavity with a high Purcell factor Q/Vm is desired, where Q and Vm denotes the quality factor and mode volume. Unfortunately, mode volumes are limited by diffraction limit. Plasmonic cavities can squeeze light in volumes significantly smaller than the diffraction limit and have drawn lots of attention recently. To fabricate multilayer and three-dimensional plasmonic nanostructures, laser-induced forward transfer (LIFT) is a simple and low -cost writing technique to choose. LIFT technique is very fascinating for the throughput and fast prototyping of various nanophotonic devices. In our research, we implement the femtosecond LIFT (fs-LIFT) technique to fabricate square-shaped multilayer plasmonic resonant cavities, and study their optical properties by both experiments and numerical simulations.

2. Results and Discussion

Figure 1 shows the schematic illustration of the experimental process. By using a magnetron sputtering system (Shibaura Mechatronics Corp.), multilayer thin films composed of Au(20 nm) / ZnS-SiO2(30 nm) / Au(20 nm) / ZnS-SiO2(30 nm) / Au(20 nm) are sputtered on a cleaned BK7 glass substrate. Under focused laser illumination, the local material on the precoated substrate (so called donor) can be transferred to the opposite substrate (so called receiver). Multilayer films of fabricated patterns can be observed in SEM images, indicating that the multilayer structures of laser-fabricated pattern are not damaged by the lateral heat dissipation during laser illumination. We also compare the experimental with simulated transmittance spectra of the plasmonic cavity illuminated by a y–polarized light at normalincidence. We found that two transmittance dips appear around 1280 nm and 1800 nm in both spectra. To understand the origin of these dips, we also analyze the plasmonic resonance modes of the structures by simulation.

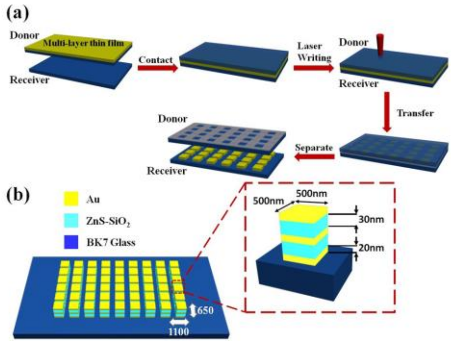

Fig. 1. (a) Schematic illustration of fs-LIFT process. (b) The feature size of a multilayered plasmonic cavity in nanometer scale. The period along x-direction P_x and y-direction P_y are 1100 nm and 650 nm.

3. Conclusions

We successfully demonstrated a low-cost, efficient and simple fabrication technique for manufacturing multilayered plasmonic resonance cavity by femtosecond laser-induced forward transfer technique. We have found the optimized laser fluence and laser raster speed on the multilayer films for making the fabricated multilayer structure uniform and smooth. Two resonance modes are alsofound in near infrared region, showing electromagnetic energy mainly stored in the sandwiched dielectric layer with subwavelength property. The optical properties of laser-fabricated plasmonic cavity quantitatively agree with simulations results. We can expect that People may readily find the optimization of processing parameters for the desired layered structures, and fabricate the designed photonic devices on the arbitrary substrates.

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