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Fabrication of Surface Plasmon Resonance Sensors with Highly Uniform Metallo-Dielectric Nanostructures Over a Large Area

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Abstract

A method to fabricate SPR sensors by combining interference lithography with nanoimprint lithography for the generation of lift-off free, large area and highly uniform metallo-dielectric nanostructures on a glass substrate is demonstrated. The obtained sensitivity was ~340 nm/RIU.

1. Introduction

Surface plasmon resonance (SPR) effects allow for label-free, real-time detection of biomolecule binding events [1]. Generally, SPR sensor chips are fabricated on glass substrates integrated with measurement systems. The Kretschmann configuration requires complex non-collinear optical setup to couple incoming light to metal film/environment surface [2]. Instead, the use of metallic nanostructure in a simple linear optical setup to couple incoming light to surface plasmon polaritons (SPPs) has proven to be a good alternative [3]. Lift-off process is often required for making such metallic mesh. However, to have a good lift-off result always requires PR pattern of high aspect ratio and vertical sidewall inclination, and good collimation for the evaporating ion beams. Otherwise, sidewall metal would be too thick when deposition thickness was increased, which blocked solvent to dissolve the sacrificial layer. Therefore, bi-layer resist structure [4] or tilt evaporation method [5] has been introduced to solve the sidewall deposition problems, but these methods either require sophisticated parameters tuning or additional evaporation tools.

In this work, by combining interference lithography (IL) and nanoimprint lithography (NIL), we demonstrated a lift-off free, large-area and high uniformity metallo-dielectric nanostructures fabricated on a glass substrate to excite SPPs. Compared to EBL and FIB, IL is potentially cost effective and more efficient to generate large-area nanostructures. The sensors sensitivity (~340 nm/RIU) and spectral uniformity are comparable to those reported previously using other fabrication methods.

2. Experimental results

A photoresist hole-array pattern with period of 500 nm was fabricated by applying double-exposure IL as schematically shown in Fig. 1(a). Then PDMS was spun over the mold to duplicate the pattern as depicted in Fig. 1(b), which served as a stamp. The pattern of imprint resist shown in Fig. 1(d) was fabricated by NIL using the stamp as shown in Fig. 1(c). After the resist residue was removed by CF_4/O_2 plasma, 50 nm gold layer was deposited on the pattern surface as shown in Fig. 1(e).

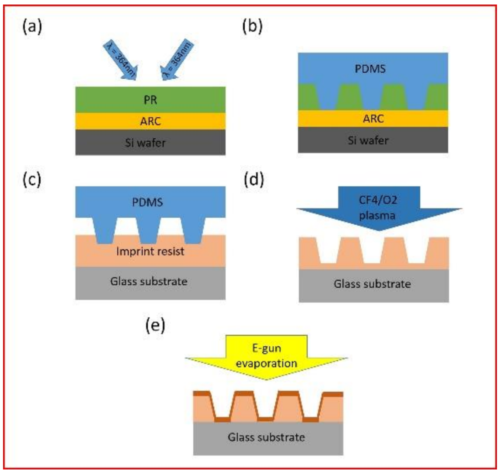

Fig. 1 Fabrication process of making SPR sensors on a glass substrate.

In Fig. 2(a), uniform diffracted color from the hole array pattern can be seen, indicating good uniformity of the imprint result. The detailed structures were examined using SEM. Fig. 2(b) shows the magnified images near the substrate center. The period is 506.1 nm as shown in the inset. Fig. 2(c) shows tilt 45° cross section of this structure. The gold/resist hybrid structures or so called metallo-dielectric nanostructures offer an alternative method to support SPPs [6]. Since the uniformity of large-area nanostructures was a critical factor for sensors, the uniformity of spectral response over the large-area nanohole arrays was examined. Fig. 3 shows the measured transmission spectra of nine spots over a 1.5x1.5 cm^2

nanohole array in air by using unpolarized light. The mean value of resonance peak in air was 596.5 nm with standard deviation 1.1 nm. Overall, all spots exhibited uniform resonance wavelength, and the intensity variations might be attributed to unstable intensity of the light source during experiment or resist height variation during spin-coating caused by glass substrate's roughness (Ra<5 nm).

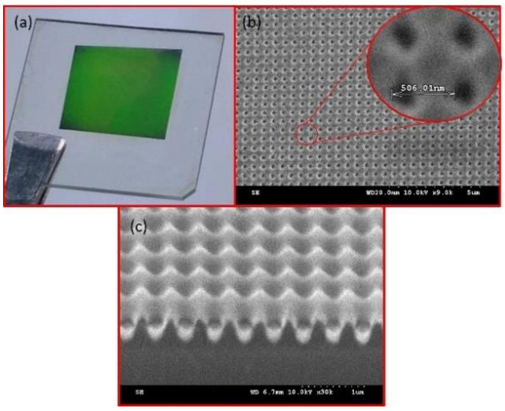

Fig. 2 (a) A photograph of the imprint glass chip. (b) SEM images of gold hole array patterns near the center of a fiber. The inset shows the dimension of the period. (c) SEM images of gold hole array patterns tilt 45° cross section.

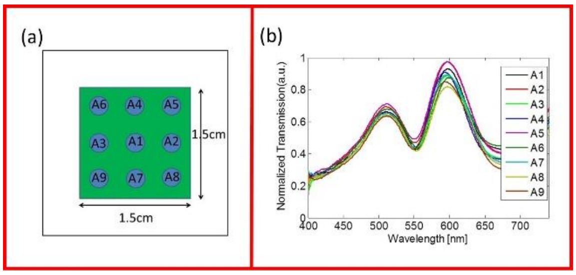

Fig.3 (a) Nine checked spots over a 1.5x1.5 cm^2 nanohole array area. Each spot is about 400 μm in diameter. (b) The transmission spectra of A1 to A9 spots.

Finally, we measured the resonant wavelength shifts for 0%-36% concertation glucose solvents as shown in Fig. 4(a), and the obtained sensitivity shown in Fig. 4(b) was 338.2 nm/RIU. The sensors sensitivity is comparable to former method reported in EBL [7] and FIB [8]. The standard deviations of resonance wavelength also shows comparable to template-stripped method reported in [9].

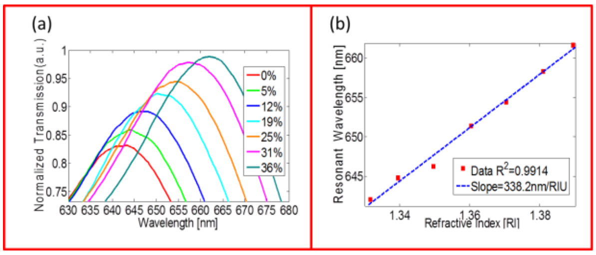

Fig. 4 (a) Wavelength shift responses for 0% to 36% concertation glucose solvents, and (b) the corresponding sensitivity of SPR sensors.

3. Conclusion

A fabrication method which combines IL with NIL to generate metallic-dielectric nanostructures (period of 506 nm) over a large area (1.5x1.5 cm^2) on a glass substrate without the need of lift-off process has been demonstrated. The resultant hybrid structure sensors exhibit a sensitivity of 338nm/RIU, which is comparable to those reported previously using other fabrication methods. It is expected that such an alternative to make SPR sensors can be integrated with microfluidic channels to be useful bio-chips for further applications.

Acknowledgements

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