Double Surface Plasmon Resonances Obtained with Bessel-Beam-Written Nanoslits Arrays

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Femtosecond laser ablation with Bessel beam profile can yield high quality structures on metal thin films at nanoscale [1]. By adjusting the laser fluence one can control size of ablated structures. Moreover, resolution can go beyond the diffraction limit when the laser energy is adjusted around the ablation threshold [2]. Advantages of using diffraction-free Bessel beams bring us to ablate 125 nm-wide stripes. In this work, we demonstrate potential of Bessel-beam nanofabrication method and optical properties of created structures for plasmonic applications. Nanoslit arrays are structured through ablation by femtosecond laser with Bessel Beams on 25 nm-thick Gold (Au) film evaporated on Fused Silica substrate. We fabricated stripes at nanoscales with different periodicities (p=500 nm, 790 nm and 810 nm). Since the fabrication method does not require high cost focusing optics or any special sample preparation, process is straightforward and well candidate to compete against standard lithographical methods.

Optical characterization experiments are also conducted in the spectral range from 400 nm to 1000 nm. A white light source is collected using objective then passes through polarizer, hitting the surface at normal incidence. Since Surface Plasmon Polaritons (SPP) is always transverse magnetic (TM), the polarization of light is set to TM in order to generate Surface Plasmon Resonance modes.

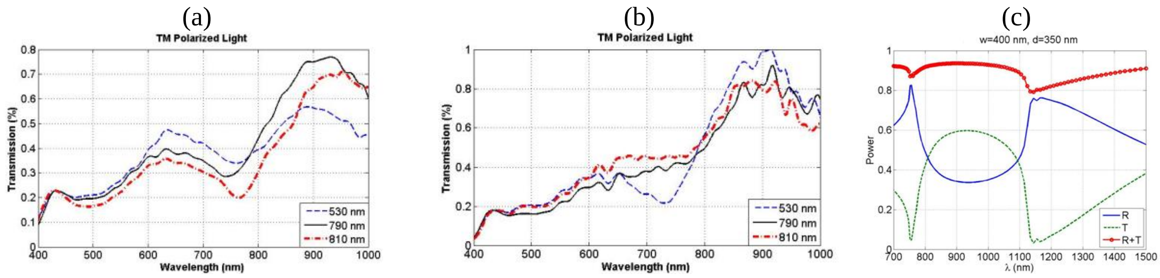

Fig. 1 (a) Normalized transmission spectra through nanoslits array with periodicities of 500 nm, 790 nm and 810 nm. (b) Transmission spectra for samples covered with glycerin. (d) Simulated transmission and reflection spectra for 750 nm period.

Fig. 1 (b) shows the transmission spectra on nanoslits with 3-different periodicities. There are noticeable drops in the transmission spectra between 700 nm and 800 nm. The SPP can be excited at both metal-air and metal-glass interfaces. To distinguish the SPR modes we do additional experiment where we cover the Au film with glycerin (dielectric constant is very close to that of fused silica). Results show that SPR modes excited at metal-air interface disappear whereas the SPR mode excited on metal-glass interface remains almost same (Fig.1 b). We theoretically calculate the SPR modes for both interfaces using plasmon dispersion relation [3] where phase-matching condition is ensured. We also simulate the light transmission through nanoslit and calculate the transmission using Lumerical. The simulated transmission spectra exhibit double transmission dips in accordance with experiments (Fig.1c). We also calculate the shift in the resonance wavelength with respect to dielectric constant of the medium. the p = 500 nm case has a sensitivity of 540 nm/RIU (refractive-index unit), which is comparable with experimental results of plasmonics sensors found in the literature [4,5]

In conclusion, periodic nanoslits arrays on semi-transparent metal film with different periodicities are written using Bessel Beams. Optical characterization experiments exhibit that SPP are excited at both side of metal surface. As compared to similar approaches, our results offer orders of magnitude larger total transmissions hence increasing the detection signal-to-noise ratio.

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