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Splitting of Surface Plasmon Resonance Peaks Under TE- and TM-polarized Illumination

Su-Jin Yoon[1,2], Jeongwoo Hwang[3], Myeong-Ju Lee[1], Sang-Woo Kang[1], Jong-Su Kim[2], Zahyun Ku[4], Augustine Urbas[4], and Sang Jun Lee[1]

[1]Division of Industrial Metrology, Korea Research Institute of Standards and Science, Daejeon, 305-340, [2]Department of Physics, Yeungnam University, Gyeongsan, 712-749, [3]Photonic-Bio Research center, Korea photonics Technology Institute, Gwangju, 500-779, Korea, [4]Air Force Research Laboratory, Wright-Patterson Air Force Base, OH 45433, USA

We investigate experimentally and theoretically the splitting of surface plasmon (SP) resonance peaks under TE- and TM-polarized illumination. The SP structure at infrared wavelength is fabricated with a 2-dimensional square periodic array of circular holes penetrating through Au (gold) film. In brief, the processing steps to fabricate the SP structure are as follows. (i) A standard optical lithography was performed to produce to a periodic array of photoresist (PR) circular cylinders. (ii) After the PR pattern, e-beam evaporation was used to deposit a 50-nm thick layer of Au. (iii) A lift-off processing with acetone to remove the PR layer, leading to final structure (pitch, p=2.2 μm; aperture size, d=1.1 μm) as shown in Fig. 1(a). The transmission is measured using a Nicolet Fourier-transform infrared spectroscopy (FTIR) at the incident angle from 0^{o} to 36^{o} with a step of 4^{o} both in TE and TM polarization. Measured first and second order SP resonances at interface between Au and GaAs exhibit the splitting into two branches under TM-polarized light as shown in Fig. 1(b). However, as the incidence angle under TE polarization is increased, the 1st order SP resonance peak blue-shifts slightly while the splitting of 2nd order SP resonance peak tends to be larger (not shown here). For the purpose of understanding our experimental results qualitatively, SP resonance peak wavelengths can be calculated from momentum matching condition (black circle depicted in Fig. 2(b)), $k_{sp}=k_{\|}\pm iG_x\pm jG_y$, where k_{sp} is the SP wavevector, $k_{\|}$ is the in-plane component of incident light wavevector, i and j are SP coupling order, and G is the grating momentum wavevector. Moreover, for better understanding we performed 3D full field electromagnetic simulations of SP structure using a finite integration technique (CST Microwave Studio). Fig. 1(b) shows an excellent agreement between the experimental, calculated and CST-simulated splitting of SP resonance peaks with various incidence angles under TM-polarized illumination (TE results are not shown here). The simulated z-component electric field (Ez) distribution at incident angle, 0^{o} and 16^{o} under TM polarization and at the corresponding SP resonance wavelength is shown in Fig. 1(c). The analysis and comparison of theoretical results with experiment indicates a good agreement of the splitting behavior of the surface plasmon resonance modes at oblique incidence both in TE and TM polarization.

Keywords: Surface Plasmon (SP), Fourier Transform Infrared Spectroscopy (FT-IR), Computer Simulation Techniques (CST Microwave Studio), Diffraction order, Transmission, TE/TM-polarization

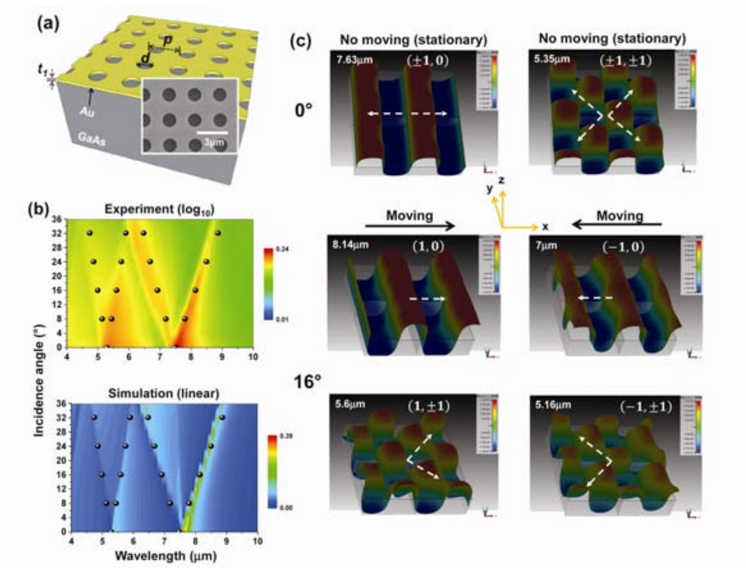

Figure 1. (a) Schematic view of SP-structure and SEM image. (b) Experimental, calculated simulated SP resonance wavelengths as a function of TM-polarized incidence angle and wavelength. (c) Simulated E_z field distribution at corresponding SP resonance wavelengths at 0° and 16° TM incident light.