Coupling of surface plasmons in Au nanorings with subwavelength holes array

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Researchers have long been investigating the optical properties of the metallic nanoantennas and the dielectric photonic crystal slab (PCS), respectively. The fundamental physics being interested in the former one involves the capability to support a localized surface plasmon resonance (LSPR) and enhance the local fields while the latter one exhibits the Fano like guided resonance (GR) due to the coupling between a continuum and a discrete number of states. Herein, we design a system and aim to numerically study both the LSPR and GR simultaneously. The proposed structure shown in figure 1 comprises Au nanorings superimposed on quartz PCS, where the outer diameter, inner diameter and the thickness of the Au nanorings are denoted as r_1, r_2 and h_1, respectively, while the diameter of the circular air holes array on quartz membrane is defined as D. The air holes with period of a on the quartz membrane are scooped but not penetrated with the resultant depth of the air holes to be h_2, leaving a thin quartz layer with thickness of h_3 used to sustain the Au ring. A real space three-dimensional finite element model based on COMSOL RF module is developed to analyze the geometry dependent far-field resonances and the optical near-field distribution in the visible light range for normal incident light with polarization as shown in figure 1. The transmittance spectra of the pure quartz PCS is first simulated. The simulation results clearly show that there exists a sharp resonant dip appeared at wavelength of 435 nm as black solid curve shown in the figure 2. Such resonant behavior is attributed to be the interference between direct transmission and the exponential decaying amplitudes of the guided modes of the quartz PCS. Next, we compute the transmittance properties of the Au nanorings array superimposed on a freestanding quartz membrane. The numerical data reveal that the Au rings behave as the optical nanoantenna with the existence of a broad resonant dip centered at the wavelength of 825 nm as red solid curve shown in the figure 2, which is caused by the LSPR of the nanometer Au nanorings and is dependent on the geometry of the Au nanorings. Finally, the transmittance spectra of the Au nanorings superimposed on quartz PCS is calculated. Consequently, two resonant dips are simultaneously observed, in which one is ascribed to the GR while the other is due to the LSPR as indicated in the blue solid curve of the figure 2. Note that the plasmon resonance dip in the blue solid curve is blue shifted as compared with the one in the red solid curve that is due to the geometry parameters of the scooped air holes array underneath. Our simulation results indicate that one can simultaneously inspect the related properties between LSPR and GR of the Au nanorings on quartz PCS and can tune the resonant properties by means of the geometries of the Au nanorings and the air holes. Detailed on the geometry dependent transmittance and local field enhancement of the Au nanorings on quartz PCS will be elaborated.

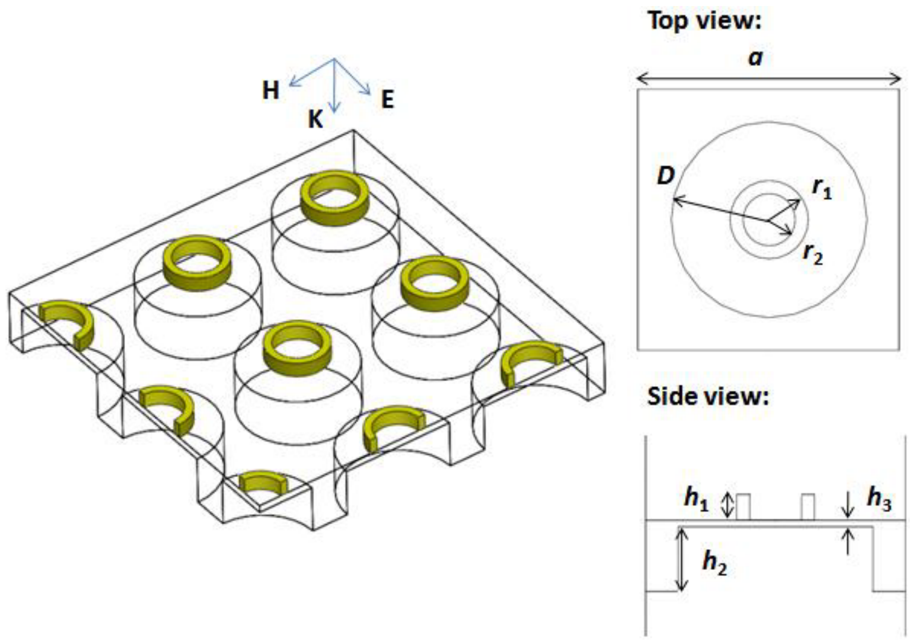

Fig. 1 Schematic drawing of the nanometer Au rings array on quartz photonic crystal slab.

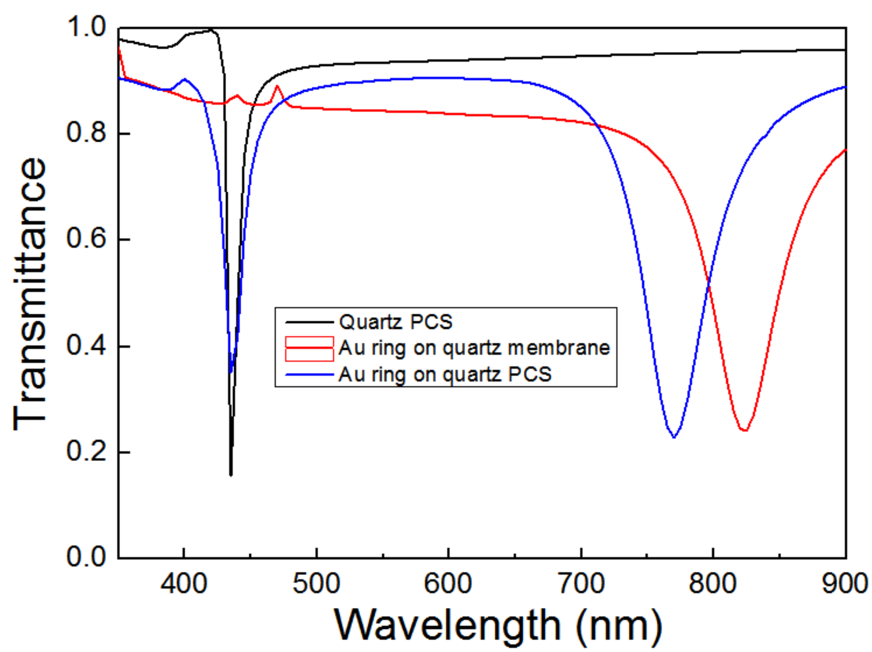

Fig. 2 Transmittance spectra calculated for pure quartz photonic crystal slab (PCS) (black solid curve), Au ring on quartz membrane (red solid curve) and Au ring on quartz PCS.