Hybrid plasmonic modes in multilayer trench grating structures

Light-matter interaction realized by plasmonic microstructures brings about a strong light confinement, which means energy can be controlled under micro- or nano-scale, providing a versatile approach to tailor optical properties precisely. However, a large Ohmic loss is inevitable in the plasmonic formations, and usually leads to the thermal instability and low efficiency of designed devices. For common plasmonic nanostructures, it is difficult to have the ability of energy confinement and low Ohmic loss simultaneously.

Recently, with the support by the National Natural Science Foundation of China, the research team led by Prof. Gao JinSong (高劲松) in the Changchun Institute of Optics, Fine Mechanics and Physics, Chinese Academy of Sciences, designed two multilayer nanostructures comprised of five alternate Al and Si layers to discuss the coexistence possibility of both strong energy confinement and low loss. The related research achievements were published in *Advanced Optical Materials* (DOI: 10.1002/adom.201700496).

The first structure they demonstrated is the multilayer gratings with a grating constant of 2 μm. It displays dual narrowband peaks in the near-infrared reflectance spectrum because the Fabry-Perot (F-P) resonance can be excited in the waveguide of multilayer grating stripes, resulting in the frequency-sensitivity and linear designable characteristic. The peak wavelengths can be figured out quantitatively through the symmetric metal-insulator-metal theory, and these calculated results accord well with the results obtained by simulations.

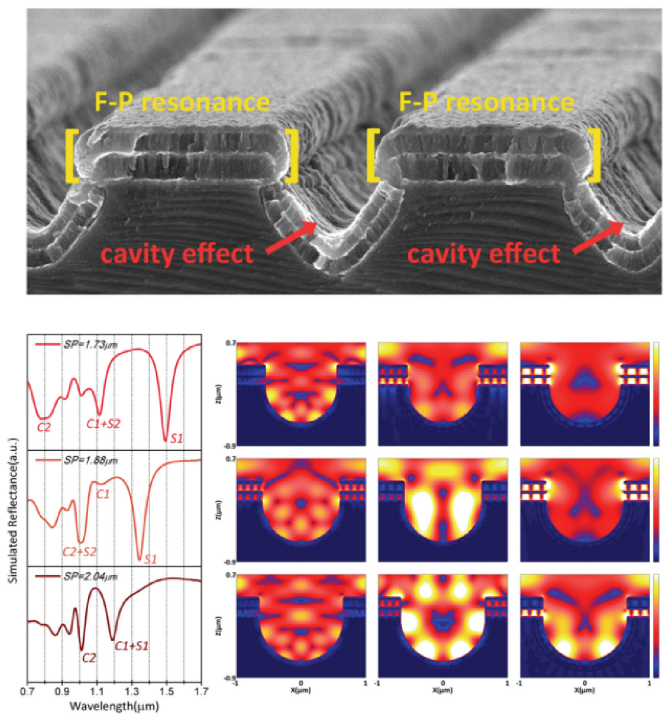

Figure The SEM image, the simulated reflectance including some hybrid modes, and the corresponding electric field distributions of multilayer trench gratings.

The second structure is the multilayer trench gratings containing both stripe and trench parts in it. Besides the F-P resonance, the trench structure can induce the excitation of cavity effect which brings about another kind of mode. When the oblique incidence is adopted, some new modes can be observed, leading to the hybrid plasmonic coupling modes. Additionally, by changing the width of the designed grating stripe, the F-P resonance modes successively merge with the cavity effect modes, generating the hybrid modes regularly. The researchers analyzed the phenomenon of hybrid modes by simulations, and verified it through experiments.

Finally, as a contrast, they calculated these two structures' quality factors to evaluate their losses and qualities. Surprisingly, the latter's quality factor value is two orders of magnitude higher than that of the former one. The results imply that the multilayer trench grating structure not only effectively reduces Ohmic loss, but strongly confines incident light energy as well.