Enhancement of absorption of light in 1D multi-layered structures with interfacial states

Y. Tsurimaki[1], S. V. Boriskina[1], Y. Huang[1] and G. Chen[1]

[1]Department of Mechanical Engineering, Massachusetts Institute of Technology, Cambridge, Massachusetts, USA, 02139

Absorption of light into a subwavelength-scale volume entails a rich variety of applications including highly-sensitive optical sensors and high-efficiency electro-optic devices. In order to guide and localize the incident light at nanoscale objects, structures that support surface plasmons resonance and phonic crystals that support guided modes have been widely investigated.

For the realization of highly-sensitive optical sensors, nanoscale metallic structures are often used which exhibit sharp absorption near the frequency of surface plasmons resonance [1]. Photonic crystals have also been widely investigated for optical sensing due to the coupling the incident light into photonic guided modes [2]. With these structures, the sensitivity can be enhanced since a sharp absorption peak at the single frequency induces a drastic change of characteristics of light including spectral shift and phase change in response to the refractive index change in the environment. However, these nanostructures often require complicated design and fabrication processes. In this study, we investigated a one-dimensional multi-layered photonic-plasmonic structure that can exhibit topologically-protected zero reflection when they are designed to support Tamm plasmons interfacial state [3]. Combined with the singular-phase optical detection [4], we numerically and experimentally demonstrated that the simple structure can show the higher sensitivity than the optical sensor based on surface plasmons resonance.

In this study, we also investigated an absorption of light by a one-dimensional multi-layered structure when the light is incident orthogonal to slab interfaces. In this structure, the incident light can couple into waveguide modes as well as surface modes that can exist at the interfaces between slabs by carefully designing the structure. In fact, it has been shown that indefinite slabs made of dielectric-metallic materials can show total absorption of light at certain frequency range and angle of incidence when the optical axis is tilted [5]. However, the effects of geometries such as thicknesses and periodicity and materials properties of the slabs on the absorption of light remain unclear. Therefore, we conducted a systematic study of absorption of light by a one-dimensional multi-layered structure when the light is incident orthogonal to slab interfaces and show that materials that are reflective in its bulk can be absorptive by guiding the light into waveguide modes and surface modes.

The authors acknowledge funding support from DOE BES (DE-FG02-02ER45977). Y.T. also acknowledges funding support from Funai Overseas Scholarship.

[1] J. Homola, “Surface plasmons resonance sensors for detection of chemical and biological species”, *Chemical Reviews*, 108(2), pp. 462-493, (2008)

[2] R. V. Nair and R. Vijaya, “Photonic crystal sensors: An overview”, *Progress in Quantum Electronics*, 34, 3, pp. 89-134, (2010)

[3] M. Kaliteevski *et al*., “Tamm plasmon-polaritons: Possivle electromagnetic states at the interface of a metal and a dielectric Bragg mirror”, *Physical Review B*, 76, 165415, (2007)

[4] V. G. Kravets *et al*., “Singular phase nano-optics in plasmonic metamateirlas for label-free single-molecule detection”, *Nature Materials*, 12, pp. 304-309, (2013)

[5] I. S. Nefedov *et al*., “Total absorption in asymmetric hyperbolic media”, *Scientific Reports*, 3, 2662,

(2013)