Towards Easily Tunable Mid-infrared Surface Plasmon Resonance With Gold Nano-crescent Structures

Fengwei Liu
St. Mary's Ryken High School, Leonardtown, MD, USA

Introduction: Mid-infrared, which interacts with most of the chemicals and creates spectra with functional group and fingerprint information, is widely used as a chemical sensing method for a variety of applications.[1] However, the applications of mid-infrared have been limited by the poor performance of the current mid-infrared detectors. Researchers have shown that the sensitivity of detectors for visible light can be improved by applying gold nanoparticles to silicon,[2] due to the surface plasmon resonance(SPR). Gold nano-crescent, due to its large aspect ratio and strong tip enhancement effect, has significant SPR effect in the mid-infrared range.[3] In this study, we proposed to use gold nano-crescent with porous structures to achieve tunable SPR in the mid-infrared.

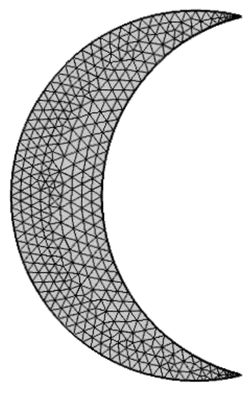

Figure 1. Gold Nano-crescnet

Computational Methods: In a Electromagnetic waves, Frequency domain study, we calculated the absorption and scattering corss sections of the gold nano-crescent structures

$$\sigma_{abs} = \frac{W_{abs}}{P_{inc}} = \frac{\frac{1}{2}\iiint_V \mathrm{Re}[(\sigma e + j\omega D)\cdot E^* + j\omega B\cdot H^*]dV}{P_{inc}} \quad (1)$$

$$\sigma_{sca} = \frac{W_{sca}}{P_{inc}} = \frac{\frac{1}{2}\oiint_S \mathrm{Re}[\ E_{sca} \times H^*_{sca}\ ]\cdot ndS}{P_{inc}} \quad (2)$$

We used refractive index of gold from Rakic et al.1998 to calculate scattering and absorption cross-sections of intact gold nano-crescent, gold-silver bimetallic nano-crescen. The refractive index of the sponge-like porous gold nano-crescent was reported by D. Garoli et al. 2017.[4]

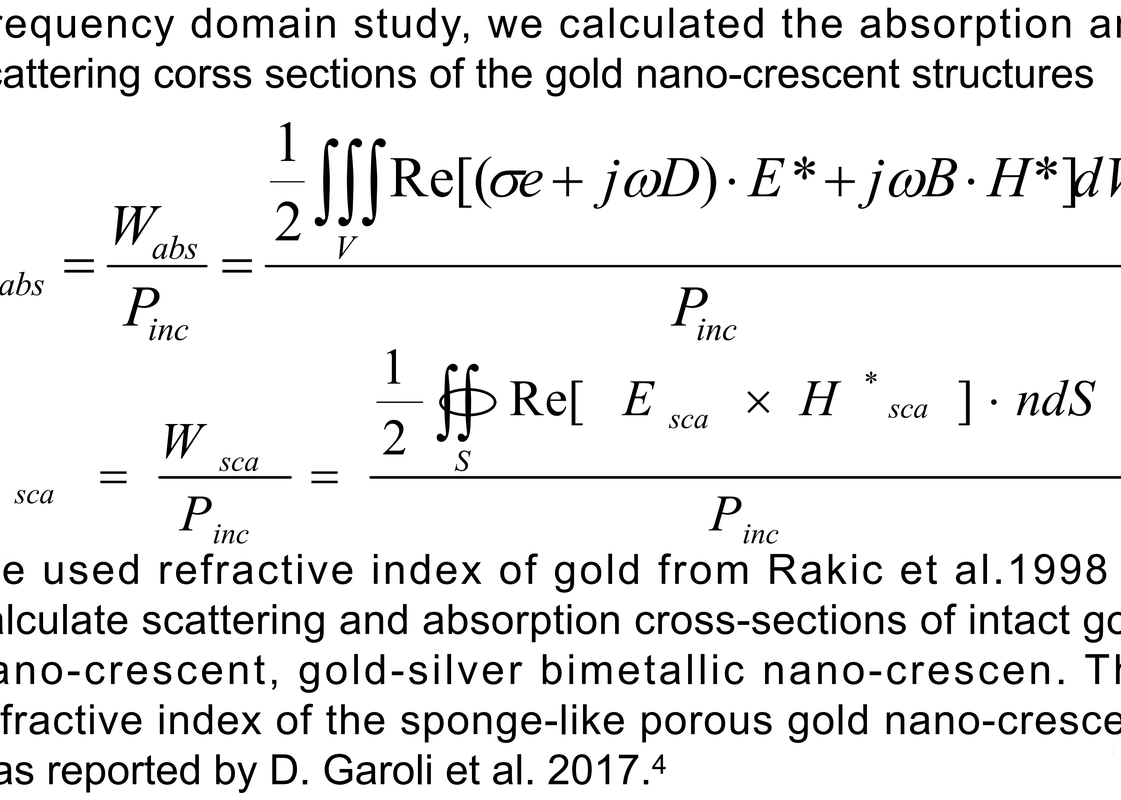

Figure 3. Real (a) and imaginary (b) parts of permitivity of porous gold (lower) vs solid gold (upper)[4]

Results:

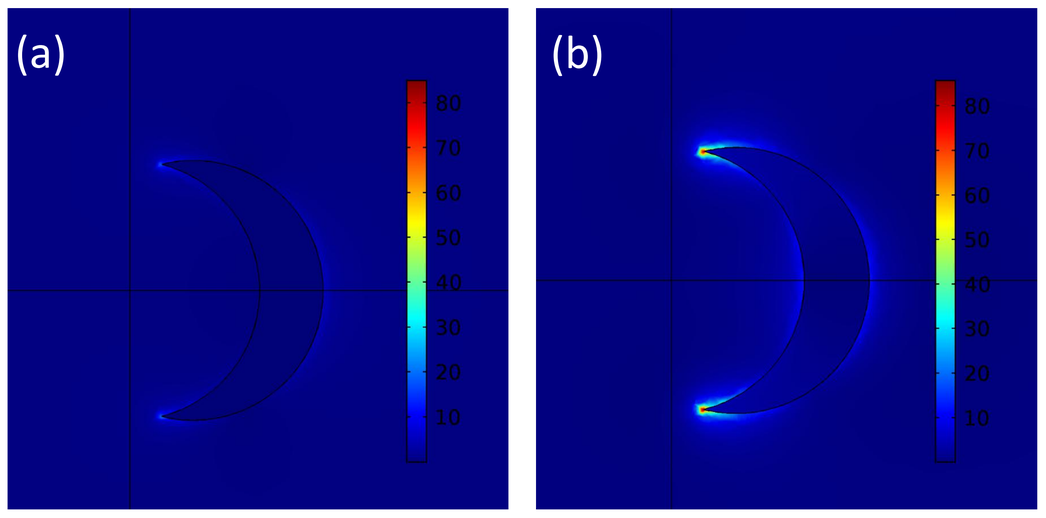

Figure 4. Electrical field distribution of gold nano-crescents. (a)Solid gold; (b)Porous gold

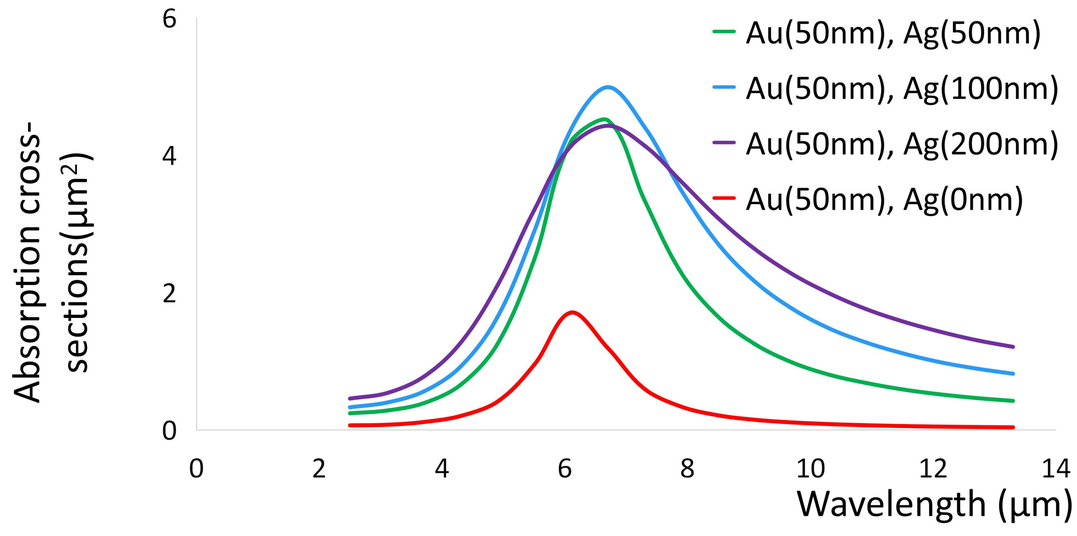

Figure 5. Solid gold vs Gold-silver bimetallic

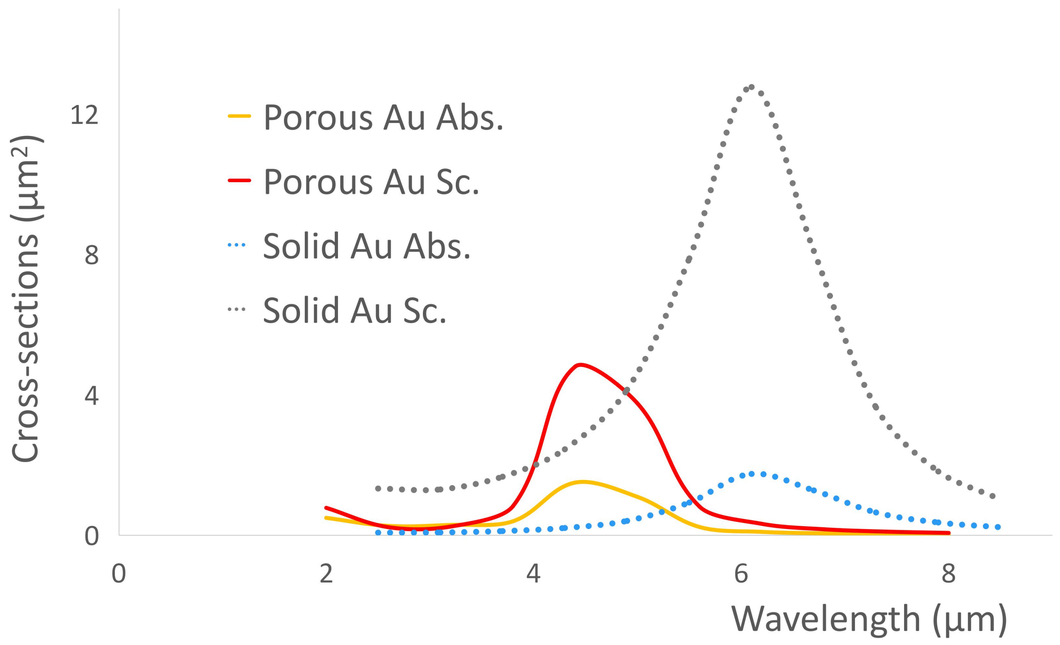

Figure 6. Solid gold vs Porous gold

Conclusions: With porous gold nano-crescent, we successfully tuned the SPR in the mid-infrared range. In the future, we plan to construct gold nano-crescent array, with solid or porous gold material and variable intervals, to further optimize tunable spr performance in the mid IR.

References:
1. Z. Li, et al., Super-Resolution Far-Field Infrared Imaging by Photothermal Heterodyne Imaging, J. Phys. Chem. B, ASAP.
2. Tsutomu Ishi, et al., Si Nano-Photodiode with a Surface Plasmon Antenna, The Japan Society of Applied Physics, 44, 12, (2005)
3. C. T. Cooper, et al., Mid-Infrared Localized Plasmons through Structural Control of Gold and Silver Nanocrescents, J. Phys. Chem. C, 119 (21), 11826, (2015)
4. D. Garoli, et al., Boosting infrared energy transfer in 3D nanoporous gold antennas, Nanoscale, 9, 915, (2017)

Excerpt from the Proceedings of the 2017 COMSOL Conference in Boston