High sensitivity nanophotonic sensor based on vertical split-ring resonator

Ching-Fu Chen[1,*], Pin Chieh Wu[1], Greg Sun[2], Wei Ting Chen[1], Yao-Wei Huang[1], Hsiang Lin Huang[3], Hai Pang Chiang[3,4,5] and Din Ping Tsai[1,4]

[1] Department of Physics, National Taiwan University, Taipei 10617, Taiwan
[2] Department of Physics, University of Massachusetts Boston, Boston, Massachusetts 02125, USA
[3] Institute of Optoelectronic Sciences, National Taiwan Ocean University, Keelung 20224, Taiwan
[4] Research Center for Applied Sciences, Academia Sinica, Taipei 11529, Taiwan
[5] Institute of Physics, Academia Sinica, Taipei 11529, Taiwan
* E-mail: cfjeffchen@ntu.edu.tw

Split-ring resonator (SRR) is a typical building block for metamaterial sensors because of its strong magnetic resonance accompanied with strong field enhancement within the SRR gap [1,2]. In this work, we report that vertical SRRs (VSRRs) are capable of lifting essentially all of the localized fields above the supporting substrate they stand on. We further demonstrate that plasmonic refractive index sensors constructed of VSRRs deliver significantly improved sensitivity over their planar counterparts, using Fourier transform infrared spectroscopy measurement and numerical simulation software.

Figure 1(a) shows the schematic concept of our designed VSRR structure standing up vertically on a fused silica substrate under normal illumination. This upright configuration strongly confines electromagnetic field within the gap as magnetic plasmon is excited. Sensing volume is increased since the enhanced field is suspended entirely in the free space, away from the dielectric substrate. Figure 1(b) shows the simulated and measured results. A sensitivity of $\delta\lambda/\delta n$ = 797 nm/RIU is predicted by the simulation, while a less value of 603 nm/RIU is obtained by measurement.

With optimized VSRRs or coupled structures, further improvement is achievable. This employment of VSRR structures in refractive index sensors is a promising method for achieving ultra-high sensitivity and label-free characteristics in bio-sensing applications.

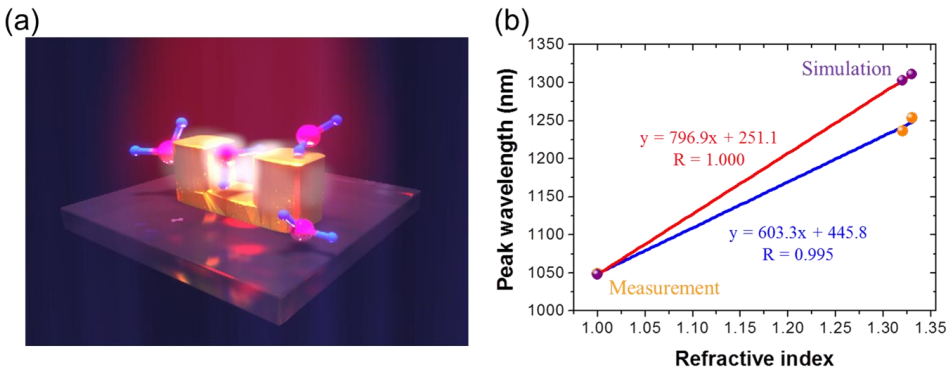

Figure 1. (a) Illustration of field distribution in the VSRR gap. (b) Resonance wavelength associated with magnetic resonance of measured (orange dots) and simulated (purple dots) results as a function of the surrounding refractive index.

[1] A. Dmitriev et al., Nano Letters 8, 3893-3898 (2008).
[2] P. C. Wu et al., Nanophotonics 1, 131-138 (2012).