Metamaterials Laboratory
Chief Scientist: Takuo Tanaka (D.Eng.)

(0) Research field

CPR Subcommittee: Engineering

Keywords:

Metamaterials, Nanophotonics, Plasmonics, Optics and Photonics, Spectroscopy

(1) Long-term goal of laboratory and research background

In the past, it has been believed that the electro-magnetic properties of materials are determined by the intrinsic property of the materials itself and no one can alter them. In this research laboratory, we are intensively investigating the breakthrough science and technologies that can artificially control the optical properties of the materials by using metal nano-structures. This technology can create unprecedented optical materials such that it can interact directly with the magnetic components of the light, in which the refractive index can be zero, negative or tremendously giant values. We collectively call these kinds of artificial materials - "metamaterials". We will also extend the application of metamaterials to develop novel and functional optical devices that will open a door for new photonic technologies.

(2) Current research activities (FY2020) and plan (until Mar. 2025)

Identification of amino acid enantiomers is the basis of asymmetric synthesis, playing an important role in the field of organic/biological chemistry and pharmacy. Chiral nature of an enantiomer can be characterized by circular dichroism (CD) spectroscopy, which is the differential absorption of left and right circularly polarized light, but such a technique usually suffers from weak signal even with a sophisticated optical instrument. By exploiting super-chiral field in a metasurface, we experimentally demonstrate high-sensitive vibrational CD spectroscopy of alanine enantiomers, the smallest chiral amino acid. Under linearly polarized excitation, the metasurface consisting of an array of staggered Au nano-rods selectively produces the left- and right-handed super-chiral fields at 1600 cm^{-1}, which spectrally overlaps with the functional group vibrations of alanine. In the Fourier-transform infrared spectrometer measurements, the mirror symmetric CD spectra of D- and L-alanine are clearly observed depending on the handedness of the metasurface, realizing the reliable identification of small chiral molecules. Our approach demonstrates a high-sensitive vibrational CD spectroscopic technique, opening up a reliable chiral sensing platform for advanced infrared inspection technologies.

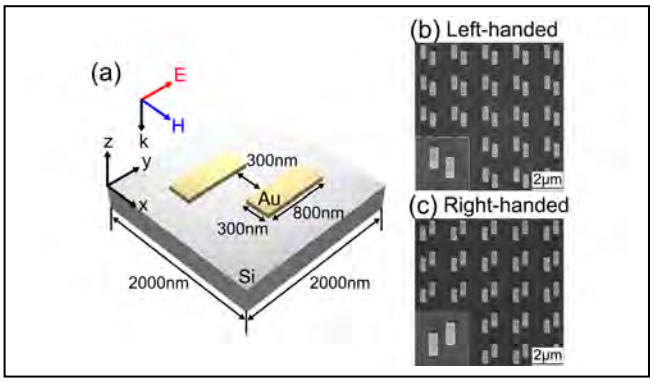

Fig. 1 Design and fabrication of the metasurfaces. (a) Schematic unit cell of a metasurface consisting of an Au nano-rod pair with a longitudinal displacement. SEM images of the fabricated (b) left- and (c) right-handed metasurfaces.

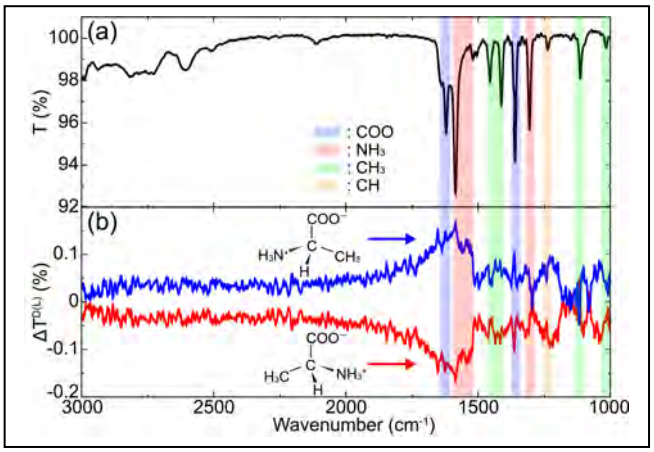

Fig. 2 Super-chiral vibrational spectroscopy in the metasurfaces. (a) Transmission spectrum of L-alanine on a bare Si substrate, exhibiting typical vibrational absorptions of the functional groups, COO, NH3, CH3, and CH. (b) Differential transmission spectra of D- (red) and L-alanine (blue) on the metasurfaces, showing the mirror symmetric spectral responses.

(3) Members as of March, 2021

(Chief Scientist)
Takuo Tanaka

(Visiting Scientist)
Takaaki Yano, Che-Chin Chen, Renilkumar Mudachathi,

(Student Trainee)
Shohei Maekawa, Kumiko Koide, Taichi Hara, Akari Kurata, Tomohisa Isegawa, Mahiro Horikawa, Shohei Katsumata, Yoshiki Oda, Satoko Yagi, Yuki Takeuchi, Masayuki Fujiwara, Shunki Sogawa, Jyun Kihara, Takuya Asakura, Hiroyuki Abe, Subaru Ito, Shun Matsuzawa, Shunki Yatabe

(Assistant)
Yi-Jung Liang

(4) Representative research achievements

1. "Whitish daytime radiative cooling using diffuse reflection of non-resonant silica nanoshells," T. Suichi, A. Ishikawa, T. Tanaka, Y. Hayashi, and K. Tsuruta, Sci. Rep. 10, 6486 (2020).
2. "Refractive index of nanoconfined water reveals its anomalous physical properties," T. Le, A. Morita, and T. Tanaka, Nanoscale Horizons **5**, 1016 (2020).
3. "Hot Carrier Generation in Two-Dimensional Silver Nanoparticle Arrays at Different Excitation Wavelengths under On-Resonant Conditions," Y. Takeuchi, A. Violas, T. Fujita, Y. Kumamoto, M. Modreanu, T. Tanaka, K. Fujita, and N. Takeyasu, The J. Phys. Chem. C **124**, 13936-13941 (2020).
4. "Super-chiral vibrational spectroscopy with metasurfaces for high-sensitive identification of alanine enantiomers," T. Iida, A. Ishikawa, T. Tanaka, A. Muranaka, M. Uchiyama, Y. Hayashi, and K. Tsuruta, Appl. Phys. Lett. **117**, 101103 (2020).
5. "Realization of Negative Permeability in Vertical Double Split-Ring Resonators with Normal Incidence," H-Y. Tsai, C-C. Chen, T-A. Chen, D. P. Tsai, T. Tanaka, and T-J. Yen, ACS Photonics **7**, 3298-3304 (2020).

Laboratory Homepage
https://www.riken.jp/en/research/labs/chief/metamaterials/index.html
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