■ Research Highlights

Infrared spectroscopy: Nanostructured metamaterials identify the chemical nature of tiny molecules

Infrared (IR) absorption spectroscopy plays a central role in materials and life sciences and security detection for the direct analysis of molecular fingerprints, including molecular structures, composition, and environment.

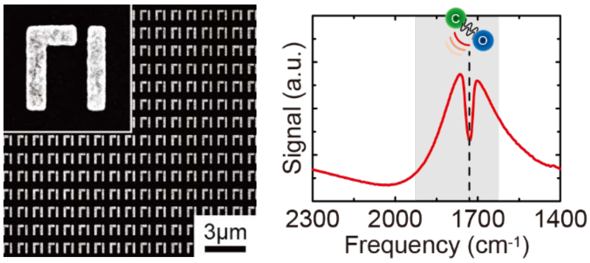

Fig.1. Researchers at Okayama University have created a new IR spectroscopic technique utilizing an engineered metamaterial to enhance the signal quality. Trials on a polymer nano-film showed a distinct IR absorption at the zeptomole level, corresponding to a few thousand organic molecules.

However, IR inspection of extremely small amounts of molecules is challenging due to background IR noise, hence there is a high demand for enhancing the signal quality of this technique.

Now, Atsushi Ishikawa and Kenji Tsuruta at Okayama University, in the collaboration with RIKEN, Japan, have developed a novel metamaterial—an engineered optical material— to manipulate IR light in the desired manner. The metamaterial could then harness the unwanted background noise, thereby dramatically boosting the ultimate sensing capability of IR spectroscopy.

The researchers came up with a unique asymmetric metamaterial design, made of 20 nm gold films on a silicon substrate (Fig.1) to rotate the polarization, that is the orientation of IR wave oscillations, during measurements. In this way, the molecules attached on the metamaterial showed different polarization from the others, and the researchers were able to detect only the target molecular signal by totally eliminating the unwanted background light.

The capabilities of the new metamaterial were tested by identifying the vibrational stretching of carbon-oxide double bonds in a poly(methyl methacrylate) (PMMA) nano-film. The measurement showed a distinct IR absorption of carbon-oxide stretching, achieving zeptomole sensitivity with a dramatically enhanced signal quality (Fig.1).

The new metamaterial approach developed by the team enabled highly-detailed IR measurements of tiny molecules at the zeptomole level, corresponding to a few thousand organic molecules. The researchers expect their new technique will open doors to the development of ultrasensitive IR inspection technologies for sophisticated applications, such as environmental monitoring and analysis of human breath for diagnostics.

Reference

Authors

Atsushi Ishikawa, Shuhei Hara, Takuo Tanaka, Yasuhiko Hayashi, and Kenji Tsuruta

Title of original paper

Cross-polarized surface-enhanced infrared spectroscopy by Fano-resonant asymmetric metamaterials

Journal

Scientific Reports **7**, 3205 (2017).

Digital Object Identifier (DOI)

10.1038/s41598-017-03545-8

Journal website

http://www.nature.com/articles/s41598-017-03545-8

Affiliations

Department of Electrical and Electronic Engineering, Okayama University.

Department website

http://www.ec.okayama-u.ac.jp/~mdd/index.html