Optical biosensing through a toy microscope over a surface 'rainbow' chip

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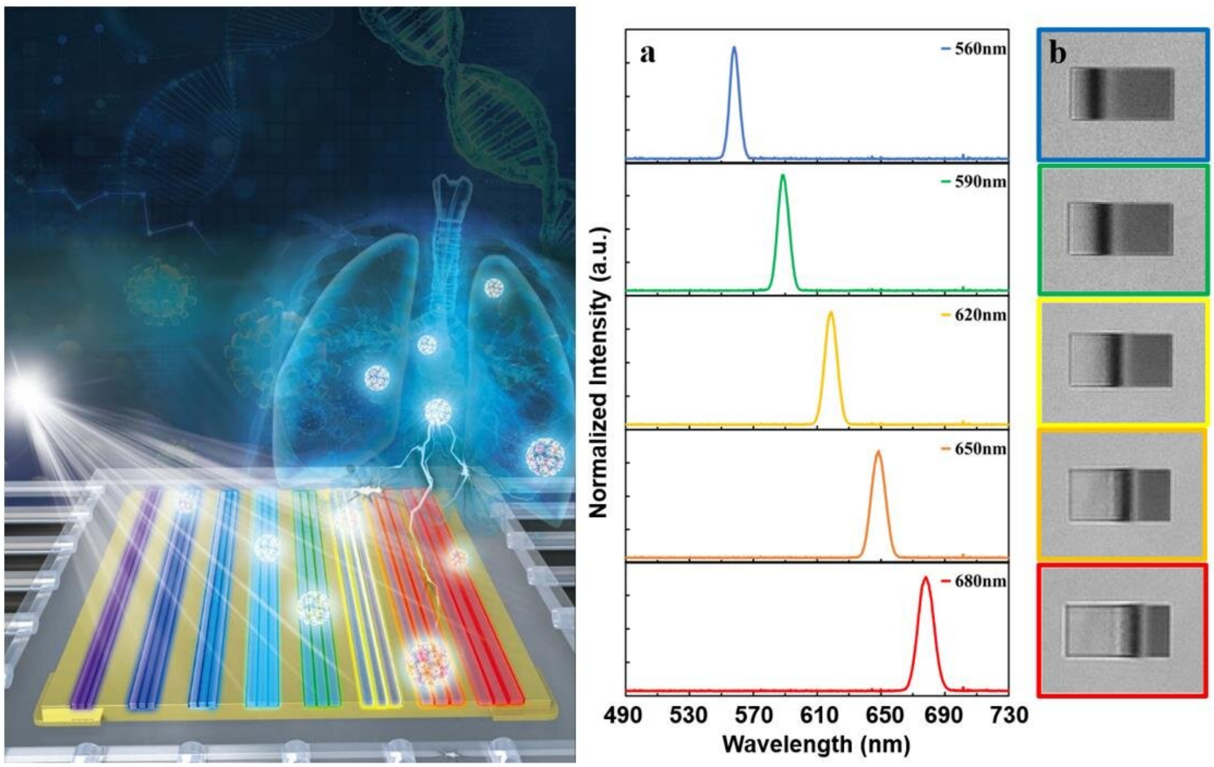

Schematic diagram of the rainbow trapping metasurface used in lung cancer diagnosis (left) and trapped "rainbow" localization images for spectral analysis observed by a 4× objective lens (right). Credit: Qiaoqiang Gan

The global spread of COVID-19 has highlighted the importance of rapid, accurate, and easy sensing of viruses and diseases. Recently, researchers have been exploring on-chip sensing technologies to tackle these emerging challenges. More and more health care monitoring functionalities are being integrated with wearable devices, including personalized sensing devices that can be implemented in one's daily life.

New research led by engineers at King Abdullah University of Science and Technology (KAUST of Saudi Arabia) and the State University of New York at Buffalo (University at Buffalo, U.S.) makes significant progress along this direction. The system is constructed by a graded surface nanograting with the period changing from 300 nm to 500 nm. Under the illumination of LEDs or lasers, one can see a dark bar in the reflection image (as illustrated in the image).

The spatial location of the dark bar is determined by the incident wavelength, that is, different incident wavelength will result in different dark bars at different positions within a 30 µm × 64 µm area (smaller than the cross-sectional area of a hair). Therefore, this phenomenon is called "rainbow" trapping on a chip. When biomolecules bind to this chip, the location of the dark bar will shift spatially, enabling the direct observation of these surface bindings.

"Rainbow trapping of light is an intriguing on-chip slow light phenomenon, which was first reported in 2007 based on negative refractive index metamaterials. However, to trap a real rainbow rather than a single wavelength, broadband negative refractive metamaterial is required. This type of material has not been realized to date," says Gan, the leading author of this work, a Professor of KAUST.

"My group demonstrated this fundamentally intriguing phenomenon using graded surface gratings and validated it using experiments. Now, we filled the gap in applications using the trapped 'rainbow' chip."

Importantly, using a 4× microscope (a low setting that can easily be realized using a toy microscope and portable cell-phone-based microscope), a wavelength shift of 0.032 nm was observed, indicating the spectroscopic analysis capability using this miniaturized chip, which is equivalent to the performance of conventional expensive fiber-based or diffraction-grating-based desktop spectrometers.

This team prepared a 2 × 2 array of the "rainbow" sensor unit on the same chip and performed a high throughput sensing of exosomal epidermal growth factor receptor (EGFR), which is a promising circulating biomarker for lung cancer diagnosis.

"The most attractive feature is that the sensitive sensing was realized using an inexpensive optical microscope system," says another leading co-author, Dr. Yun Wu, an associate professor of biomedical engineering at University at Buffalo. "The sensing results distinguished lung cancer patients from healthy controls, which is equivalent to conventional techniques. But our current rainbow chip system is much simpler and more cost-effective, and can be integrated with future smart phone systems."

The research was published in *Engineering*.

More information: Lyu Zhou et al, Super-Resolution Displacement Spectroscopic Sensing over a Surface "Rainbow", *Engineering* (2022). DOI: 10.1016/j.eng.2022.03.018

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