Metasurface-enhanced multiplexed nanospectroscopy and molecular diagnostics

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Metamaterials or metasurfaces – materials that are engineered to have properties that are not found in natural materials – allow us to overcome physical limitations. Metasurface science is further not only expanding field of optics and photonics by providing ultra-compact and multifunctional flat optical devices, also resolves challenging problems in diverse sectors like healthcare, optical display, imaging, and military affairs. In this talk, I will introduce metasurface-enhanced multiplexed nanospectroscopy and molecular diagnostics.

Obtaining single molecular level fingerprints of biomolecules and electron transfer dynamic imaging in living cells are critically demanded in postgenomic life sciences and medicine. However, the possible solution called Plasmonic Resonance Energy Transfer (PRET) spectroscopy remains challenging due to the fixed scattering spectrum of a plasmonic nanoparticle and limited multiplexing. Here, we report multiplexed metasurfaces-driven PRET hyperspectral imaging to probe biological light-matter interactions. We first design pixelated metasurfaces with engineered scattering spectra over the entire visible range by the precision nanoengineering of gap plasmon and grating effects of metasurface clusters. We create pixelated metasurfaces and optically characterize its full darkfield coloration with visible color palettes and high-resolution color printings. Furthermore, we apply three different biomolecules on metasurfaces for color palettes to obtain selective molecular fingerprint imaging due to the unique biological light-matter interactions with application-specific biomedical metasurfaces.

Polymerase chain reaction (PCR) is now a gold standard for nucleic acid amplification applied in various areas including molecular diagnosis, genotyping, and gene expression analysis. However, due to the widespread of pandemic diseases, the demand for portable PCR devices for point-of-care (POC) diagnostics has drastically increased. Here, we introduce a low-power-consuming PCR device composed of a meta-absorber that can rapidly go through thermocycling steps using single IR LED. The ultrafast thermalization time (~0.15 ps) of the titanium nitride enables the rapid heating and cooling of the meta-absorber by the photothermal effect. The meta-absorber is fabricated using multiple colloidal lithography patterning which enables a large-scale fabrication with low cost. In addition, we demonstrate an ultrafast photonic RT-PCR with 30 thermocycles from 65 ℃ (annealing temperature) to 95 ℃ (denaturation temperature) achieving 23.08 ℃Cs-1 heating rate and 4.52 ℃Cs-1 cooling rate. Overall, the low power consumption and highly efficient photothermal effect of our meta-absorber demonstrate that metasurface can be used for ultrafast RT-PCR for POC molecular diagnostics.

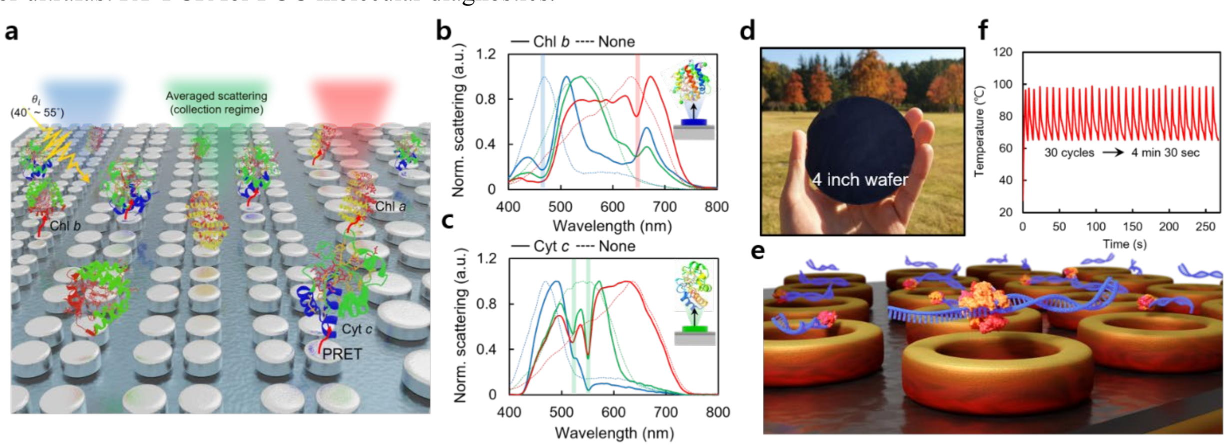

Fig. 1 (a-c) Metasurface-enhanced multiplexed nanospectroscopy, or Meta-PRET. (a) Schematic of Meta-PRET. (b, c) PRET measurement of chlorophyll b and cytochrome c using metasurfaces. (d-f) Metasurface-enahnced molecular diagnostics, or Meta-PCR. (d) Wafer-scale metamaterial perfect absorber for photonic PCR. (e) Schematic of Meta-PCR. (f) Experimental demonstration of ultrafast thermal cycling.