Photo Thermoelectric Effect Triggered by Local Heat under Localized Surface Plasmons

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Heat generation in metallic nanostructure under plasmon is known as plasmonic local heat, and it has been utilized in various applications, for example, cancer therapy, photohermal chemistry, nanowire growth, and so on [1]. G. Baffou et al. reported that Au single nanoparticle generates local heat about 90 K under the light irradiation of 100 mW/cm^2 [2]. These facts indicate plasmonic nanostructures will be effective nano-heaters.

We came up the idea to utilize the plasmonic local heat as a photo-detector. Here, we propose to combine the local heat of plasmon and the thermoelectric conversion to realize the photo thermoelectric device as a novel photo detector. We expected that the plasmonic local heat under light irradiance would induce a heat distribution in a themoelectric material, resulting in a current flow based on the Zeebeck effect.

In order to detect the current induced by plasmonic local heat, we used poly (3, 4-ethylenedioxythiophene): poly (4-styrenesulfonate) (PEDOT:PSS) as a thermoelectric material. Silver (Ag) nanorod arrays with a periodicity of 300 nm were fabricated on a glass substrate by electron beam lithography. Their long- and short-axis are 180 and 105 nm, respectively. The Ag nanorod arrays were located at the one side of the glass substrate and a PEDOT:PSS thin film was uniformly formed on a glass substrate by spin-coating. The film thickness of the PEDOT:PSS was around 100 nm. Finally, we formed Ag electrodes on the both edges of PEDOT:PSS thin film and fabricated a photo-thermoelectric device triggered by the local heating effect as shown in Fig. 1(a). We irradiated polarized monochromatic light to the Ag nanorod arrays to excite the plasmon resonance, and measured the electric current generated in the PEDOT:PSS thin film.

Figure 1(b) shows a comparison of the Ag nanorod transmission spectrum under short-axis polarization with the measured electric current. The short-axis plasmon resonance wavelength of the Ag nanorod was 623 nm, implying the local heat will be generated in the Ag nanorod and transferred to the surrounding PEDOT:PSS at the wavelength. We expected the plasmonic local heat will create temperature distributions in the PEDOTPSS film, resulting in electric currents between the two electrodes of PEDOT:PSS owning to Seebeck effect.

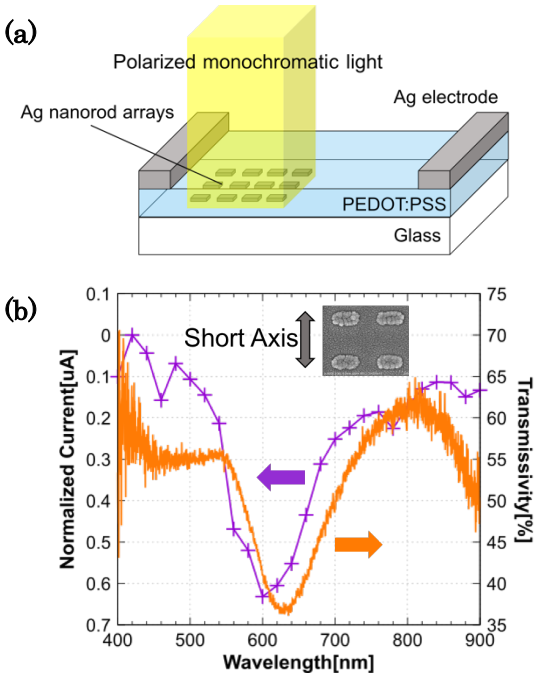

Fig. 1 (a) Schematic of the fabricated photo thermoelectric device, and (b) measured transmissivity of Ag nanorod arrays (orange) and wavelength dependence of photocurrent (purple) of PEDOT: PSS thin film.

As a result, the measured electric current in Fig. 1(b) recorded the maximum value at 600 nm, which is close to the short-axis plasmon resonance of the Ag nanorod. Furthermore, the wavelength dependence of the electric current showed similar tendency to the transmission spectrum of the Ag nanorod. These results suggest that the local heat of the Ag nanorod under plasmon is a driving force to created electric current flows in the film. We concluded the photo thermoelectric effect triggered by plasmon local heat was realized, and expect this phenomenon will be applied for photo detector.

References

[1] M. L. Brongersma, N. J. Halas, and P. Nordlander, "Plasmon-induced hot carrier science and technology," *Nat. Nanotech.*, **10**, 25-34(2015).
[2] G. Baffou, P. Bon, J. Savatier et al., "Thermal Imaging of Nanostructures by Quantitative Optical Phase Analysis," *ACS Nano*, **6**, 2452-2458(2012).