Hole Array Perfect Absorbers for Spectrally Selective Midwavelength Infrared Pyroelectric Detectors

Thang Duy Dao[1,2], Satoshi Ishii[1,2], Takahiro Yokoyama[1,2], Tomomi Sawada[1,2], Ramu Pasupathi Sugavaneshwar[1,2], Kai Chen[1,2], Yoshiki Wada[1], Toshihide Nabatame[1,2], and Tadaaki Nagao[1,2,3]

[1]International Center for Materials Nanoarchitectonics, National Institute for Materials Science (NIMS), 1-1 Namiki, Tsukuba, Ibaraki 305-0044, Japan; [2]CREST, Japan Science and Technology Agency, 4-1-8 Honcho, Kawaguchi, Saitama 332-0012, Japan; [3]Department of Condensed Matter Physics, Graduate School of Science, Hokkaido University, Kita 8, Nishi 5, Kita-ku, Sapporo 060-0810, Japan.
*Emails: Dao.Duythang@nims.go.jp, NAGAO.Tadaaki@nims.go.jp

1. Introduction

Uncooled pyroelectric infrared sensors are widely used in many applications ranging from infrared spectroscopy to thermal imaging because they exhibit fast and wide spectral response with high sensitivity and robustness, low costs and room temperature operation. To realize high performances as well as making them more industry compatible, besides focusing on the development of pyroelectric materials, the structural design has been intended to efficiently absorb the thermal radiation, especially at desired wavelengths in which their spectrum responses can exhibit the wavelength selectivity for such applications in infrared spectroscopy and multicolor infrared imaging. In this work, by taking advantage of the spectrally-selective and efficient light-heat conversion of plasmonic hole array perfect absorber, integrated with a highly *c*-axis oriented hexagonal ZnO film crystal, we demonstrate an efficient design for wavelength-selective pyroelectric infrared detectors [1].

2. Results and discussion

The schematic design of the perfect absorptivity pyroelectric detector (PA-PIR) is shown in Fig. 1a. The parameters of the predesigned PA-PIRs were optimized using the numerical electromagnetic simulation and then the devices were fabricated by colloidal-mask lithography combined with reactive-ion etching process [1].

Figures 1b-d, from top to bottom panels, present simulated absorptivity spectra, measured absorptivity spectra and spectral responsivity curves, respectively, of the three devices S1 (Fig. 1b), S2 (Fig. 1c) and S3 (Fig. 1d) with different resonant peak positions and intensities. The measured absorptivity spectra are in good agreement with the simulated absorptivity spectra. The resonances of PA-PIRs can be tuned from a dual-band PA-PIR at 3.86 μm and 5.24 μm (S1) to a nearly single-band PA-PIR at 3.66 μm (S3). The responsivity curves of the three fabricated devices are perfectly reflecting their absorptivity spectra, which have evidenced that the pyroelectric ZnO films are effectively heated when the infrared light was resonantly absorbed by the PAs.

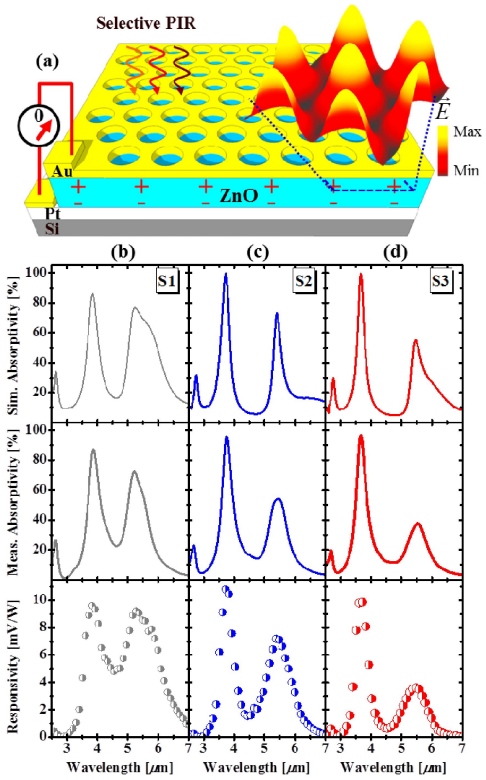

Figure 1. (a) Schematic illustration of the proposed PA-PIR. Performance of the three fabricated PA-PIRs: (b) S1; (c) S2 and (d) S3. From top to bottom: simulated absorptivities, measured absorptivities and spectral responsivity curves of the three devices.

3. Conclusions

We have demonstrated a compact design of wavelength-selective MWIR pyroelectric detectors which can be realized by a facile fabrication process of colloidal-mask lithography combined with reactive-ion etching. The responses of PA-PIRs show excellent selectivity and controllability. The design demonstrated here can also be applied for other types of infrared detector such as photoconductive or thermoelectric sensors.

References

[1] T. D. Dao, S. Ishii, T. Yokoyama, T. Sawada, R. Sugavaneshwar, K. Chen, Y. Wada, T. Nabatame, T. Nagao, ACS Photonics, DOI: 10.1021/acsphotonics.6b00249.