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Plasmonic Hole Array Perfect Absorbers for Wavelength-Selective Infrared Pyroelectric Detectors

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Abstract

We propose an efficient design of trilayered Au hole - insulator – Pt plasmonic perfect absorbers exploiting a highly *c*-axis oriented hexagonal ZnO film crystal as an insulator for uncooled wavelength-selective infrared pyroelectric detectors.

1. Introduction

Uncooled pyroelectric infrared sensors are widely used in many applications ranging from infrared spectroscopy to thermal imaging because it possesses such advantages as 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 industrial compatible, besides focusing on 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 as non-dispersive infrared spectroscopy (NDIR) and multi-color infrared imaging. In this work, by taking advantage of the spectrally-selective light-heat conversion of perfect absorbers, combined with a highly *c*-axis oriented hexagonal ZnO film crystal, we propose an efficient design for wavelength-selective pyroelectric infrared detectors. [1]

The plasmonic perfect absorber based pyroelectric infrared sensor (PA-PIR) composes of a *c*-axis oriented textured ZnO film as a pyroelectric material, sandwiched between a Pt film and a Au film patterned with a hexagonal array of micro-holes. The optical property of ZnO film is retrieved by the spectroscopic ellipsometry for the numerical electromagnetic simulations based on the rigorous coupled-wave analysis to optimize the geometry parameters. A scalable fabrication technique of colloidal-mask lithography combined with reactive etching process is used to realize the predesigned PA-PIRs [2]. By tuning the diameter of Au hole, we demonstrate the wavelength-selective property of the proposed PA-PIRs. The design demonstrated here can also be easily applied for other infrared selective sensing devices such as photoconductive or thermoelectric sensors.

2. Results and discussion

Our proposed PA-PIR is illustrated in Fig. 1a where a hexagonal array of plasmonic Au hole and bottom Pt film is insulated by a ZnO layer. The thicknesses of Au hole array and Pt films are fixed at 0.1 µm and 0.2 µm, respectively. The diameter - *d*, the periodicity - *p* of Au hole array, and the thickness - *t* of the ZnO film and the periodicity - p of Au hole array were optimized using the RCWA simulation to have a perfect absorptivity in the range of 3 - 7 µm (MWIR region). By controlling the thickness of the ZnO layer, nearly perfect absorptivity at these resonant modes can be achieved. The resonance of the PA-PIR can be tuned by changing the ZnO thickness – t, periodicity – p or the diameter of Au hole – d (Fig. 1b). Here we focus on the tunability of the PA-PIR by changing the diameter of Au hole – d whereas the ZnO thickness – t and periodicity – p were fixed at 0.68 µm and 3.0 µm, respectively.

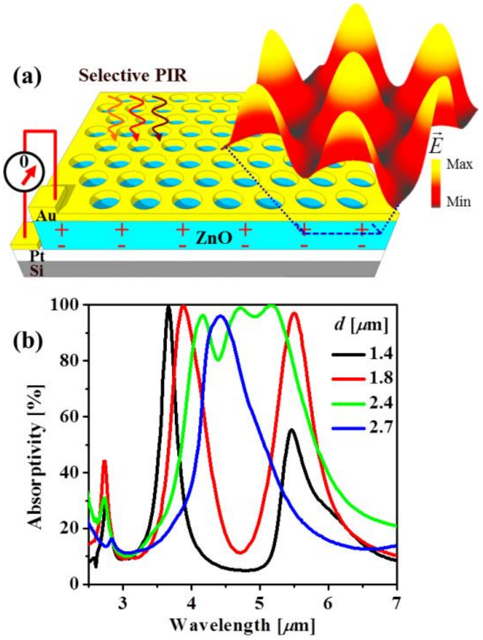

Fig. 1 (a) A schematic diagram of the PA-PIR with definition of geometrical parameters: periodicity - *p*, Au hole diameter - *d* and pyroelectric ZnO thickness - *t*. (b) Simulated absorptivity spectra of PA-PIRs show the tunability by tuning Au hole sizes (1.4, 1.8, 2.4 and 2,7 µm) whereas the periodicity and the ZnO thickness are 3.0 µm and 0.68 µm, respectively for all the four samples.

The PA-PIRs were fabricated by colloidal-mask lithography combined with RIE process. We fabricated three PA-PIR devices with different diameters; S1 with largest Au hole size (d = 1.9 μm), S2 (d = 1.6 μm) and S3 (d = 1.4 μm). Fig. 2 reveals a set of the spectra taken from the three fabricated PA-PIR devices, including absorptivity spectra and spectral responses. As seen from the results, when the Au hole size decreases, the short-wavelength resonance is gradually blue-shifted with a relatively increased absorptivity, whereas the long-wavelength resonance is red-shifted with a relatively decreased absorptivity. All three devices exhibit excellent spectral responses which are effectively embodied by the designed wavelength-dependent absorptivities of the PAs.

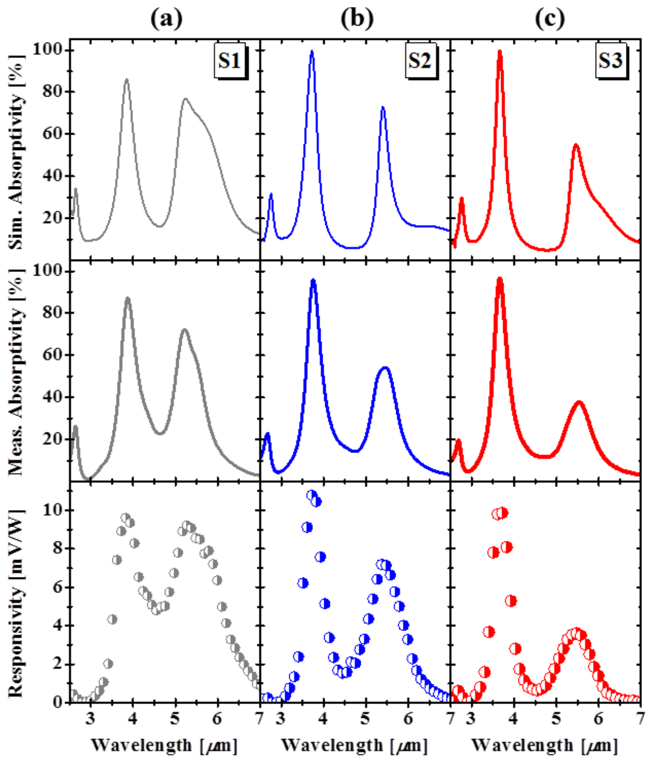

Fig. 2 Performance of three fabricated PA-PIRs: (a) S1; (b) S2 and (c) S3. From top to bottom: simulated absorptivity spectra, measured absorptivity spectra and spectral responsivity curves of three devices.

3. Conclusions

We demonstrate a simple design and facile fabrication process to realize low-cost, wavelength-selective pyroelectric MWIR detectors. The PA-PIRs were systematically designed to have narrowband and spectrally selective perfect absorptivity in the MWIR region to demonstrate effective integration with pyroelectric ZnO films. The resonances of PA-PIRs show excellent controllability by tuning the diameter of the holes in the top Au electrodes and also yield high sensitivity without having any thermal isolation. The design demonstrated here can also be easily applied for other infrared selective sensing devices such as photoconductive or thermoelectric sensors.

References

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