Infrared Phase-Change Meta-Devices with In-Situ Switching

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ABSTRACT

We describe a possible device design approach and an experimental test platform suitable for the realization and characterization of phase-change based meta-devices incorporating in-situ switching and operating at infrared wavelengths. Measurements on such a prototype device working at 1.55 μm are presented.

Keywords: Meta-material, meta-devices, phase-change optoelectronics

1. INTRODUCTION AND METHODOLOGY

Phase-change meta-devices (i.e. devices that combine optical metasurfaces with a switchable phase-change layer to deliver novel optoelectronic functionality) working in the infrared wavelengths have many potential and important applications ranging from infrared detection and imaging to spatial light modulators, holography, beam steering and much more [1-3]. However, in most work to date, the phase-change layer in such meta-devices is switched using ex-situ excitation, e.g. via the use of an external laser. This is in part due to the fact obtaining uniform switching of the relatively large areas/volumes of phase-change material intrinsic to most infrared meta-device designs is difficult using direct electrical switching approaches (i.e. using similar methods to that used in phase-change memory device applications). An alternative switching approach is therefore required. In Fig. 1(a) we present one possible design. Here a metallic bottom electrode is patterned into a bowtie shape with a constriction in the centre. Electric pulses are applied to the two ends of the bowtie to resistively heat up the central region, so causing the phase-change layer deposited on the top of the electrode to be thermally switched between crystalline and amorphous states. Metallic plasmonic resonators deposited (and patterned) on top of the phase-change layer provide the desired meta-device response. Thus, an electrically controlled meta-device with in-situ switching of the phase-change layer is realised.

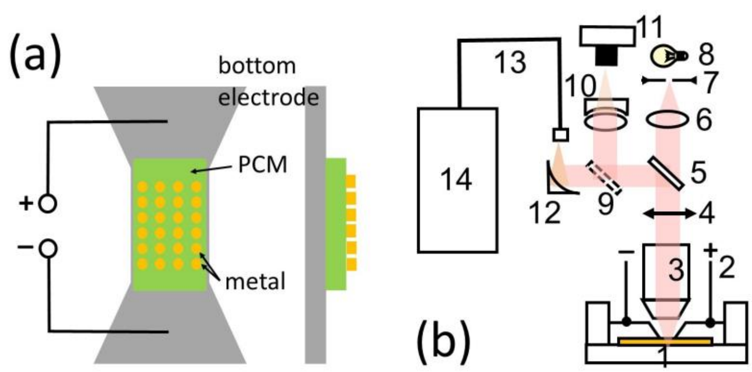

Figure 1 . (a) Illustration of the proposed meta-device with in-situ switching: Top view (left) and side view (right). (b) Experimental test platform to characterize the proposed infrared meta-device. (1) Sample, (2) electrical connection, (3) objective, (4) polarizer, (5) beam splitter, (6) lens, (7) pinhole, (8) tungsten bulb, (9) removable mirror, (10) achromatic doublets lens, (11) infrared camera, (12) parabolic mirror, (13) fiber optics and (14) spectrometer.

Figure 1(b) illustrates the experimental setup utilized to test the above proposed meta-devices. The device (1) is electrically connected (2) through fast RF probes. Infrared light from a tungsten source (8) is focused on the device. The reflected light is directed to a spectrometer (14).

2. RESULTS

A metallic micro-bridge heater of the form shown in Fig. 1(a) and capped with phase-change material has been fabricated, as shown in Fig. 2(a). Electrical pulses applied to the micro-bridge lead to cycling of the phase-change material between amorphous and crystalline states, as shown in Fig. 2(a) to 2(e).

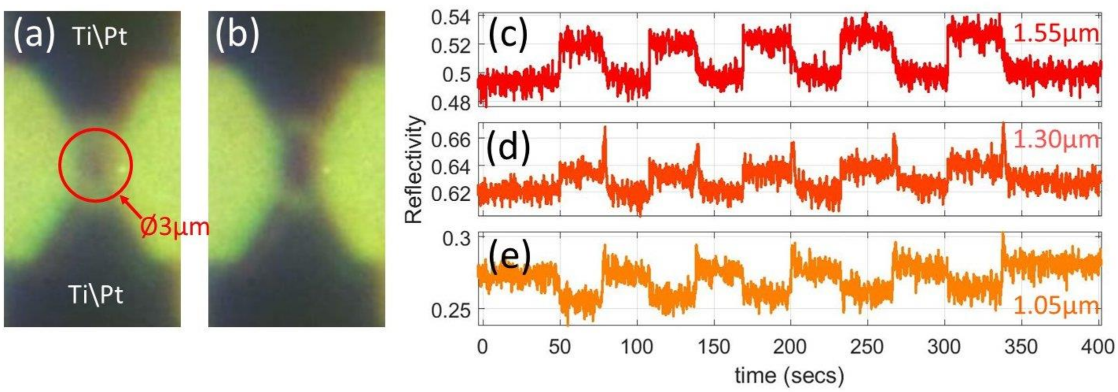

Figure 2 (a) and (b) Optical micrograph of the Ti\Pt micro-bridge device with the phase-change layer in the (a) crystalline and (b) amorphous states. (c) to (e): Infrared reflectivity at 1.55, 1.30 and 1.05 μm respectively as the phase-change layer is switched in-situ through several cycles.

3. CONCLUSIONS

We have demonstrated the detection of a modulated infrared reflectance in a configuration suitable for phase-change meta-devices with in-situ switching using a micro-bridge heater type approach.

4. ACKNOWLEGEMENTS

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