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Development of an optoelectronic test station for novel phase-change device characterisation and develpoment

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ABSTRACT

Optoelectronic applications of phase-change devices are of increasing interest and importance. To enable the proper experimental characterisation of device optoelectronic properties, and to allow for the future development of device designs with improved optoelectronic performance, we have constructed an optoelectronic test station that can simultaneously measure the optical and electrical properties of phase-change devices with high optical resolution and with high electrical bandwidths. The design of this test station, and some preliminary test applications are described.

Key words: Phase-change optoelectronics, optoelectronic probe station.

1. INTRODUCTION

Traditional applications of phase-change materials and devices have been confined to the purely optical mode (e.g. re-writable optical discs) or to the purely electrical mode (e.g. phase-change memories, or PCMs). However, exploiting both modes simultaneously has recently become of interest since it can deliver entirely new optoelectronic-type phase-change applications, such as phase-change displays [1], integrated phase-change photonics [2] or phase-change meta-photonics [3]. To properly characterise and exploit such optoelectronic modes (illustrated in concept in Fig. 1(a)), we have developed a device test station (see Fig. 1(b)) that can simultaneously measure properties in both the optical and electrical domains.

2. EXPERIMENTS

The test station (see Fig. 1(b)) combines long working distance objective lenses, fast laser sources and photodetectors, low-profile RF electrical probes, ultra-fast digital oscilloscopes and precision scanning sample stages to provide a combination of high resolution optical imaging, ultra-fast laser excitation and ultra-wide bandwidth (ultra-fast) electrical excitation/measurement. We have used this test station to carry out a number of interesting optoelectronic investigations of phase-change devices, including, for example, the optical switching of phase-change crossbar cells (as a precursor to the possible development of optically-gated electrical switches) and the optical visualization of the thermal switching of phase-change cells (as possibly used for RF switches – [4])

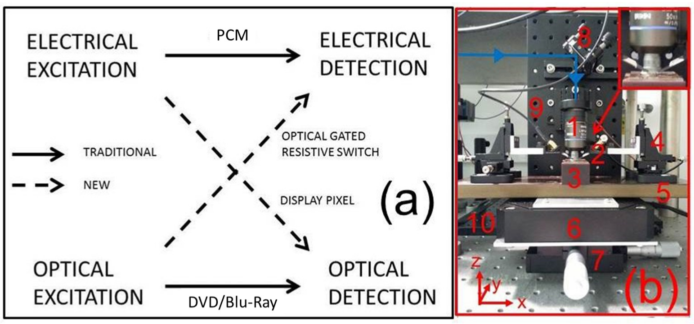

Figure 1: (a) Illustration of optoelectronic possibilities in phase change devices. (b) Photograph of the optoelectronic probe station: (1) Objective, (2) picoprobe, (3) sample, (4) micro-stage, (5) support stage, (6) lateral piezo stage, (7) lateral manual stage, (8) mirror, (9) vertical breadboard, and (10) horizontal sliding platform.

3. RESULTS & DISCUSSION

Phase-change crossbar cells having a cross-sectional area of 100×100 nm^2 were fabricated using e-beam lithography. A 30 nm thick ITO layer was used as the top electrode so as to allow for both electrical and optical access (other device details can be seen in Fig. 2). The cell was set into the crystalline state, in which it demonstrated a conductance of roughly 30 µS (~ 33 kΩ). It was then excited by a 405 nm laser pulse having a duration of 20 ns and power of 13 mW. During, and immediately after, the application of the laser pulse the cell conductance was monitored; it exhibited an initial transient increase (due to the photothermal effects) followed by a rapid decrease on termination of the pulse (Fig. 2). We estimate the cooling rate from the conductance/time response and, at its maximum, the cooling rate was several tens of degrees per nanosecond, fast enough for the cell to quench into the amorphous state, as confirmed by the final low value of the measured conductance.

As another example of novel measurements that can be made using our custom-built test station, we show in Fig. 3 the optical imaging and reflectance monitoring of a thermally-switched phase-change device (as might be used for phase-change RF switch applications [4]). The device consists of a pair of tungsten electrodes connected by a micro-bridge in the centre (see Fig. 3(a)) and coated with a 15 nm thick GST film covered by 200 nm of SiO_2. The GST layer can be switched between amorphous and crystalline states by simple thermal conduction as the micro-bridge is electrically (Joule) heated using electrical excitation pulses applied to the tungsten electrodes. The switching is revealed as a change in contrast of the phase-change layer lying directly on top of the micro-bridge, as evidenced in Fig. 3(b).

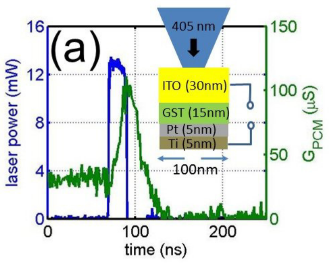

Figure 2: (a) A RESET laser pulse is applied to a 100×100 nm^2 crossbar cell while recording device conductance

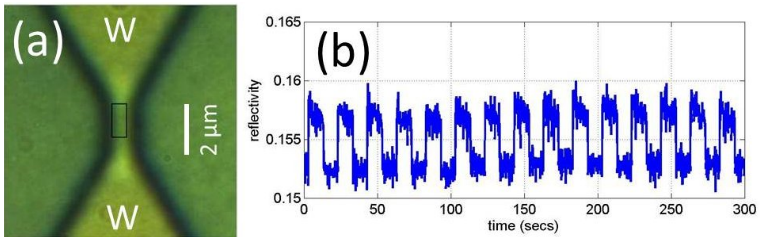

Figure 3: (a) Optical image of the thermal switch device. (b) Reflectivity of the area inside the black rectangle in (a), revealing repeated switching of the GST layer as a result of Joule heating of the micro-bridge by electrical pulses applied every 10 secs.

4. CONCLUSION

To investigate the optoelectronic potential of phase change devices we have constructed a versatile, high optical resolution, high electrical bandwidth optoelectronic probe station and demonstrated some of its capabilities using devices that might find applications in areas such as ultra-fast optically-gated switches and thermally-induced RF electrical switches.

REFERENCES

1. P Hosseini, C D Wright and H Bhaskaran, *Nature* 511, 206 (2014)
2. C Rios et al., *Nature Photonics* 9, 725 (2015)
3. B Gholipour et al., *Adv. Mater.* 25, 2050 (2013)
4. N. El-Hinnawy et al., *IEEE Trans. Electron Device Lett.* 34, 1313 (2013)