Towards A Phase-Change Metamaterial Subtractive CMY Display

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ABSTRACT

A phase-change based metal-insulator-metal metamaterial absorber structure is proposed for the creation of cyan, magenta and yellow (CMY) pixels that could provide the first steps towards the realization of a fast, non-volatile CMY-type subtractive display.

Key words: optoelectronics, metamaterial, display.

1. INTRODUCTION

Chalcogenide phase-change materials (such as $Ge_2Sb_2Te_5$ or, as used in this paper, GeTe) exhibit a large refractive index change when switched between their amorphous and crystalline phases. Such switching can be achieved by electrical, optical or thermal means, and is fast, reversible and non-volatile. These properties have recently been exploited to develop entirely new types of phase-change based reflective optoelectronic RGB-type displays based on a Fabry-Perot resonant cavity design [1]. Such displays can provide ultra-high resolution, ultra-fast frame rates and, since they are non-volatile, require no power to maintain an image.

In this paper we explore a possible alternative approach for the provision of phase-change based reflective displays, namely that based on subtractive colour generation. One of the first steps towards a subtractive approach is the development of cyan, magenta and yellow (CMY) pixels. To provide such CMY pixels we take advantage of recent advances in optical metasurfaces that allow us to control the amplitude and phase of reflected light via its interaction with arrays of metallic resonators [2]

2. RESULTS AND DISCUSSION

Our CMY display structure is formed by a layer of the phase-change alloy GeTe sandwiched between a bottom metal layer and a top ITO layer, on top of which is an array of lithographically-defined circular metal 'dots'. A unit-cell for such a structure is thus as shown in Fig. 1 (here with all metal parts shown as Al, though other metals may be used). The resonant frequency (wavelength) of such a structure was adjusted to produce the necessary CMY colour pixels (see Fig. 2) by changing the geometrical parameters that form the optical cavity, namely the size of the Al 'dot' and the thickness of the ITO layer. Our design also maximizes the coupling strength of the light incident on the device when the GeTe layer in the crystalline phase. However, when the GeTe layer is switched to the amorphous phase, the resulting change in refractive index decouples the cavity from its resonant absorption state, resulting in a relatively flat spectral response (i.e. it generates a 'white' reflectance spectrum when the GeTe is amorphous - see Fig. 2.

The high resolution, non-volatility, simplicity and low power consumption of our CMY subtractive colour approach has interesting possible applications in areas such as wearables, signage, security identifiers and e-paper.

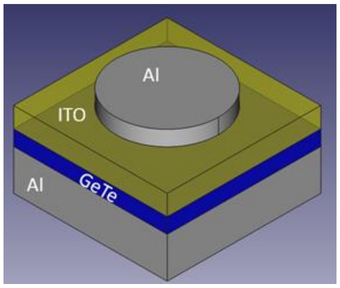

Figure 1 Unit-cell of the CMY phase-change pixel.

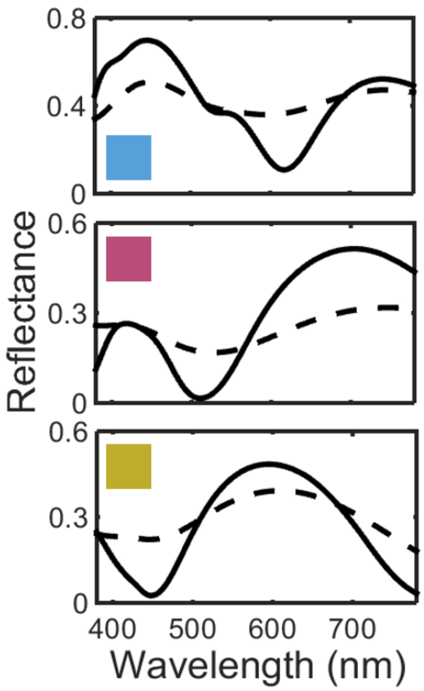

Figure 2 Reflectance spectra for pixels of the form shown in Fig. 1 and with the GeTe layer in the crystalline (solid lines) and amorphous (dashed lines) state; inset shows pixel colour (for GeTe crystalline) for the CIE Standard Illuminant D65.

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