Non-volatile Optoelectronic Phase-Change Meta-Displays

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Abstract-Phase-change materials have a pronounced contrast between their electrical and optical properties when in the amorphous to crystalline phases, and can be switched between these phases quickly and repeatedly by electrical or optical means. These characteristics have very recently been exploited to produce a novel form of non-volatile optoelectronic display technology. In this paper we combine such phase-change display devices with metamaterial arrays, so as to gain additional control over their spectral properties.

Chalcogenide phase-change materials, such as the ternary alloy germanium antimony telluride ($Ge_2Sb_2Te_5$, GST) used here, are well known for exhibiting a fast reversible change in their structure (from amorphous to crystalline) over a great number of cycles and resulting in a very considerable change in their optical (refractive index) and electrical (resistivity) properties between phases. This has made phase-change materials very attractive use in non-volatile optical and electrical memory applications [1]. However, in very recent times there has been much interest in the development of new functionalities for these remarkable materials, such as the exploitation of ultra-thin phase-change layers to deliver an entirely new form of non-volatile optoelectronic display [2], along with the combination of phase-change materials with metamaterial structures to provide tuneable/adaptable meta-devices, such as perfect absorbers and reflectarrays [3].

In this paper we combine ideas from metamaterial array design with that for a phase-change based optoelectronic display, with a view to providing more control over the purity of the colour spectrum produced by phase-change pixels. The basic structure for a phase-change display is shown in Fig.1(a), along with an example (reflection) image produced by such an approach (for further details see [2]). The proposed modification to this basic structure is the inclusion of a metamaterial array in the form of split-ring resonators embedded in the bottom ITO layer, as shown in Fig. 1(b) or in the form of metal strips patterned on top of the upper ITO layer (not shown). The effect of introducing the metamaterial arrays can clearly be seen in the reflectance spectra shown in Figs. 1(c) and (d); the inclusion of the metamaterial resonator structures leads to 'purer' colour spectra. Such reflectance spectra were here simulated using COMSOL Multiphysics, and photometric and colorimetric calculations and optimisations of various phase-change meta-display configurations, which will also be reported, were carried out using Matlab and Livelink for Matlab [4].

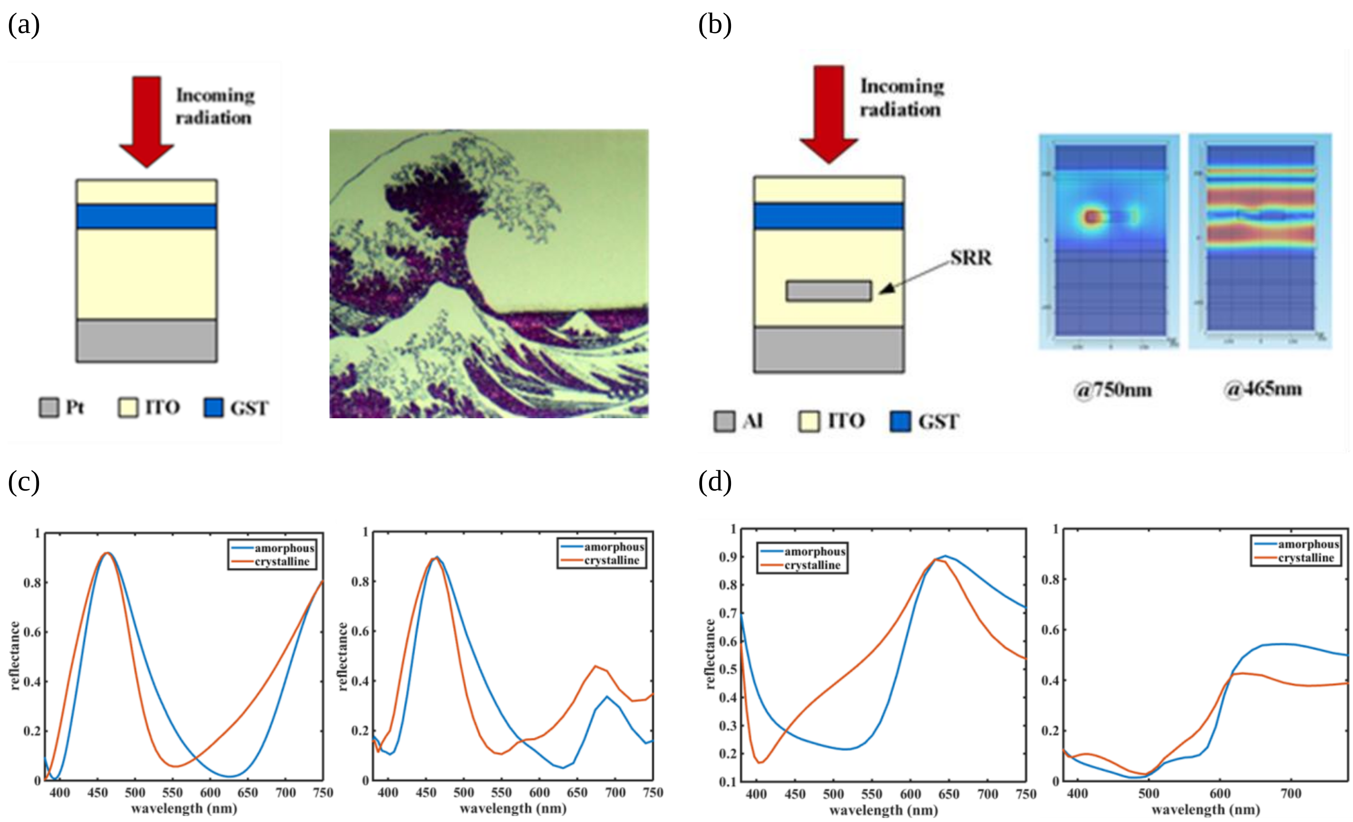

Figure 1. a) (left) Phase-change display device structure proposed in [2], formed by a platinum bottom mirror and a GST layer sandwiched between two ITO layers; (right) a high resolution (70x70 µm) image produced in such a structure. **b)** (left) Introduction of an embedded **s**plit ring resonator (SRR) array into the display structure and (right) electric field plot at the excitation wavelengths for maximum (750nm) and minimum (450nm) interaction of the resonance of the cavity with the SRR. **c)** Reflectance spectra with the GST layer in amorphous and crystalline phases for the photonic cavity without (left) and with (right) the SRR**.** A reinforcement in blue wavelengths in the reflectance spectra caused by the interaction of the plasmonic resonator with the standing wave can be observed. **d)** Reflectance spectra of the photonic cavity without (left) and with (right) an alternative metamaterial array structure consisting of patterned metal strips on top of the upper ITO layer; this structure attenuates blue wavelengths and preserve red wavelengths.

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