Bismuth-based gap-plasmon metasurfaces for visible photonics with volatile tuning potential.

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Gap-plasmon metasurfaces based on metal-insulator-metal (MIM) nanostructures have been extensively employed over the last years, as they provide a versatile design platform for local and/or global control of the amplitude, phase and polarisation of light from the visible to the THz domain [1]. However, current research in plasmonic metasurfaces lacks of good material building blocks, as the material choice is fundamentally limited to Ag, Au and Al [2]. Particularly in the visible spectrum, Ag and Al are the preferred (and the only realistic) option towards the development of MIM metasurfaces, as they suffer from lower plasmonic losses with respect to other metallic elements. Recently, bismuth-based nanostructures have been proved as an excellent material for plasmonics in the ultraviolet and visible [3, 4, 5]. However, its use in MIM metasurfaces for the visible spectrum remains largely unexplored. Furthermore, bismuth exhibits a relatively low melting temperature (~270 °C), with its solid-to-liquid phase transition being accompanied by significant changes in its permittivity function [6]. This potentially paves the way for active plasmonics [7].

In this work, we will demonstrate the use of bismuth for the design of MIM metasurfaces at visible wavelengths towards the development of highly efficient, and high purity structural colour generators. The basic metasurface unit cell structure is depicted in Fig. 1(a), where an ultrathin SiO_2 layer is sandwiched between a continuous Bi plane and a Bi nanodisk. The whole structure is encapsulated with an ultrathin Al_2O_3 layer. Via proper optimisation of the geometrical parameters (namely disk radius, SiO_2 thickness and unit cell period), we can create a set of high purity and high efficiency colours such as magenta (Fig. 1(b)) and yellow (Fig. 1(c)). This can be readily achieved via excitation of super absorption resonances at the wavelength bands corresponding to green and blue (i.e. the complementary colours for magenta and yellow respectively).

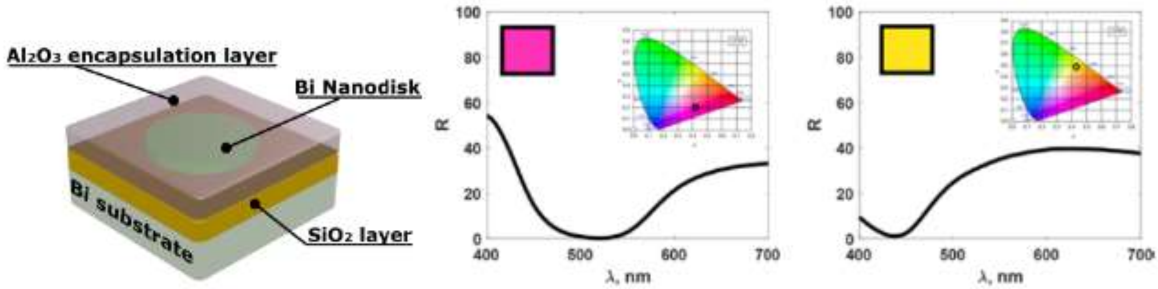

Fig. 1 (a) Schematics showing the nit cell structure of our bismuth based MIM metausrfaces. **(b-c)** Reflectance spectra for bismuth MIM metasurfaces optimised to produce **(a)** Magenta, and **(b)** Yellow. Insets show colorimetry calculations employing the D65 illuminant.

The metasurfaces will be fabricated using standard microfabrication processcombining pulsed laser deposition, sputtering and lithography techniques. In addition, we will show how the solid-to-liquid phase transition of bismuth (previously encapsulated by Al_2O_3) can be exploited to change the reflectance spectra (thus colour appearance) of the as-designed structure. We believe the work presented herein opens a new way to alternative, cost-effective and reconfigurable visible plasmonics with potential applications in volatile tunable colour displays or visible multispectral imaging.

References

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