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Active narrowband filter based on 2.5D metasurface from Ge2Sb2Te5

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Abstract. We propose a new concept of an active narrowband filter based on a 2.5D metasurface from Ge2Sb2Te5 (GST). In this paper, we present a numerical calculation of the transmission spectrum from a structure of ellipsoids of revolution. For this 2.5D metasurface, modulation of narrow peaks in the IR range for s- and p-polarization is shown. A manufacturing technique using two-photon lithography and laser electrodispersion is proposed.

Introduction.

The phase transition between amorphous and crystalline state in the chalcogenide phase-change medium from germanium antimony telluride has long been used in rewritable optical storage discs [1]. During the last decade the possibility of using the chalcogenide materials for signal modulation by photonic metastructures in the optical range was demonstrated [2, 3, 4]. However, most available methods for fabrication such structures are not able to provide enough degrees of freedom to achieve a multifunctional response, which limit their efficiency. A possible solution is to combine a two-dimensional (2D) metasurface into a multilayer 2.5D structure [5, 6].

In this paper, we propose the concept of an active narrowband filter based on a 2.5D metasurface made of $Ge_2Sb_2Te_5$ (GST). For considered structures, numerical calculations were performed in the near-infrared spectral range, and the manufacturing procedure was presented.

1. Transmission spectra for 2.5D metasurfaces.

To obtain the reflection spectra, the commercial package CST Studio Suite 2020 was used, which is based on the finite-difference scheme in the frequency domain. The unit cell contains 2 identical ellipsoids of revolution from the GST with a polar radius of 200 nm and an equatorial radius of 250 nm. The period between the ellipsoids is 1.5 mkm. The height between the ellipsoids was a freely variable parameter. The complex dielectric constant of the GST was taken from [7]. The ellipsoids are embedded in the air. For our calculations, a linearly polarized plane wave was incident on a unit cell along the normal to the metasurface.

Figure 1 shows the reflection spectra of a 2.5D GST metasurface for two polarizations of the incident light. For s-polarization at a wavelength of 1645 nm, a narrow transmission dip is observed. For p-polarization, a doublet is observed with dips centered at 1614 and 1628 nm. The switching the GST phases between amorphous and crystalline the dips leads to disappearing of

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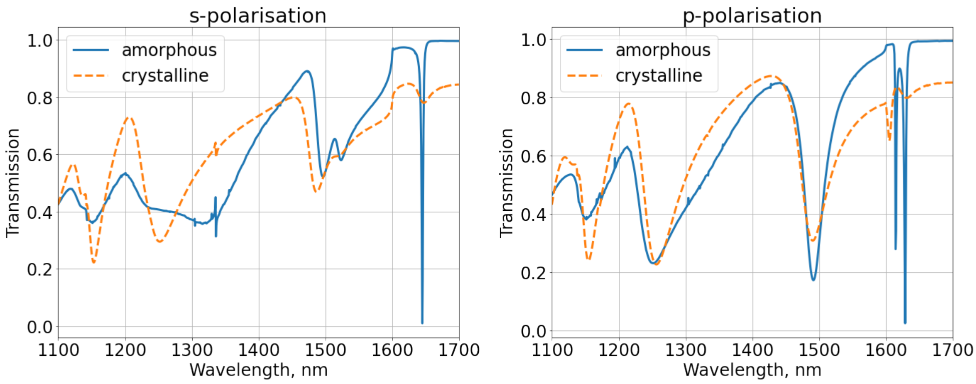
the dips. By varying the free parameter (i.e. the interlayer distance), the peak can be tailored to the operating range in the telecommunication wavelengths.



(a) (b)

Figure 1. The calculated transmission spectra for the 2.5D metasurface from GST for s-polarization (a) and p- polarization (b)

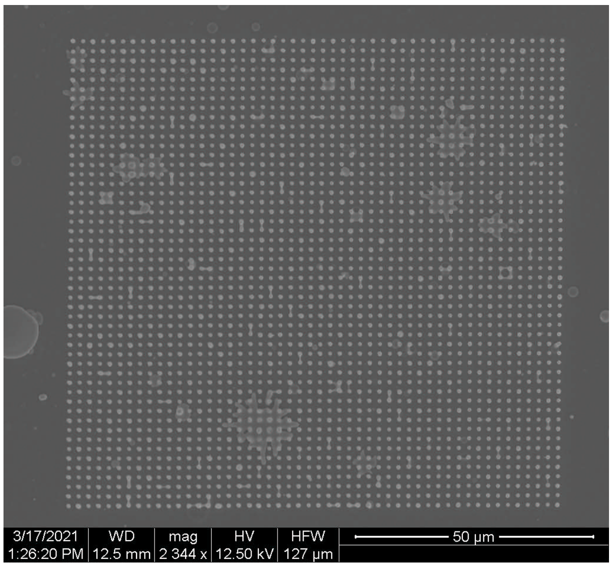


Figure 2. SEM images of 2.5D metasurface after GST film deposition.

2. Fabrication of 2.5D metasurface from GST.

We used following procedures for fabricating 2.5D metasurfaces corresponding to the simulated structures. At the first stage, polymer posts were made of zirconium propoxide with an Irgacure 369 photo-initiator by the method of two-photon lithography [8]. For this, the radiation of a 50-fc TiF-100F laser with a central wavelength of 780 nm was focused on the non-developed polymer film using a 40X microscope objective with numerical aperture NA = 0.75.

At the next stage, a GST layer is applied to the polymer posts by laser electrodispersion [9]. During deposition, the laser beam melted the GST target, pulling out submicron drops charged with plasma from the surface. When the force of the Coulomb repulsion exceeds the force of surface tension, it breaks up into many smaller droplets. The effect of the lack of repulsive forces can be seen in Fig. 2. White and shapeless spots are uncrushed GST droplets.

Conclusion

To summarize, the numerical simulations of the transmission spectra of 2.5D metasurfaces have been carried out in this work show the possibility of modulating the transmission in the IR range during the phase transition between the amorphous and crystalline states in GST. We have demonstrated that the proposed manufacturing technique using two-photon lithography and laser electrodispersion allows us to develop the design of a narrow-band filter and conduct an experimental comparison with the results of numerical calculations.

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References

[1] Kolobov A V, Fons P, Frenkel A I, Ankudinov A L, Tominaga J and Uruga T 2004 *Nature materials* **3** 703–708
[2] Ahmadivand A, Gerislioglu B, Sinha R, Karabiyik M and Pala N 2017 *Scientific Reports* **7** 1–8 ISSN 20452322
[3] Sámson Z, MacDonald K, De Angelis F, Gholipour B, Knight K, Huang C, Di Fabrizio E, Hewak D and Zheludev N 2010 *Applied Physics Letters* **96** 143105
[4] Gholipour B, Karvounis A, Yin J, Soci C, MacDonald K F and Zheludev N I 2018 *NPG Asia Materials* **10** 533–539
[5] Fu X, Zhang Z, Jiang Y, Zhang W, Bi K, Sun K and Fan R 2020 *Advanced Engineering Materials* **22** 1901126
[6] Mansouree M, Kwon H, Arbabi E, McClung A, Faraon A and Arbabi A 2020 *Optica* **7** 77–84
[7] Dyakov S A, Gippius N A, Voronov M M, Yakovlev S A, Pevtsov A B, Akimov I A and Tikhodeev S G 2017 *Physical Review B* **96** ISSN 24699969
[8] Farsari M and Chichkov B N 2009 *Nature photonics* **3** 450–452
[9] Yavsin D, Kozhevin V, Gurevich S, Yakovlev S, Melekh B, Yagovkina M and Pevtsov A 2014 *Semiconductors* **48** 1567–1570