Optical Reconfigurable Terahertz Devices using Phase Change Materials

Maxime Pinaud, Georges Humbert, Sebastian Engelbrecht, Lionel Merlat, Aurelian Crunteanu, Bernd H Fischer

► To cite this version:

Maxime Pinaud, Georges Humbert, Sebastian Engelbrecht, Lionel Merlat, Aurelian Crunteanu, et al.. Optical Reconfigurable Terahertz Devices using Phase Change Materials. 44th International Conference on Infrared, Millimeter and Terahertz Waves, IRMMW-THz 2019, 1-6 September 2019 - Paris, France, Sep 2019, Paris, France. hal-02333519

HAL Id: hal-02333519

<https://hal.science/hal-02333519>

Submitted on 25 Oct 2019

HAL is a multi-disciplinary open access archive for the deposit and dissemination of scientific research documents, whether they are published or not. The documents may come from teaching and research institutions in France or abroad, or from public or private research centers.

L'archive ouverte pluridisciplinaire **HAL**, est destinée au dépôt et à la diffusion de documents scientifiques de niveau recherche, publiés ou non, émanant des établissements d'enseignement et de recherche français ou étrangers, des laboratoires publics ou privés.

Optical Reconfigurable Terahertz Devices using Phase Change Materials

M. Pinaud¹, G. Humbert¹, A. Crunteanu¹, S. Engelbrecht², L. Merlat², B. Fischer²

¹ XLIM Research Institute, UMR 7252 CNRS/ University of Limoges, 87060, Limoges, France

² ISL, French-German Research Institute of Saint-Louis, 68300, Saint Louis, France

Abstract—Phase change materials (PCMs) have the ability to change their electrical and optical properties under electrical or optical excitations over a large frequency spectrum. This properties are attractive for developing future reconfigurable Terahertz (THz) devices. We report the demonstration of a THz device entirely fabricated with PCMs which can largely modify the transmission and polarization state of an incident THz wave using reversible phase changes in a GeTe material (insulating to metallic phase transition using optical excitations). Furthermore, we investigate the possibility to optically imprint grating-type GeTe crystalline structures within an amorphous GeTe film for further demonstrating reconfigurable THz devices.

I. INTRODUCTION

THz frequencies hold very promising applications such as wireless communication, security screening, chemical identification and non-destructive sensing [1]. Nevertheless, the development of practical THz applications is hindered by the lack of fast and reconfigurable devices to manipulate terahertz waves. We propose to exploit the unique properties of PCMs to develop new reconfigurable and rewritable devices using optical activation.

PCMs have been very used in optical and electrical domain. PCMs in the form of chalcogenides like GeTe or $\text{Ge}_2\text{Sb}_2\text{Te}_5$ -GST are fascinating materials due to their ability to be electrically or optically switched in a repeatedly, bi-stable manner between an amorphous (insulating state) to a crystalline (conducting state) using short DC current or laser pulses. The phase transition (crystalline to amorphous and opposite) is achievable at the nanosecond timescales [2]. The material's bi-stability and its broadband response (from DC to THz and optical frequencies) are key advantages of the PCM-based technology. Indeed, the material does not require a permanent bias to be maintained in a specific, prepared state. In the THz domain, there are very few studies on PCMs [3]. However, they have not completely exploited their bi-stability properties (the device was fixed in crystalline state). Thus, they study only the device response and not the device reconfigurability. For the first time to the best of our knowledge, we demonstrate an all-dielectric and optically reconfigurable THz device fabricated entirely on GeTe.

II. RESULTS

We demonstrate the possibility to change repeatedly a GeTe film between its two phases using a UV laser (248 nm wavelength, 30 ns pulse duration). The good dynamic between the two states (Fig 1.(a)) make possible the realization of THz reconfigurable devices. The proposed device consists of a GeTe-based grating structure fabricated on a silica substrate (GeTe stripes having widths of 3 μm , spaced by 3 μm and with a thickness of 500 nm). Initially, the GeTe is amorphous/insulator and transparent to the THz waves, with

THz transmissions higher than -0.4 dB, identical for TE and TM polarizations of the incident beam. When irradiated with short optical pulses from an UV laser, the GeTe structures are transformed to their crystalline/conducting state, behaving like a metallic polarizer[4]. The TM normalized transmission of the grating (Fig 1.(b)) does not change compared with the initial value (when the GeTe is amorphous), whereas for the TE polarized wave transmission is drastically decreased below -15 dB. By applying a new optical pulse, the GeTe structures can be transformed back to their amorphous/ insulating state and become transparent again. Thus, we realized an all-dielectric (metal free) and reconfigurable structure based solely on GeTe which has the ability to control the polarization state of the THz waves.

In a different approach, we will also present our preliminary studies towards the implementation of the 2D patterning of GeTe metallic structures within the bare amorphous GeTe thin film using a similar optical activation technique (Fig 1.(c)) which can be subsequently erased to their initial amorphous state. This optical activation scheme associated with the bi-stability of the PCM is a very promising approach towards THz reconfigurable metasurfaces with multifunctional capabilities.

Figure 1. Measured normalized THz transmission (using THz-TDS) for (a) crystalline and amorphous GeTe crystalline and for (b) crystalline GeTe gratings for TE and TM polarization; (c) 2D printing of a GeTe metallic grating structure within a bare GeTe amorphous

REFERENCES

- [1] M. Tonouchi, « Cutting-edge terahertz technology », *Nat. Photonics*, vol. 1, p. 97, févr. 2007.
- [2] A. Crunteanu *et al.* « Optical switching of GeTe phase change materials for high-frequency applications », in *2017 IEEE MTT-S International Microwave Workshop Series on Advanced Materials and Processes for RF and THz Applications (IMWS-AMP)*, 2017, p. 1–3.
- [3] C. H. Kodama *et al.* « Tunable split-ring resonators using germanium telluride », *Appl. Phys. Lett.*, vol. 108, n° 23, juin 2016.
- [4] L. Y. Deng *et al.*, « Extremely high extinction ratio terahertz broadband polarizer using bilayer subwavelength metal wire-grid structure », *Appl. Phys. Lett.*, vol. 101, n° 1, p. 011101, juill. 2012.