Ultra-high extinction tri-layer thin-film wire-grid THz polarizer

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***Abstract*— An ultra-high extinction THz polarizer with a tri-layer wire-grid structure was proposed here. The performance of the THz polarizer was theoretically evaluated through FEM software (HFSS), and showed a greater than 90 dB extinction ratio at 1 THz, which is the highest as far as the authors' knowledge.**

I. Introduction And Background

THE Terahertz (THz) waves generated by time-domain spectroscopy (TDS) usually have mixed polarizations. Thus, a THz polarizer can be used to remove unwanted minor polarizations [1] and facilitate the characterization of birefringent materials and devices in THz spectrum. Currently, there are two major issues challenging the development of THz polarizers. The first is the multi-reflection issue which occurs when the THz wave passes through THz polarizers with a thick supporting substrate: this eventually induces signal interference in the THz spectrum. The second challenge is that it is difficult to achieve a high extinction ratio while keep a low transmission loss. To tackle both these issues, a THz polarizer (SLP) with a single-layer aluminum (Al) grid on a thin-film silica substrate [2] was proposed firstly – it achieved no multi-reflections (up to 20 THz) and low transmission loss (below 0.8 dB for 0.2-2.0 THz). However, its extinction ratio was limited and comparable with the commercial products (about 30 dB at 1 THz). Then, a THz thin-film polarizer (BLP) with a bilayer Al grid structure [3] was recently reported. This achieved a much higher extinction ratio (above 50 dB for 0.2-1.1 THz). In this paper, a thin-film THz polarizer based on a tri-layer wire-grid structure is studied to further increase the extinction ratio.

II. Design And Results

The schematic diagram of the proposed thin-film tri-layer metallic grid polarizer (TLP) is shown in Fig. 1. It consists of four parts: tri-layer Al grids, SiO_2 thin film, Si substrate, and a polymer cover. Here, the thin-film SiO_2 layer supports the Al grids at the central aperture and the thick (~420 µm) Si supports the polarizer at the surroundings. A polymer thin film separates each Al grid layer and covers the entire surface to protect the metal grids. This TLP design has more advantages as the extra Al grid layer provides more tunable lateral displacement parameters: *d* for the lateral displacements between the middle and top / bottom grid layers respectively. To demonstrate the idea, the polymer spacing and the total thickness are chosen as t_{spacer} = 2 µm, and t_{total} = 8.7 µm respectively. The performance can be tuned by the lateral phase shift (*LPS*) among grids, defined as $LPS = d / P \times \pi$ (P = 14 µm here), is shown in Fig. 2. It is clearly indicated that the extinction ratio increases from ~45 dB when *LPS* = 0, reaching ~55 dB when *LPS* = π/2, and to above 90 dB when *LPS* = π at 1 THz, which is more than 3 times higher than for the SLP [2]. Furthermore, the extinction ratio at 2 THz can also be tuned to ~ 90 dB when *LPS* = π.

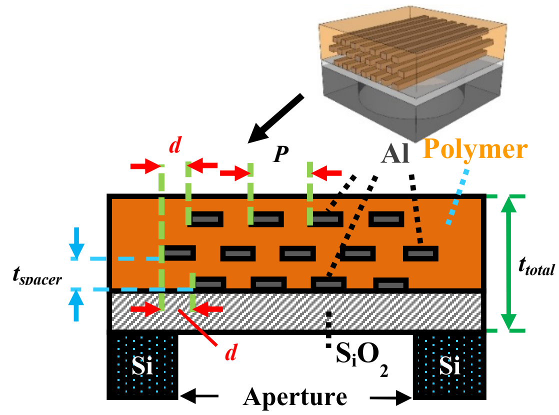

Fig. 1. Schematic diagram and cross-section view of the thin-film tri-layer wire-grid polarizer. *P*: pitch size: 14 µm.

Meanwhile, the transmission loss at 1 THz only increases slightly to ~1.4 dB. The extinction enhancement is the highest ever achieved so far.

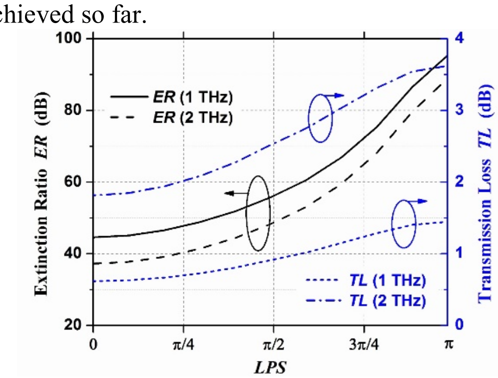

Fig. 2. The extinction ratio and transmission loss of TLP with the change of the lateral phase shift by FEM simulation.

III. Conclusion

In summary, a thin-film THz polarizer with a tri-layer metal grid is proposed. The designed tri-layer polarizer has an extinction ratio greater than 90 dB at 1 THz with a relatively low loss (approximately 1.4 dB at 1 THz) by FEM simulation. Moreover, the polarizer performance tuned by the lateral phase shift is studied. The polarizer is currently in the progress of fabricating. This work was supported by the Strategic Research Grant (SRG NO. 7004055) of the City University of Hong Kong.

References

[1]. H. Park, E. P. J. Parrott, Z. Huang, H. P. Chan, and E. Pickwell-MacPherson, "Accurate photoconductive antenna characterization using a thin film polarizer," Appl. Phys. Lett., vol. 101, 121108 2012.

[2]. Z. Huang, H. Park, E. P. J. Parrott, H. P. Chan, and E. Pickwell-MacPherson, "Robust Thin-Film Wire-Grid THz Polarizer Fabricated Via a Low-Cost Approach," IEEE Photon. Techn. Lett., vol. 25, pp. 81–84, 2013.

[3]. Z. Huang, E. P. J. Parrott, H. Park, H. P. Chan, and E. Pickwell-MacPherson, "High extinction ratio and low transmission loss thin-film terahertz polarizer with a tunable bilayer metal wire-grid structure", Opt. Lett., vol. 39, pp. 793–796, 2014.