Near-Unity THz Absorption in a 2D Phosphorene–MoS_2/Graphene Nanoribbon Structure

Amine El Moutaouakil, Omnia Samy,
Department of Electrical and Communication Engineering, College of Engineering, United Arab Emirates University, P.O. Box No. 15551, Al Ain, UAE
a.elmoutaouakil@uaeu.ac.ae

Abstract (Arial 10)

This study extends our earlier theoretical work on MoS_2/graphene heterostructures, where approximately 50% THz absorption and frequency tunability were achieved through adjustments in nanoribbon width and applied voltage [1]. Here, we significantly enhance the absorption characteristics by introducing a phosphorene nanoribbon of width $W_{n\text{-}BP}$ between two MoS_2/graphene nanoribbons (Fig. 1). The resulting structure attains absorption levels exceeding 90%, while preserving tunability through geometric variation and voltage control, allowing frequency sweeping across a wide THz range (1.3–10 THz) (Fig. 2 dashed lines). The proposed absorber employs only 2D materials—graphene, phosphorene, and MoS_2—and avoids the use of noble metals, resulting in a simplified architecture compatible with scalable fabrication techniques such as CVD and dry transfer. Compared with prior high-absorptivity designs that rely on complex, bulky metallic layers, this structure offers a low-cost, compact, and easily manufacturable solution [2]. The absorptivity could be increased to ~ 100% by adding an Ultra-thin metallic ground plane of gold (5 nm) at the bottom of the structure. The gold plane reflected back the transmitted waves from the substrate where they absorbed (Fig. 2 solid lines). [3]. Future research will focus on experimental fabrication, exploring doping effects, and optimizing the structure for narrower bandwidth absorption.

References

[1] O. Samy, M. Belmoubarik, T. Otsuji, and A. El Moutaouakil, Nanomaterials (2023), 13(11), 1716. https://doi.org/10.3390/nano13111716
[2] O. Samy, T. Otsuji, and A. El Moutaouakil (2023). 48th International Conference on Infrared, Millimeter, and Terahertz Waves (IRMMW-THz), 1–2. Montreal, QC, Canada: IEEE. https://doi.org/10.1109/IRMMW-THz57677.2023.10298957
[3] O. Samy and A. El Moutaouakil, Results in Physics (2024), 58, 107490. https://doi.org/10.1016/j.rinp.2024.107490

Figures

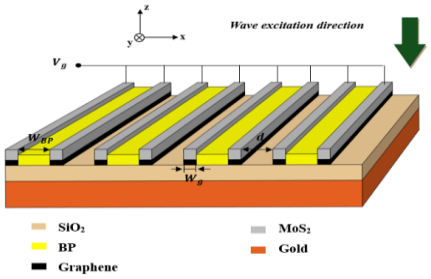

Figure 1: 3D schematic of a four-element array of the proposed structure.

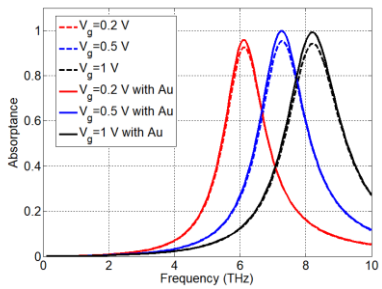

Figure 2: The absorptance of the structure in case of using gold (solid lines), and without using gold (dashed lines) at different gate voltages.