

## Responsivity enhancement of a strained silicon field-effect transistor detector at 0.3 THz using the terajet effect: supplement

IGOR VLADILENOVICH MININ,<sup>1</sup>  OLEG VLADILENOVICH MININ,<sup>1</sup>   
JUAN SALVADOR-SÁNCHEZ,<sup>2</sup> JUAN ANTONIO  
DELGADO-NOTARIO,<sup>2,3</sup>  JAIME CALVO-GALLEGO,<sup>2</sup>  MIGUEL  
FERRANDO-BATALLER,<sup>4</sup> KRISTEL FOBELETS,<sup>5</sup> JESÚS ENRIQUE  
VELÁZQUEZ-PÉREZ,<sup>2</sup> AND YAHYA MOUBARAK MEZIANI<sup>2,\*</sup>

<sup>1</sup>Tomsk Polytechnical University, 30 Lenin Avenue, Tomsk, 634050, Russia

<sup>2</sup>Nanotech Group, Salamanca University, Facultad de Ciencias, Plaza de la Merced, s/n. Edificio Trilingüe, 37008, Salamanca, Spain

<sup>3</sup>CENTERA Laboratories, Institute of High Pressure Physics, Polish Academy of Sciences, 29/37 Sokołowska Str., Warsaw, Poland

<sup>4</sup>Department of Communications, Telecommunication Engineering School, Universitat Politècnica de València, 46022, Valencia, Spain

<sup>5</sup>Department of Electrical and Electronic Engineering, Imperial College, South Kensington Campus, London SW7 2AZ, UK

\*Corresponding author: [meziani@usal.es](mailto:meziani@usal.es)

---

This supplement published with The Optical Society on 21 June 2021 by The Authors under the terms of the [Creative Commons Attribution 4.0 License](https://creativecommons.org/licenses/by/4.0/) in the format provided by the authors and unedited. Further distribution of this work must maintain attribution to the author(s) and the published article's title, journal citation, and DOI.

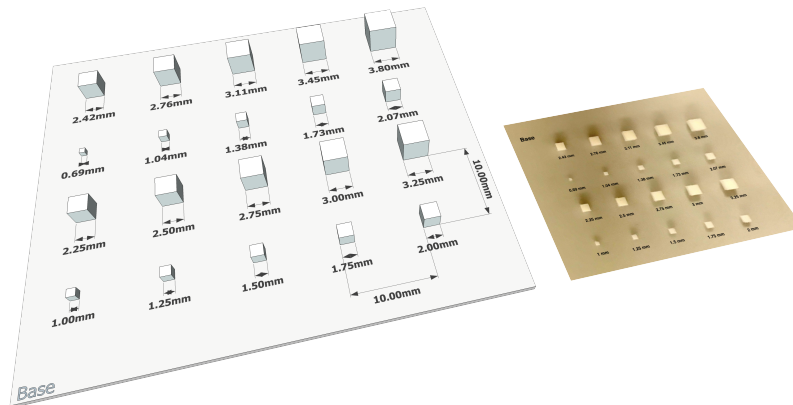
Supplement DOI: <https://doi.org/10.6084/m9.figshare.14781381>

Parent Article DOI: <https://doi.org/10.1364/OL.431175>

# Supplementary materials: Responsivity enhancement of a Strained Silicon Field Effect Transistor detector at 0.3 THz using the terajet effect

## 1. TEFLON CUBES AS A MESOSCOPIC PARTICLE

Teflon based cubes were used as dielectric mesoscopic particles to improve the response of a Silicon-based solid-state THz detector. They were designed and fabricated using a CNC machine on a Teflon base. The CNC milling machine used for the fabrication was a DATRON M25. The machine area was 500x500x240 mm with a feed rate and positioning feed of 10 m/min. The minimum precision is about 50  $\mu\text{m}$  in all three spatial directions. More information can be found in <sup>1</sup>. The thickness of the base is 1mm and the separations between cubes was 10 mm to avoid interference with the THz beam. Figure S1 shows the cubes on the base with their respective dimensions. Figure S2 shows the cubes base on the xy stage at the focale point of the THz beam and in front of the detector.

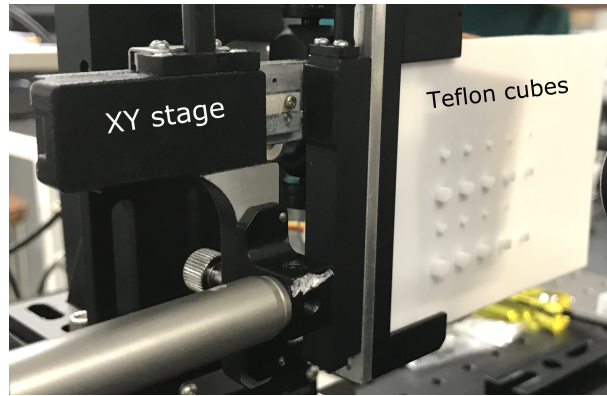


**Fig. S1.** The design of the fabricated cubes on the Teflon base (left) and photography of the cubes on the base (right).

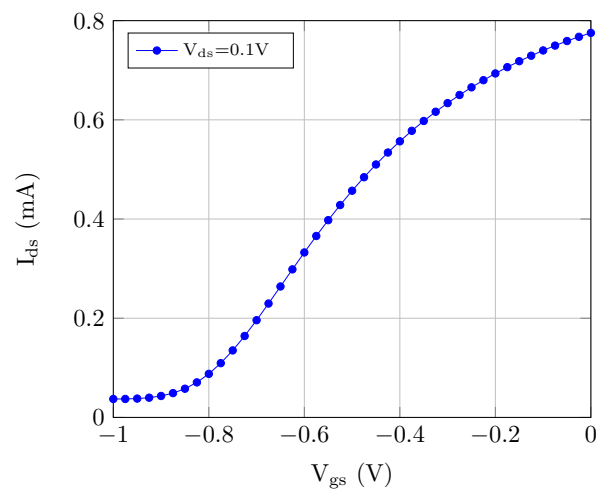
## 2. CHARACTERISTICS OF THE TERAHERTZ DETECTOR

Figure S3 shows the transfer characteristics of the device at  $V_{ds} = 0.1$  V. The transistor is a depletion-mode device, so a negative bias voltage must be applied to the gate (i.e., a negative gate-to-source voltage,  $V_{gs}$ ) to cut off the channel. The threshold voltage was obtained to be  $V_{gs} \sim -0.8$  V. The transistor shows a small leakage current in the sub-threshold region ( $V_{gs} < V_{th}$ ). This was related[1] to the double deck structure of the supply layers, which ensures a suitable concentration of the electron plasma in the channel that is important to achieve a good performance of the transistor in THz detection.

<sup>1</sup>DATRON M25: [https://www.solectro.se/Archive/Documents/Delkatalog/DATRON\\_M25\\_GB.pdf](https://www.solectro.se/Archive/Documents/Delkatalog/DATRON_M25_GB.pdf)



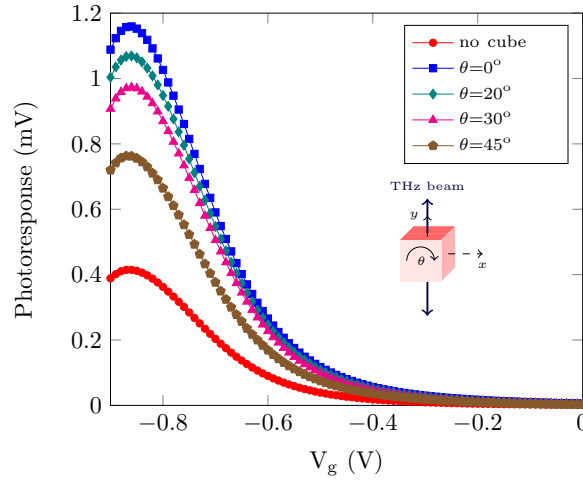
**Fig. S2.** The cubes on the *xy* stage and in the front of the detector.



**Fig. S3.** Transfer characteristics of the device at  $V_{ds}=0.1V$ .

### 3. PHOTORESPONSE BEHAVIOR WITH THE POLARIZATION

We measured the photoresponse versus the rotation angle of the cube and the results are shown in Figure 3 below. The cube was rotated along the polarization direction of the THz beam due to the lack of polarizer or waveplate in our setup. This preliminary result shows that the response exhibits a maximum of the response at  $0^\circ$  and it decreases with the rotation angle. The polarization of the incident wavefront affects the parameters of the terajet depending on the shape of the dielectric particle. For a spherical particle the polarization has little effect [2, 3]. For a cubic particle the effect of the polarization is stronger since the physics of terajet formation in this case differs from the one generated using a spherical particle (see for example, Refs [4–6]). Accordingly, if the polarization vector of a linear plane wave is oriented along the diagonal of the cube, then for the refractive index and dimensions selected, the terajet will shift towards the inside of the cube from its shadow surface. This will lead to a weakening of the terajet effect.



**Fig. S4.** Photoresponse versus rotation angle of the cube along the direction of the THz beam polarization.

### REFERENCES

1. J. A. Delgado-Notario, J. E. Velazquez-Perez, Y. M. Meziani, and K. Fobelets, "Sub-THz Imaging Using Non-Resonant HEMT Detectors," *Sensors* **18**, 543 (2018).
2. Y. Liu, B. Wang, and Z. Ding, "Influence of incident light polarization on photonic nanojet," *Chin. Opt. Lett.* **9**, 072901–072901 (2011).
3. S. Zhou, "Effects of light polarization in photonic nanojet," *Opt. Quantum Electron.* **51**, 112 (2019).
4. D. Turan, N. Yardinci, and M. Jarrahi, "Plasmonics-enhanced photoconductive terahertz detector pumped by ytterbium-doped fiber laser," *Opt. Express* **28**(3), 3835–3845 (2020).
5. L. Yue, B. Yang, J. Monks, W. Z., N. Tung, V. Lam, O. V. Minin, and I. V. Minin, "A millimetre-wave cuboid solid immersion lens with intensity-enhanced amplitude mask apodization," *J. Infrared, Millimeter, Terahertz Waves* **39**(6), 546–552 (2018).
6. N. Pham, S. Hisatake, O. V. Minin, T. Nagatsuma, and I. V. Minin, "Enhancement of spatial resolution of terahertz imaging systems based on terajet generation by dielectric cube," *APL Photonics* **2**, 056106 (2017).