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Editorial: Advanced Terahertz spectrum and metamaterials for biochemical sensing and detection

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Editorial on the Research Topic
Advanced Terahertz spectrum and metamaterials for biochemical sensing and setection

Terahertz (THz) electromagnetic spectroscopy, located between microwaves and infrared radiation, is a promising analytical method for sensitive probing in a label-free and nondestructive manner [1]. THz spectrum can provide unique fingerprint information regarding various biochemical or organic molecules [2, 3], and can be used for qualitative or quantitative sensing and detection of biochemical substrates. Although the development of THz sensing and detection has been overshadowed by the great progress achieved in microwave and infrared spectroscopies, its uniquely attractive features have encouraged researchers to explore the potential of this band. However, traditional THz systems rely on bulk amounts of the analyte tablet in order to increase the interaction between THz waves and the sample, which is not in accordance with the real-world requirements for the detection of trace substrates, because the biochemical analyte is usually present in extremely low quantities.

It is notable that the collective resonances of subwavelength, periodic artificial structures have endowed THz metamaterials with local field enhancement, enhancing interactions between THz waves and the target biochemical or organic molecules [4–7]. This strategy not only provides an important method for the sensitive detection of substrates, but also facilitates the advance of THz sensing from laboratory demonstrations to practical applications [8, 9]. This Research Topic presents novel research that contributes to the design of functional THz metamaterials for sensing and detection applications, as well as spectral diagnostic techniques in the THz band. Four articles were collected and are explained below.

Shang et al. applied THz time-domain spectroscopy to study laser-induced damage of an ITO thin film. The peak-to-peak value in the time domain and the amplitude in the frequency domain for the damaged area evidently increased compared with those of the undamaged area. The increased laser-induced energy resulted in a larger damaged area and increased surface roughness, as shown in Figure 1. The variation, both in time- and frequency-domain spectra, can distinguish the type of damage on the optical thin film irradiated by a laser. This research provides a new approach for laser-induced damage identification of thin films using THz spectra.

This Research Topic also contains three articles focused on THz metamaterials. Abdulkarim et al. proposed a broadband metamaterial based on vanadium dioxide (VO_2) resonators. Its absorption characteristics could be adjusted by the temperature, because of the phase change of VO_2 from insulating to metallic.

In the article by Lu et al., equivalent circuit models were utilized to analyze the resonance of THz metamaterials comprised of cross rectangular, split-ring resonators. The sensing performances of the metamaterials were discussed, and the results show that they exhibited high refractive index sensitivities of 309 GHz/RIU and 730 GHz/RIU at two resonant frequencies.

Hu et al. designed a graphene-based THz metasurface sensor using an air spacer. Structural design and material selection enabled tuning of the sensor's resonance characteristics through the dynamic electrical properties of graphene and the thickness of the air spacer. The sensitivities of the two resonance peaks reached 450 GHz/RIU and 717 GHz/RIU.

In conclusion, this Research Topic aims to contribute to the design of different types of functional THz metamaterials to achieve high sensitivity sensing and detection. Obtaining THz spectra of the sensing target by using THz time-domain spectroscopy can provide a clear understanding of the resonant mechanisms of THz metamaterials, providing a pathway for their application in the field of biochemical sensing and detection. We are grateful to the Frontiers in Physics team for technical assistance during publishing.

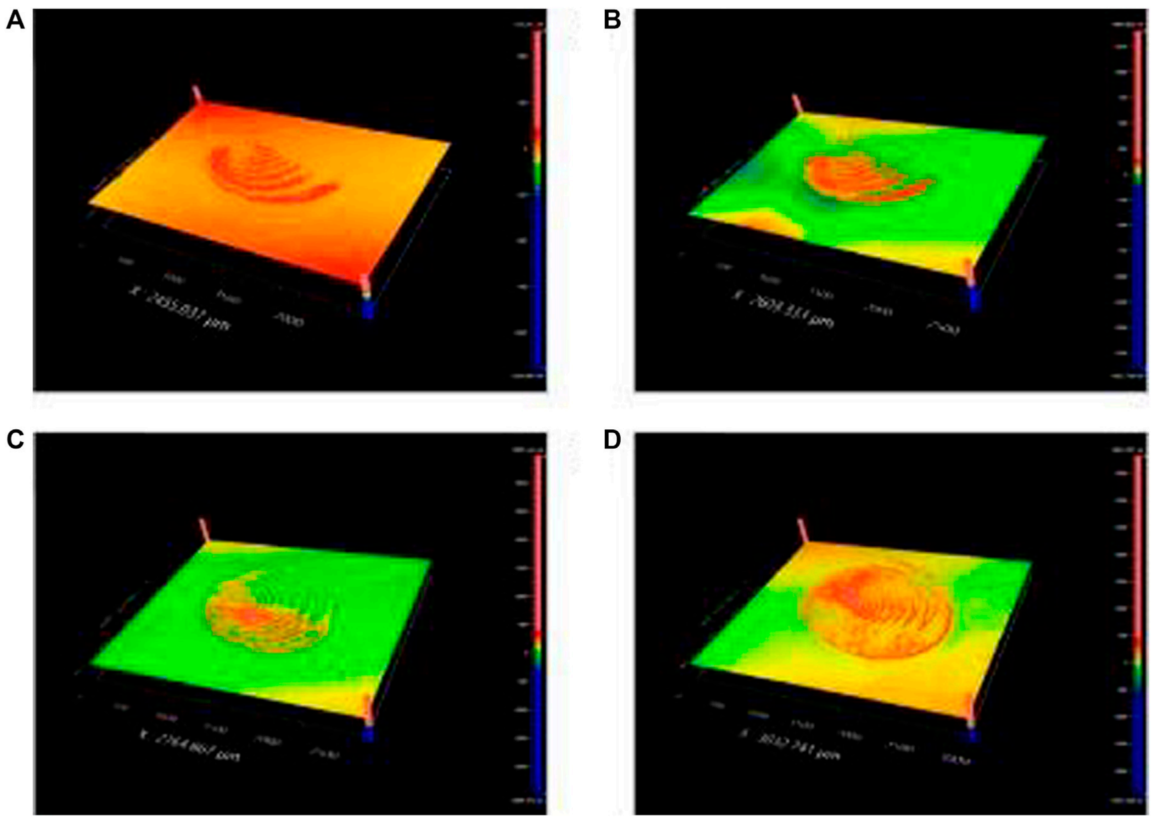

FIGURE 1
Damage profile of an ITO thin film sample irradiated by a laser at different energy densities: **(A)** 1.03 J/cm^2, **(B)** 1.28 J/cm^2, **(C)** 1.55 J/cm^2, and **(D)** 2.23 J/cm^2.

Author contributions

YW drafted the Editorial and led the Research Topic. All authors have made a substantial, direct, and intellectual contribution to this Research Topic.

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Conflict of interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

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