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TERAHERTZ IMAGING AND SENSING FOR HEALTHCARE

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Abstract: Recently, terahertz spectroscopy has received a lot of attention because of its unique properties such as biosafety, fingerprint spectrum, and good penetration. In this review, we focus on the research progress of terahertz spectroscopic techniques for the detection and recognition of substances. First, we describe the fundamentals of terahertz spectroscopy. Then, we outline the applications of terahertz spectroscopy in biomedicine, agriculture, food production, and security inspection. Subsequently, metamaterials, which have recently received extensive attention, are also investigated for their applications in terahertz spectroscopic detection and recognition of substances is illustrated. Finally, the development trend of terahertz spectroscopy for substance detection and recognition has also been prospected.

I. INTRODUCTION

Currently, the terahertz (THz) regime of the spectrum is rapidly becoming a research hotspot with great potential to bring a new era in the healthcare industry including in biomedical imaging for cancer among many other biomedical applications of THz imaging, spectroscopy, and sensing. The Global Terahertz (THz) market size was valued at USD 420 million in 2022 and is predicted to reach USD2,879 million by 2030, with a Compound Annual Growth Rate (CAGR) of 23.8% between the 2022-2030 period. The evolution of advanced technologies, the emergence of new diseases, population health management, better-informed customers, and inventions are some among many other factors which are improving the demand for THz technology in healthcare. This has led to ongoing research and developments in the advancement of THz devices that are capable of sensing monitoring and detection, imaging, spectroscopy, and characterization. THz radiation has been investigated in the healthcare domain for diagnosis and monitoring of other disorders including foot diabetes, skin dehydration, wounds, burns, dentistry, dermatology, etc.. The application of THz technologies like THz imaging, sensing, and THz Time Domain Spectroscopy (THz-TDS) have also advanced in other applications like non-destructive testing (NDT), surveillance and security checks, material characterizations etc. and is expected to expand. The focus of this paper is on the application of THz technology for biomedical imaging and sensing of cancer as shown in Fig 1. The ‘‘Terahertz radiation’’ is also termed T-rays, THz waves or THz light . As shown in Fig. 1, the THz region ranges between the frequencies 0.1–10 THz and wavelength 3mm to 30µm, where 1THz = 1ps = 33cm-1 = 0.3mm = 4.1meV = 48K . Due to a vast difficulties related to detectors and sources, the THz frequency regime of the spectrum has been previously called the ‘‘Terahertz gap’’. The significance of crossing the gap have been identified through realization of THz frequency as spectrum of molecular vibrations e.g., molecular rotational, crystalline photon, torsional as well as inter-and intra-molecular vibrations.

II. LITERATURE SURVEY

[1] "Terahertz spectroscopy: a powerful new tool for the chemical sciences?" by C. J. Strachan and P. H. Beton, published in Chemical Society Reviews in 2010. This article provides an overview of the potential of terahertz spectroscopy in chemical analysis and highlights its advantages and limitations

[2] "Terahertz time-domain spectroscopy for detection and identification of explosives" by R. Mendis, Y. Gong, R. T. Chen and D. M. Mittleman, published in IEEE Journal of Selected Topics in Quantum Electronics in 2012. This article discusses the use of terahertz spectroscopy for the detection and identification of explosives, which is one of the most promising applications of this technology.

[3] "Terahertz spectroscopy and imaging for defense and security applications" by X. C. Zhang and D. H. Auston, published in Proceedings of the IEEE in 2004. This article provides an overview of the use of terahertz spectroscopy and imaging in defense and security applications, such as the detection of concealed weapons and explosives.

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[4] "Recent advances in terahertz technology for biomedical applications" by Y. F. Zhang, X. Y. Zhou, H. F. Tian, Y. H. Zhang, X. C. Zhang and J. Xu, published in Quantitative Imaging in Medicine and Surgery in 2012. This article discusses the potential of terahertz technology in biomedical applications, such as cancer diagnosis and imaging.

[5] "Terahertz spectroscopy and imaging: a cutting-edge technology for non-destructive inspection of pharmaceutical products" by S. K. Sharma, A. Thakur and R. K. Gupta, published in Journal of Pharmaceutical Investigation in 2017. This article discusses the use of terahertz spectroscopy and imaging for non-destructive inspection of pharmaceutical products, which is becoming an increasingly important application of this technology in the pharmaceutical industry.

III. TECHNOLOGY INVOLVED

In terms of technologies involved, the paper primarily focuses on THz spectroscopy and its applications. THz spectroscopy is a non-destructive imaging technique that uses electromagnetic radiation in the terahertz frequency range (0.1 to 10 THz) to identify and analyze the molecular and structural properties of materials. The paper also discusses some of the techniques used in THz spectroscopy, such as time-domain spectroscopy (TDS) and frequency-domain spectroscopy (FDS). TDS involves the generation and detection of THz radiation pulses, while FDS involves the use of a continuous THz source and a spectrometer to measure the frequency response of a sample. Additionally, the paper briefly touches on some of the sample preparation and handling techniques used in THz spectroscopy, such as sample grinding, pelletizing, and liquid handling.

Overall, the main technology discussed in the paper is THz spectroscopy, with some discussion on the techniques and sample handling methods used in conjunction with it.

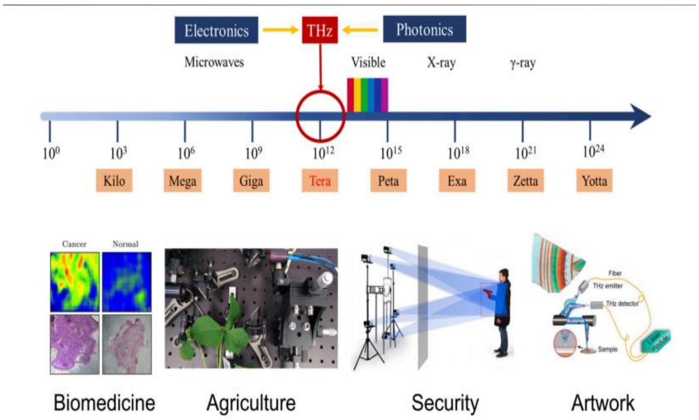

Fig 1: Terahertz spectroscopy and some typical applications

IV. ADVANTAGES

- Salient features of THz Technology for cancer detection
- Strong Absorption by water
- Non-ionizing and noninvasive properties
- Existing challenges and prospective opinion
- High sensitivity to water
- Thz system size and equipment cost
- Low acquisition speed
- Low flexibility of THz systems

V. FUTURE SCOPE

- Recent advances in Thz imaging and sensing.
- Recent advances are focusing on miniaturized, compact, and optimized THz imging technology for real operational convenience, enhanced functionality, and reduced power consumption.

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VI. CONCLUSION

The authors conclude that THz spectroscopy has significant potential in the detection and recognition of various substances due to its unique advantages, such as high sensitivity, non-destructive detection, and the ability to differentiate between substances with similar chemical structures. The paper also discusses some of the current challenges and limitations of THz spectroscopy and proposes potential solutions to overcome them, including the development of new THz sources, detectors, and imaging systems. Overall, the paper highlights the promising future of THz spectroscopy in various fields, including materials science, chemistry, and biomedical applications.

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