SMWD 2023, KTH Royal Institute of Technology, Stockholm, 23rd – 25th May 2023

Exploring life sciences with terahertz electronics

H. Rodilla
Terahertz and Millimetre Wave Laboratory, Chalmers University of Technology, Gothenburg, Sweden.

Summary

While major strides of terahertz technology remind in its niche applications of space and remote sensing, new opportunities have been appearing in the last decades in life science applications. In this conference I will present the opportunities and challenges of terahertz electronics in life sciences applications. I will present the efforts at the terahertz and Millimetre Wave laboratory at Chalmers in this new research field, focusing in two main research areas: on-chip characterization of aqueous solutions and opportunities in the pharma industry.

1. Introduction

Terahertz waves are consistent with discrete molecular vibrational, rotational and librational modes in solids and liquids. This, together with low photon energy level which makes the interaction with matter non-ionizing and nondestructive, makes the terahertz frequency range an attractive ground for life science applications [1].

2. Spectroscopy of aqueous samples

Methods based on the interaction of biomolecules and electromagnetic waves from different parts of the spectrum are critical for understanding molecular structure and function. Within the electromagnetic spectrum, the use of terahertz waves to trigger molecular dynamics in the picosecond time scale has been limited by the lack of technological maturity of terahertz instrumentation and a strong absorption of terahertz waves by water. Most advances in the field have been restricted to artificial conformations like dry protein powders, hydrated films, or protein crystals to minimize water absorption, which imposes strong restrictions on their molecular dynamics. In our lab, we are working towards the development of a terahertz on-chip sensing platform for resolving picosecond dynamics of biomolecules in solution (see Fig. 1 right). For this we have designed, fabricated, and characterized terahertz planar structures on silicon membranes (see Fig. 1 left) [2, 3], calibration structures, and by integrating the RF chip with a microfluidic channel, being able to resolve for the first time high water content solutions on-chip up to 1.1 THz [4].

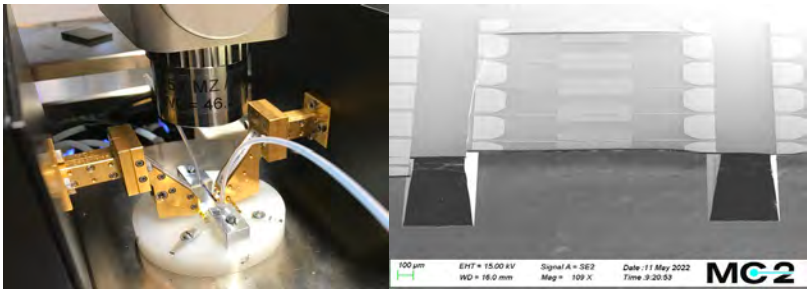

Fig. 1. Left, Photograph of the S-parameter on-chip measurement setup to characterize aqueous solutions up to 1.1 THz. Right, SEM picture of a Planar Goubau Line filter fabricated on a 10 μm silicon membrane.

3. Opportunities in the pharma industry

The pharmaceutical industry has been moving toward continuous manufacturing, increasing the need for process analytical technologies that can be integrated into the manufacturing line, allowing advanced process monitoring and control of the process and product. With less scattering effect and higher penetration depth in powders and tablets than commonly used NIR or Raman spectroscopy, terahertz waves provide an attractive sensing option for the pharmaceutical industry. In this context, we have explored the applicability of terahertz frequency-domain techniques for characterizing pharmaceutical tablets and powders. We have demonstrated the ability of terahertz frequency domain spectroscopy to quantify tablet porosity [5] and showed that, by combining terahertz spectral data obtained from S-parameters (Fig. 2) with multivariate analysis, it is possible to quantify the drug content and tablet density in pharmaceutical tablets, demonstrating that terahertz technology is a complementary technique to

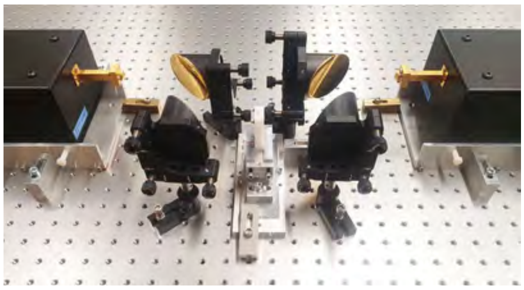

Fig. 2 Photograph of the experimental set-up used for the THz S-parameter characterization of tablets.

Raman and NIR spectroscopy with the advantage of low scattering effects and particular interest on the characterization of physical properties of tablets [6]. I will also present our recent results on terahertz radar sensing for real-time characterization of flowing pharmaceutical powders with the long-term goal to monitor the flow dynamics of powder streams in pharmaceutical production lines.

Acknowledgements

This research was supported by the Swedish Research Council (VR) under grant 2020-05087, the Swedish foundation for strategic research (SSF) under the grant ID 17-0011 and from AstraZeneca, Gothenburg, Sweden.

References

[1]. P. H. Siegel, “Terahertz Technology in Biology and Medicine,” *IEEE Trans. Microwave Theory Tech*., vol. 52, no. 10, pp. 2438 – 2447, Oct. 2004. doi: 10.1109/TMTT.2004.835916.

[2]. J. Cabello-Sánchez, V. Drakinskiy, J. Stake and H. Rodilla, “Capacitively-Coupled Resonators for Terahertz Planar-Goubau-Line Filters,” *IEEE Trans. Terahertz Science and Tech*, vol. 13, no. 1, pp. 58–66, 2023. doi: 10.1109/ TTHZ.2022.3220599.

[3]. J. Cabello-Sánchez, V. Drakinskiy, J. Stake and H. Rodilla, “A Corrugated Planar-Goubau-Line Termination for Terahertz Waves,” *IEEE Microwave and Wireless Components Letters*, In print, Feb. 2023. doi:10.1109/LMWT.2023.3239984.

[4]. J. Cabello-Sánchez, V. Drakinskiy, J. Stake and H. Rodilla, “On-Chip Characterization of High-Loss Liquids Between 750 and 1100 GHz,” *IEEE Trans. Terahertz Science and Tech*., vol. 11, no. 1, pp. 113 – 116, Jan. 2020. doi: 10.1109/TTHZ.2020.3029503.

[5]. A. Moradikouchi, A. Sparén, S. Folestad, J. Stake and H. Rodilla, “Terahertz frequency domain sensing for fast porosity measurement of pharmaceutical tablets,” *International Journal of Pharmaceutics*., vol. 618 (121579), 2022. doi:10.1016/j.ijpharm.2022.121579.

[6]. A. Moradikouchi, A. Sparén, O. Svensson, S. Folestad, J. Stake and H. Rodilla, “Terahertz Frequency-Domain Sensing Combined with Quantitative Multivariate Analysis for Pharmaceutical Tablet Inspection,” *International Journal of Pharmaceutics*., vol. 632 (122545), 2023. doi:10.1016/j.ijpharm.2022.122545.