Terahertz Biomedical Applications

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Abstract

Various medical applications using terahertz technology are presented. Examples include the dynamic imaging of skin drug absorption, the diagnostic imaging of cancers such as brain tumors and oral melanoma, and the analysis of blood substances. Measurement depth enhancement techniques for terahertz imaging are also discussed.

Terahertz (THz) imaging is a promising modality for medical diagnosis because it is non-ionizing, sensitive to water molecules, and capable of spectroscopic analysis [1]. In this presentation, various examples of medical imaging using THz radiation will be reviewed. First, the feasibility of THz dynamic imaging for visualizing serial changes in the distribution and penetration of a topical transdermal drug is demonstrated and compared with the Franz cell diffusion test [2,3]. Secondly, some cases of cancer imaging using THz radiation are shown, which include brain tumor and oral melanoma [4]. The THz imaging results are also compared with magnetic resonance (MR) imaging and conventional histology. Thirdly, the principle of terahertz molecular imaging (TMI) technique using nanoparticles is explained and the factors related to molecular imaging, such as sensitivity, resolution, and quantification property are characterized. The technique is applied to the diagnosis of cancerous tumors targeted with phase-conjugated nanoparticles and the distribution measurement of nanoparticle drug delivery to organs *in vivo* and *ex vivo* [5-7]. Lastly, THz imaging is also utilized to analyze blood non-invasively. The THz complex optical constants of blood and its constituents such as water, plasma, and red blood cells (RBCs) are measured and used to extract the concentrations of RBCs. To enhance the limited penetration depth of terahertz waves into biological tissues, several techniques have been devised and the measurement depth has shown to be improved by using bio-compatible agents [8]. In conclusion, the author believes that there are some points where terahertz imaging can contribute to the real-world medicine.

Acknowledgments

The author is grateful to the co-authors listed in references below for their contribution to the works presented here.

References

[1] J.-H. Son, “Terahertz electromagnetic interactions with biological matter and their applications,” *J. Appl. Phys.*, vol. 105, pp. 102033 1-10, 2009.
[2] K. W. Kim, H. Kim, J. Park, J. K. Han, and J.-H. Son, “Terahertz tomographic imaging of transdermal drug delivery,” *IEEE Trans. Tera. Sci. Tech.*, vol. 2, pp. 99-106, January 2012.
[3] K. W. Kim, K.-S. Kim, H. Kim, S. H. Lee, J.-H. Park, J.-H. Han, S.-H. Seok, J. Park, Y. S. Choi,1 Y. I. Kim, J. K. Han, and J.-H. Son, “Terahertz dynamic imaging of skin drug absorption,” *Opt. Express*, vol. 20, pp. 9476-9484, April 2012.
[4] Y. C. Sim, K.-M. Ahn, J. Y. Park, C. Park and J.-H. Son, “Temperature-dependent terahertz imaging of excised oral malignant melanoma," accepted for publication in *IEEE Trans. Inform. Tech. Biomed.*

978-1-4673-5225-3/14/$31.00 ©2014 IEEE

[5] S. J. Oh, J. Kang, I. Maeng, J.-S. Suh, Y.-M. Huh, Haam, S. and J.-H. Son, “Nanoparticle-enabled terahertz imaging for cancer diagnosis,” *Opt. Express* vol. 17, pp. 3469-3475, March 2009.

[6] S. J. Oh, J. Choi, I. Maeng, J. Y. Park, K. Lee, Y.-M. Huh, J.-S. Suh, S. Haam, and J.-H. Son, “Molecular imaging with terahertz waves,” *Opt. Express* vol. 19, pp. 4009-4016, February 2011.

[7] J. Y. Park, H. J. Choi, G.-E. Nam, K.-S. Cho, and J.-H. Son, “In vivo dual-modality terahertz/magnetic resonance imaging using superparamagnetic iron oxide nanoparticles as a dual contrast agent,” *IEEE Trans. Tera. Sci. Tech.*, vol. 2, pp. 93-98, January 2012.

[8] S. J. Oh, S.-H. Kim, K. Jeong, Y. Park, Y.-M. Huh, J.-H. Son, J.-S. Suh, “Measurement depth enhancement in terahertz imaging of biological tissues,” *Optics Express* vol. 21, pp. 21299-21305, September 2013.