Nanoparticle Contrast Agents for Terahertz Medical Imaging

Seung Jae Oh[a], Inhee Maeng[b], Hee Jun Shin[b], Jaewon Lee[c], Jinyoung Kang[c], Seunjoo Haam[c], Yong-Min Huh[d], Jin-suck Suh[d] and Joo-Hiuk Son[b*]
[a] Brain Korea 21 Project for Medical Science, Yonsei University, Seoul 120-752, Korea
[b]Department of Physics, University of Seoul, Seoul 130-743, Korea
[c]Department of Chemical Engineering, Yonsei University, Seoul 120-752, Korea
[d]Department of Radiology, College of Medicine, Yonsei University, Seoul 120-752, Korea
* email : joohiuk@uos.ac.kr

We show in this study that nanoparticle composites can be used as contrast agents to enhance the sensitivity of terahertz medical imaging. The terahertz reflection signal increases by nearly 50 % for the sample with nanoparticles upon near infrared laser beam irradiation. This is due to the hyperthermia effect induced by surface plasma polaritons. This technique facilitates cancer diagnosis with a micron resolution.

I. Introduction And Background

Terahertz (THz) imaging has been placed in the spotlight because of its potential as a new medical imaging modality. The sensitivity of THz electromagnetic (EM) waves to water molecules allows for the utilization of the THz technique in diagnosing cancers, because cancerous tumors contain more interstitial water within the afflicted tissues than the healthy tissues. The higher water content, combined with structural changes such as increased cell and protein density, yields a larger THz absorption and refractive index for the tissues with tumors.[1] However, this system has to be further developed to be adopted in the real world of clinical medicine. The highest contrast between normal and cancerous tissues is obtained at a frequency of 0.5 THz.[1] The use of this frequency will limit the lateral resolution, which THz imaging could have an advantage over conventional medical imaging technique such as magnetic resonance imaging (MRI), to a few hundred microns. The more serious problem with THz cancer diagnosis is the low contrast between normal tissue and the tumor unless the cancer is much developed. These limitations can be overcome if contrast agents are used in THz imaging, similar to the MRI technique.[2]

We have studied the interactions between THz EM waves and various nanoparticle composites for use as THz imaging contrast agents to enhance the sensitivity of cancer diagnosis by targeting the composites to tumors.[2,3] This will allow the use of higher frequency components of THz signals for better resolution. This technique will also help distinguish between cancerous tumors and inflammation that is not straightforward with an ordinary THz imaging technique.

II. Results and Discussion

We have fabricated two kinds of nanoparticles. One is the hydroxyapetitie gold nanocomposites (HGNC), composed of a hydroxyapetitie core and an outer thin gold shell, the other is the gold nano-rods (GNRs). These two kinds of nanoparticles are dispersed into de-ionized water. The THz responses of water with and without nanoparticles were measured using a reflection-mode THz time-domain spectroscopic system, which can also be used as a medical imaging setup. The THz reflection signals from the two samples (with and without HGNC) were almost identical. However, the peak reflection amplitude increased by nearly 50%, as shown in Fig. 1, upon near infrared (NIR) laser beam irradiation from a CW Ti:sapphire laser for the water with HGNC, although there was almost no change for water only. This arises from the water temperature increase due to the hyperthermia effect induced by surface plasma polaritons, because the refractive index of water increases as the temperature rises.

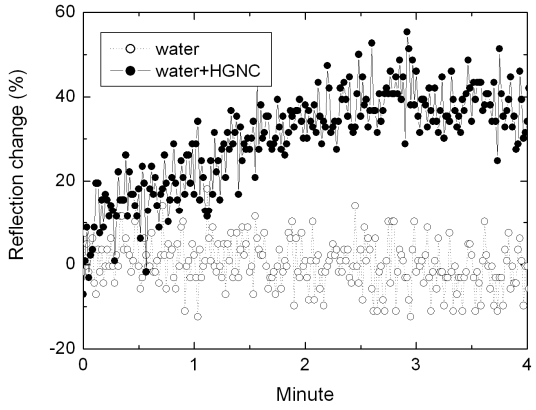

Fig. 1. The peak amplitudes of reflected THz signals from water (open circles) and the water with HGNC (closed circles) upon 800-nm CW laser beam irradiation.

We have also measued the THz reflection signals from water with and without GNRs upon the irradiation of NIR laser beam. The increase of NIR laser intensity raised the peak reflection amplitudes, as shown Figure 2.

We have bound the GNRs with epidermoid carcinoma A431 cell by electrostatic force between GNRs and the cells. As shown in Figure 3, the peak reflection amplitude increased upon the irradiation of NIR laser beam to the cancer cells with GNRs, although there was almost no change for cancer cells without GNRs. The change of peak reflection amplitude was nearly 20 % from the cancer cells with GNRs upon NIR laser irradiation.

978-1-4244-2120-6/08/$25.00 ©IEEE.

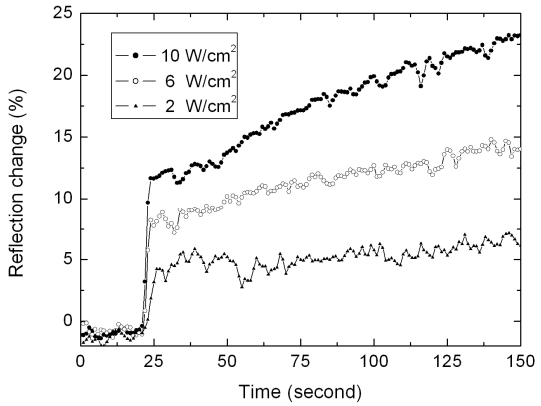

Fig. 2. The NIR power dependence of the peak amplitudes of reflected THz signals from water with GNRs, 10 W/cm^2 (closed circle), 6 W/cm^2 (open circle), 2 W/cm^2 (solid triangle).

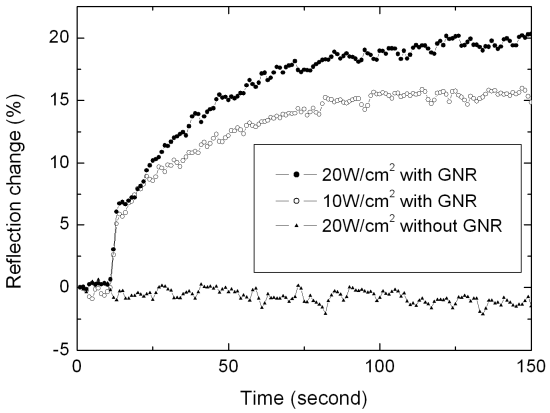

Fig. 3. The NIR power dependence of the peak amplitude of reflected THz signals from the living cancer cells with and without GNRs. 20 W/cm^2 with GNR (closed circle), 10 W/cm^2 with GNR (open circle), 20 W/cm^2 without GNR (solid triangle).

These results show that the highly sensitive THz medical imaging can be accomplished with nanoparticle contrast agents with an optical beam resolution.

III. Conclusion

We found that the huge sensitivity increase is possible in THz imaging with nanoparticle contrast agents which can be targeted to cancerous tumors. Since modulation occurs by the illumination of infrared laser beam, THz medical imaging can be realized with a micron resolution, thereby facilitating diagnosis of cancers at a very early stage.

References

[1] E. Pickwell and V. P. Wallace, *J. Phys. D: Appl. Phys.* **39**, R301 (2006).
[2] J.-H. Lee, Y.-M. Huh, Y.-W. Jun, J.-W. Seo, J.-T. Jang, H.-T. Song, S. Kim, E.-J. Cho, H.-G. Yoon, J.-S. Suh, and J. Cheon, *Nature Medicine* **13**, 95 (2007).
[3] J. Lee, J. Yang, H. Ko, S. J. Oh, J. Kang, J.-H. Son, K. Lee, S.-W. Lee, H. -G. Yoon, J.-S. Suh, Y.-M. Huh, and S. Haam, *Adv. Func. Mat.* **18**, 258 (2008).

978-1-4244-2120-6/08/$25.00 ©IEEE.