Terahertz Reflection Imaging of Hypertrophic Scar Tissue in Vivo

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***Abstract*—we use terahertz reflection imaging to measure hypertrophic scar tissue in vivo. The reflected terahertz wave from the scar tissue is significantly different from the reflected wave from surrounding healthy tissue. The absorption coefficient of both areas is calculated and shows that the absorption coefficient of the scar tissue is much lower than the healthy tissue. These data suggest that it could be possible to use in vivo terahertz imaging to quantitatively monitor the effectiveness of wound healing treatments.**

I. INTRODUCTION

TERAHERTZ light is sensitive to the hydration level in tissues as well as the structure. Several applications have been explored based on this fact including tissue type characterization [1] and skin burn wound sensing [2]. In this work we demonstrate terahertz reflection imaging of hypertrophic scar tissue in vivo.

A hypertrophic scar is a cutaneous condition characterized by deposits of excessive amounts of collagen which gives rise to a raised scar. It is reported that the collagen bundles of the hypertrophic scar are stretched and aligned in the same direction while in normal healthy skin the collagen bundles are relaxed and random in direction [3]. Investigating the difference between the scar tissue and the normal tissue helps to track the scar formation and monitor the efficiency of scar treatments.

II. METHODS

A commercial terahertz reflection imaging system was used in 30 degree reflection geometry. The image resolution was 0.5mm ×0.6mm. The scar is located on the elbow of a student who had a bicycle accident around 3 months before the imaging measurement. The image is acquired by resting the elbow on a piece of quartz imaging window for around 15 minutes. The scar was measured again two month later with the same method and imaging parameters.

III. RESULTS AND DISCUSSIONS

From the result of our first experiment, we find that the reflected terahertz signals from the hypertrophic scar tissue and the surrounding healthy tissue are different as shown by the time domain waveform in fig. 1 (a). The higher reflectivity of the normal tissue is due to its larger refractive index and suggests higher water content [2]. This point is further corroborated by calculating the absorption coefficient of the two types of tissues. Fig. 1 (b) plots the average absorption coefficient of the scar tissue and healthy tissue. The scar tissue has a much lower absorption coefficient than the normal healthy tissue and enables us to distinguish the two types.

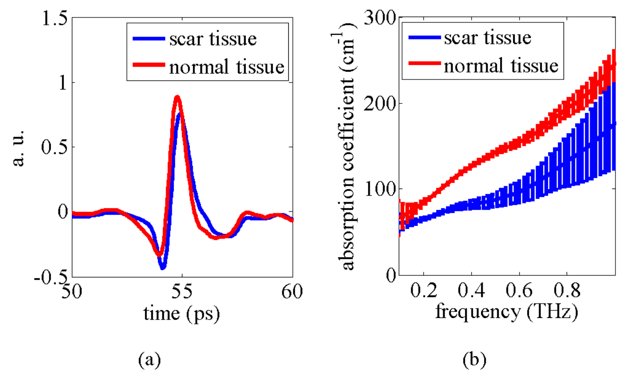

Fig. 1 (a) The time domain terahertz signals for the scar tissue and the normal tissue. (b) The absorption coefficient averaged over an area on the scar tissue and the normal tissue; the error bar is the standard deviation.

Fig. 2 shows a photo of the scar tissue and the corresponding terahertz image acquired by plotting the absorption coefficient at 0.45 THz for each measured pixel. The SNR of terahertz spectrum for our system peaks at 0.45 THz where the largest contrast is observed. The shape of the scar in the terahertz image differs slightly from that of the photo. This is most likely due to the scar being on the elbow as the exact shape of the scar depends on how straight the subject's arm is.

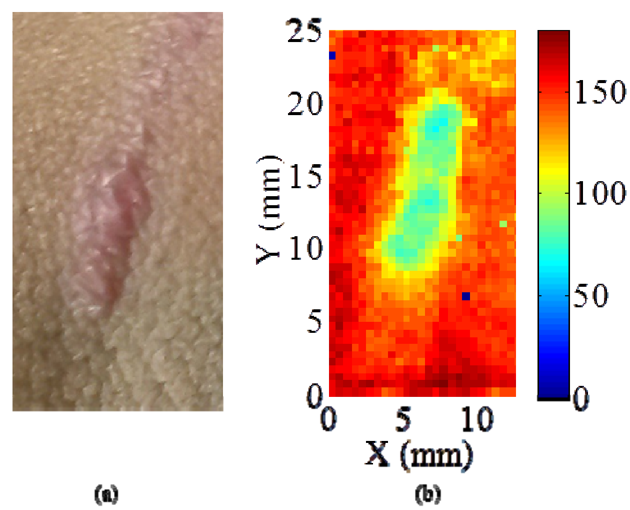

Fig. 2 (a) A photo of the scar and its surrounding healthy tissue. (b) A terahertz image of the scar acquired by plotting the absorption coefficient at 0.45 THz.

In our second experiment which is performed two months after the first one, the contrast in the absorption coefficient is not observed as is illustrated in Fig. 3(b). The visible image in Fig.3 (a) also indicates the healing of the scar: the scar has become less distinguishable from the healthy tissue. However, the scar tissue is still clearly different from its surrounding tissue in the refractive index (Fig. 3 (c)).

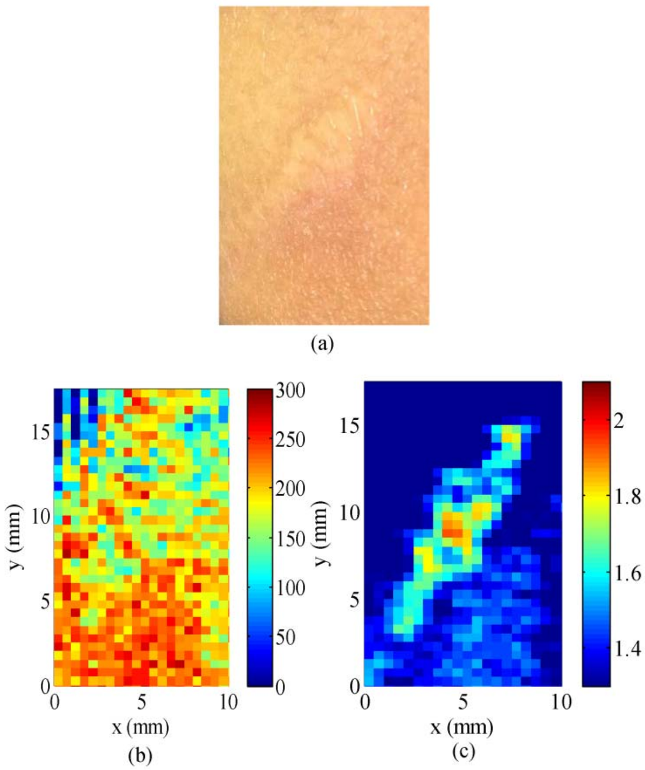

Fig. 3 (a) A visible image of the scar tissue, (b) the absorption coefficient and (c) the refractive index plot at 1 THz.

This finding corresponds with the studies in the dermatology area. The water evaporated from inside of the scar tissue is higher than that of the normal tissue because the injured stratum corneum (SC) layer of the scar tissue lost some of its water barrier function [4] .This barrier function will gradually recover with the healing process of the wound. The time needed for the water evaporation of a wound to return to normal is usually relevant to the depth of the wound [5]. Therefore, new scars and old scars are likely to respond differently in the terahertz range. Our current results indicate that in our first experiment the scar we measured is still very new and that the water barrier function of its SC layer is not fully recovered yet. In our second experiment, the water content in the wounded area returns to the normal level as the healthy tissue, indicating the recovery of its SC layer. The contrast in the refractive index is likely due to the structural difference of the scar from that of the healthy tissue as mentioned in the introduction: the collagen bundles align in different ways in the scar and the healthy tissue. Further experiments on the scar are needed to investigate the mechanism of contrast in the refractive index.

IV. Summary

We imaged hypertrophic scar tissue on the elbow with a commercial terahertz reflection system with 2 months' intervals. The scar tissue and surrounding healthy tissue give rise to significantly different reflected terahertz signals due to fundamental differences in their terahertz properties. The absorption coefficient is of particular interest as it gives insight into the hydration of the skin tissue. The results of our two experiments demonstrate that new scar and old scar have different terahertz response, and it can be well explained with the current findings in the dermatology area. Therefore, we may be able to use THz imaging to quantitatively monitor wound healing with a view to developing better scar treatments.

V. Acknowledgement

The authors thank the partial support from the Research Grants Council of Hong Kong (415313), and the CUHK Direct Grant (4055001).

References

[1] S. Huang, Y. Wang, D. Yeung, A. Ahuja, Y. Zhang and E. Pickwell-MacPherson, "Tissue characterization using terahertz pulsed imaging in reflection geometry," *Phys. Med. Biol.,* vol. 54, pp. 149, 2009.

[2] Z. Taylor, R. Singh, M. Culjat, J. Suen, W. Grundfest, H. Lee and E. Brown, "Reflective terahertz imaging of porcine skin burns," *Opt. Lett.,* vol. 33, pp. 1258-1260, 2008.

[3] T. Tuan and L. S. Nichter, "The molecular basis of keloid and hypertrophic scar formation," *Mol. Med. Today,* vol. 4, pp. 19-24, 1998.

[4] T. Suetake, S. Sasai, Y. Zhen and H. Tagami, "Effects of silicone gel sheet on the stratum corneum hydration," *Br. J. Plast. Surg.,* vol. 53, pp. 503-507, 2000.

[5] T. Suetake, S. Sasai, Y. Zhen, T. Ohi and H. Tagami, "Functional analyses of the stratum corneum in scars: sequential studies after injury and comparison among keloids, hypertrophic scars, and atrophic scars," *Arch. Dermatol.,* vol. 132, pp. 1453-1458, 1996.