In-vivo stratum corneum hydration inspection using a non-invasive terahertz hand-held scanner

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Terahertz (THz) light is a potentially powerful tool for medical applications in non-invasive tests [1]. This is primarily due to the strong interaction of water molecules present in biological agents. Additionally, the energy of THz photons (4.14 meV at 1 THz) is much lower than the energy necessary to impose any changes in the DNA, resulting in a safe technique. However, the strong absorption of water (200 cm^{-1} at 1 THz) prevents THz radiation from penetrating further than few tens of microns into living skin, making this technique better suited for the evaluation of epithelial tissues such as the skin. Since the early 2000's it has been suggested the use of THz light to inspect skin cancer evolution, as such disease is well known for changing the water levels of the affected areas [2]. Unfortunately, commercially available pulsed THz spectrometers are not designed to be used for medical applications. Using our own home-built hand-held THz scanner, we successfully measured the hydration dynamics and thickness of the most external layer of skin; the stratum corneum (SC) of 95 healthy volunteers accurately.

For the measurements, our hand-held system is placed in contact with the skin of the volar aspect of the forearms of the volunteers for 60 seconds. In that time, the scanner is able to record four THz pulses reflected from skin every second giving a total of 240 pulses for 60 seconds time lapse. Two pressure sensors are installed on the part of the scanner in contact with skin in order to ensure equal force of contact throughout the tests. The accumulation of water in the skin reduces the reflected amplitude of the THz pulse as function of time. This process is well known as occlusion and it can be used to study the dynamic hydration of skin or the effect of moisturizer products on it. The results of one volunteer are shown in Fig. 1.

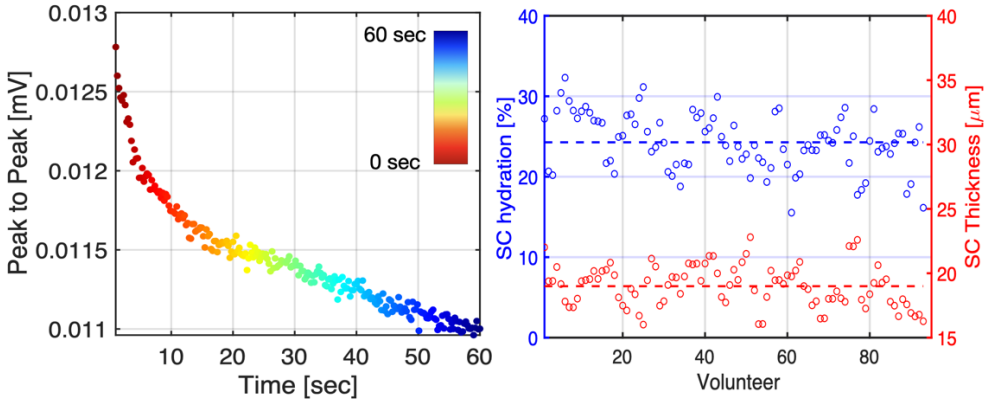

Fig. 1 (Left) Peak to peak amplitude of the THz pulses reflected from the volar aspect of forearm of one volunteer during the 60 seconds of the test showing qualitatively the dynamics of the occlusion of skin. (Right) Stratum Corneum (SC) hydration levels and thickness of the 95 volunteers 55 sec into occlusion.

This figure shows the change in amplitude of the reflected THz pulsed light from skin during the 60 seconds of the test (left). Additionally, by comparing the reflected pulses with our own mathematical model, the hydration and thickness of the Stratum Corneum (SC) can be retrieved in a non-invasive fashion. The results are shown in the right panel for the measurements taken 55 seconds into occlusion. These results indicate a thickness mean value (discontinuous lines) of 25 % for hydration levels whilst thickness reaching a mean value of 18 μm, agreeing reasonably with values reported in literature. The decrease in the peak to peak amplitude shown in the right panel indicate a rapid accumulation of water in the skin during the first 5 seconds whilst a more linear trend is observed afterwards, making THz methods a strong candidate for the inspection of water dynamics of skin in a safe mode.

References

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