T-ray technology reveals what's getting under your skin

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A demonstration of how the T-ray equipment can be used to scan an individual's skin. Credit: University of Warwick

A new method for analyzing the structure of skin using a type of radiation known as T-rays could help improve the diagnosis and treatment of skin conditions such as eczema, psoriasis and skin cancer.

Scientists from the University of Warwick and The Chinese University of Hong Kong (CUHK) have shown that using a method that involves analyzing T-rays fired from several different angles, they can build a more detailed picture of the structure of an area of skin and how hydrated it is than current methods allow.

Their method is reported in Advanced Photonics Research and could provide a new tool for scientists and clinicians for characterizing the properties of skin in individuals, to assist in managing and treating skin conditions.

Terahertz (THz) radiation, or T-rays, sit in-between infrared and WiFi on the electromagnetic spectrum. T-rays can see through many common materials such as plastics, ceramics and clothes, making them potentially useful in non-invasive inspections. The low-energy photons of T-rays are also non-ionizing, making them very safe in biological settings including security and medical screening.

Only the T-rays passing through the outer layers of skin (stratum corneum and epidermis) before being reflected back can be detected, as those traveling deeper are attenuated too much. This makes T-ray imaging a potentially effective way of monitoring these outermost layers. To test this, terahertz light is focused onto the skin via a prism, to align the ray in a particular focal plane. Depending on the properties of the skin, that light will be reflected back slightly differently. Scientists can then compare the properties of the light before and after it enters the skin.

There are limitations in standard THz reflection spectroscopy however, and to overcome these the scientists behind this new research instead used ellipsometry, which involves focusing T-rays at multiple angles on the same area of skin.

They successfully demonstrated that using ellipsometry they could accurately calculate the refractive index of skin (which determines how fast the ray travels through it) measured in two directions at right angles to each other. The difference between these refractive indices is termed birefringence—and this is the first time that the THz birefringence of human skin has been measured in vivo. These properties can provide valuable information on how much water is in the skin and enable the skin thickness to be calculated.

Professor Emma Pickwell-MacPherson, from the Department of Physics at the University of Warwick and the Department of Electronic Engineering at CUHK, said: "We wanted to show that we could do in-vivo ellipsometry measurements in human skin and calculate the properties of skin accurately. In ordinary terahertz reflection imaging, you have thickness and refractive index combined as one parameter. By taking measurements at multiple angles you can separate the two.

"Hydrated skin will have a different refractive index from dehydrated skin. For people with skin disorders, we'll be able to probe the hydration of their skin quantitatively, more so than existing techniques. If you're trying to improve skincare products for people with conditions like eczema or psoriasis, we would be potentially be able to make quantitative assessments of how the skin is improving with different products or to differentiate types of skin.

"For skin cancer patients, you could also use THz imaging to probe the skin before surgery is started, to get a better idea of how far a tumour has spread. Skin cancer affects the properties of the skin and some of those are unseen as they're beneath the surface."

Dr. Xuequan Chen, the study's first author and post-doctoral fellow from the Department of Electronic Engineering at CUHK, said: "T-rays have been known to be sensitive to the hydration level of skin. However, we point out that the cellular structure of the stratum corneum also reacts to the terahertz reflections. Our technique enables this structure property to be sensitively probed, which provides comprehensive information about the skin and it is highly useful for skin diagnosis."

To test their method, the researchers had volunteers place their arm on the imaging window of their T-ray equipment for 30 minutes, after acclimatizing to the ambient temperature and dryness of the laboratory. By holding their skin against the surface of the imaging window, they blocked water from escaping from their skin as perspiration, a process referred to as occlusion.

The researchers then made four measurements at right angles to each other every two minutes over half an hour, so they could monitor the effect of occlusion over time. Because T-rays are particularly sensitive to water, they could see a noticeable difference as water accumulated in the skin, suggesting that the method could show how effective a product is at keeping skin hydrated, for example.

Further research will look at improving the instrumentation of the process and how it might work as a practical device.

Professor Pickwell-MacPherson said: "We don't have anything that's really accurate for measuring skin that clinicians can use. Dermatologists need better quantitative tools to use, and use easily.

"If this works well you could go into a clinic, put your arm on a scanner, your occlusion curve would be plotted and a suitable product for your skin could be recommended. We could get more tailored medicine and develop products for different skin responses. It could really fit in with the current focus on tailored medicine."

More information: Xuequan Chen et al. Exploiting Complementary Terahertz Ellipsometry Configurations to Probe the Hydration and Cellular Structure of Skin In Vivo, *Advanced Photonics Research* (2020). DOI: 10.1002/adpr.202000024

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