# Experimental Characterization of Artificial Human Skin with Melanomas for Accurate Modelling and Detection in Healthcare Application

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***Abstract*— A preliminary investigation is carried out on the artificial human skin tissues with and without metastatic melanomas using Terahertz Time Domain Spectroscopy (THz-TDS). Both the refractive indexes and absorption coefficients of artificial skin with melanomas are higher than the normal artificial skin samples over the entire frequency range between 0.2 THz to 1.6 THz. The reason is that tumour cells degrade the contraction of fibroblasts causing more water content in malignant tissues. This study quantifies the impact of melanomas on the optical parameters of artificial skin tissue and can help in techniques that will diagnose and prevent tumours at the early stage.**

## I. INTRODUCTION

THz technology as a tool to detect the tumour has been widely studied in the breast cancer [1], skin cancer [2], and liver cancer [3]. Focusing on the skin cancer, the systematic spectroscopy study in THz properties of the basal cell carcinoma (BCC) and normal skin tissue was done in [4], which shows that the contrast in spectroscopy can help distinguish the normal and diseased skin tissues. However, the source mechanism for the contrast is not clearly understood. Besides BCC, there is a lack of study on other skin cancer types.

Skin can be divided into three main layers: epidermis, dermis and subcutaneous fat. Melanoma is one common skin cancer that begins in the melanocytes, which are present in the epidermis layer as shown in Fig. 1. Melanoma is dangerous because it is much more likely to spread to other parts of the body if not caught early. In our work, we study with WM1158, which is a highly aggressive melanoma cell line with mesenchymal morphology. In normal human skin, melanocytes are aligned at the basement membrane, separating the epidermis from dermis. However, WM1158 melanoma cells invade into the dermis layer [5].

With the extensive implementation of THz-TDS in characterizing biological tissues and detecting malignant tissues, we are motivated to precisely quantify the difference of THz parameters between artificial skin tissue with and without WM1158 melanomas.

Human skin fibroblasts cultured in a hydrated lattice of type I collagen appears to be a substitute for normal living dermis and it has been used as a replacement for human skin in various fields of skin biology [6]. The collagen lattice is contracted and water is squeezed out in the contraction process. In general, the collagen concentration and the number of cells determine the rate of contraction [6].

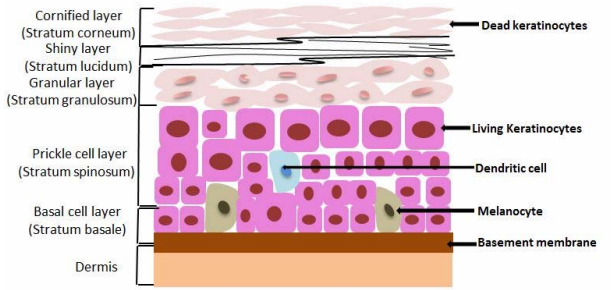


Fig. 1. The structure of epidermis.

## II. SAMPLE PREPARATION AND METHODS

The standard collagen mixture is made up in the following parts: type I collagen makes up 8 parts of final mix, 10X Minimum Essential Medium (MEM) makes 1 part and Fetal Bovine Serum (FBS) containing the desired number of fibroblast cells makes 1 part. Collagen lattices were made with a final collagen concentration of 2mg/ml. The reason for choosing 2mg/ml concentration is that the THz parameters of artificial skin with such collagen are closer to the real skin as demonstrated in [3]. The collagen lattices were cast in 12-well plastic dishes with 1ml of the lattice mixture.

In the normal skin tissue-like samples, $5 * 10^5$ fibroblasts solely were seeded in collagen solution and incubated for gelation at 37 °C, 5% $CO_2$ for approximately 15 minutes. While in the comparison ones, $2.5 * 10^5$ fibroblasts were cast in collagen solution to allow gel. After gelling, we added $2.5 * 10^5$ WM1158 melanomas suspended in 1ml RPMI (Roswell Park Memorial Institute) medium on the top of the comparison gels to make diseased samples. After 5 days' contraction, we conducted measurement on the samples.

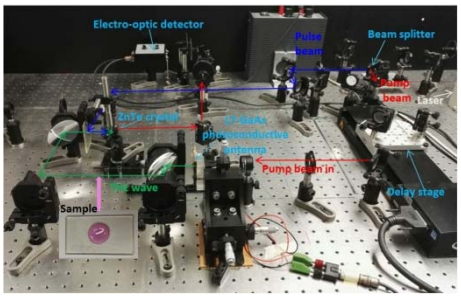


Fig. 2. THz-TDS in transmission mode at Queen Mary University of London

The THz-TDS in transmission mode used in our experiment is shown in Fig. 2. The details about the setup are presented in [7]. The artificial skin samples were placed on one TPX (poly-

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4-methyl pentene-1) plate and then mounted on a sample holder as shown in Fig. 2. Two duplicate samples of each case were tested and each sample was scanned three times.

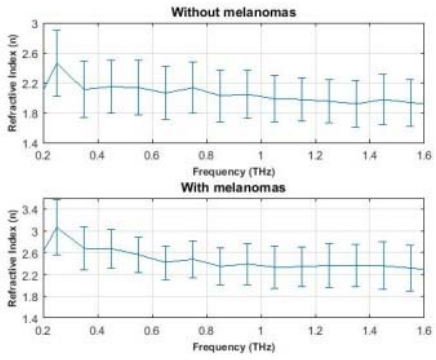
The original data measured by the spectroscopy system are time domain signals which are directly proportional to the THz electric field. Fourier transformation is performed on the time domain waveforms to recover both phase and amplitude information. The estimation of frequency-dependent refractive index $n_s$ and absorption coefficient $\alpha_s$ can be calculated as [8],

$$n_s(f) = n_0 - \frac{c}{2\pi f d}(\phi_{samp}(f) - \phi_{ref}(f)) \quad (1)$$

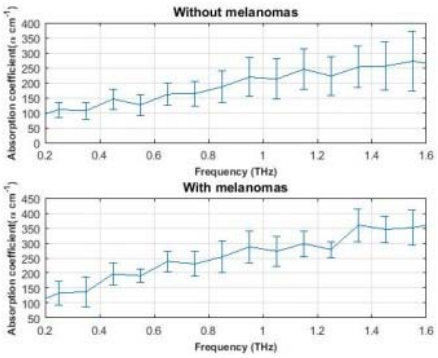
$$\alpha_s(f) = -\frac{2}{d}\ln(|H(f)|\frac{2\hat{n}_s(f)(n_0+n_T)}{(\hat{n}_s(f)+n_T)(\hat{n}_s(f)+n_0)}) \quad (2)$$

where $c$ is the speed of light in vacuum, $d$ is the transmission distance, $n_0$ is the refractive index of air, $n_T$ is the refractive index of the TPX material. $\hat{n}_s(f)$ is the complex refractive index of the measured material. $\phi_{samp}(f)$ and $\phi_{ref}(f)$ are the phases of the measured transmission coefficient over the reference material and sample, respectively. $H(f)$ is the transfer function which can be obtained from normalizing the sample spectrum by the reference. More detailed parameter extraction algorithms which can extract both complex refractive index and sample thickness simultaneously are provided in [8].

## III. Results and Discussion




(a) Refractive index




(b) Absorption coefficient

Fig. 3. The refractive index and absorption coefficient of artificial skin tissues with and without metastatic melanomas. The line and error bar represent the mean value and standard deviations of the optical parameters.

The obtained frequency-dependent refractive indexes and absorption coefficients of artificial human skin tissues with and without metastatic melanomas are shown in Fig. 3. It shows that the refractive indexes and absorption coefficients of artificial skin with melanomas are higher than the normal artificial skin samples over the entire frequency range between 0.2 THz to 1.6 THz. The reason is that tumour cells have a reduced capacity to contract lattices [9]. It means that less water is squeezed out from the tumours in the contraction process. The obtained results are in accordance with the lattice contraction and high sensitivity of THz signal to water.

## IV. Summary

This study finds the statistical mean and standard deviation of the refractive indexes and absorption coefficients artificial human skin tissues with and without metastatic melanomas in a THz band from 0.2 THz to 1.6 THz. Artificial skin samples with metastatic melanomas have higher refractive indexes and absorption coefficients than normal skin samples. The macroscopic reason is that the tumours contain more water than normal tissues, and the THz wave is sensitive to the water content. The intrinsic reason for the water contrast is that tumour cells have a reduced capacity to contract lattices, causing less water squeezed out in the contraction phenomenon. This quantification of the impact of melanomas on the optical parameters of artificial skin tissue can help in techniques that will diagnose and prevent tumours at the early stage.

## V. Acknowledgement

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