Mueller matrix polarimetry for dermatoscopic application

Dierk Fricke*, Lennart Jütte*, Merve Wollweber*, Bernhard Roth**

*Hannoversches Zentrum für Optische Technologien
**Cluster of Excellence PhoenixD

dierk.fricke@hot.uni-hannover.de

An epiluminescence microscope, the so called dermatoscope, is the standard device for non-invasive skin examination. It is used to generate images for an optical evaluation of skin diseases. The dermatoscope is known for its use in early diagnosis of skin cancer, but it is also employed to obtain a magnified view of skin areas in case of inflammatory skin diseases. To extend the 2D image information which is generated by the camera of a dermatoscope we present experimental skin polarimetry by applying the Mueller matrix (MM) formalism. In order to investigate the diagnostic power of the experimental setup, different skin phantoms were studied to correlate MM information with skin properties such as morphology.

1 Introduction

Dermatoscopes are the standard devices for skin examination. Most devices are contact-based and pressed on the skin during examination. In previous work, we proposed a non-contact dermatoscope [1,2] which has several advantages compared to a contact device. For example, it prevents pain in case open wounds or hypersensitive areas are examined and does not affect blood perfusion which usually leads to changes in the color representation and makes it more difficult to observe blood vessels in the upper skin layer. Also, our non-contact dermatoscope can be used both for diagnoses and documentation purposes. First results indicate its potential for diagnosis of inflammatory skin diseases [3].

2 The Mueller matrix

The 4 x 4 Mueller matrix (MM) describes the polarization changing properties of a sample (or optical element) [4]. If the MM is known, the outgoing Stokes vector $\vec{S}_o$ can be calculated vor every incoming Stokes vektor $\vec{S}_i$ which is interacting with the sample as follows:

$$\begin{pmatrix} \vec{S}_{o1} \\ \vec{S}_{o2} \\ \vec{S}_{o3} \\ \vec{S}_{o4} \end{pmatrix} = \begin{pmatrix} M_{11} & M_{21} & M_{31} & M_{41} \\ M_{12} & M_{22} & M_{32} & M_{42} \\ M_{13} & M_{23} & M_{33} & M_{43} \\ M_{14} & M_{24} & M_{34} & M_{44} \end{pmatrix} \cdot \begin{pmatrix} \vec{S}_{i1} \\ \vec{S}_{i2} \\ \vec{S}_{i3} \\ \vec{S}_{i4} \end{pmatrix} \qquad (1)$$

The MM contains all polarization changing information of the sample; however, the resulting matrix is not directly connected to its physical appearance. A polar decomposition [5] can be performed to interpret the measurements. For this purpose, the MM is expressed through matrices with known physical meaning such as a diattenuator, a retarder and a depolarizer.

The goal is to generate information about the structure of, for example, collagen which exhibits birefringence and, in some cases, a specific orientation in the tissue. In general, tissue polarimetry is an own field of research [6–8].

3 Mueller Matrix imaging

In MM imaging, a spatially resolved MM is measured. The outcome is 4 x 4 matrix of images, see Fig. 1.

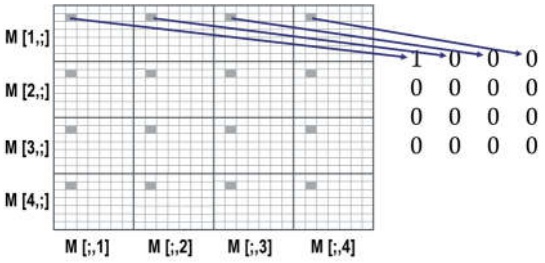

Fig. 1 *4 x 4 MM image matrix. The MM is measured for every pixel and therefore the measurement is spatially resolved. Every image from the matrix stands for a specific MM entry. (The MM on the right is only for illustrative purposes and displays the MM of an ideal diffusor.)*

To perform MM imaging in vivo, a system is required which can quickly measure the MM. It needs to be realized without moving parts, e.g. using liquid crystal retarders to generate and measure all different polarization states which are necessary to calculate the MM image matrix [9].

4 Experimental results

We investigated the potential to detect total orientation and degree of orientation based on the pro-

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cess parameters of electrospun fiber mats which are used for tissue engineering [10]. The current goal is to realize tissue implants with a gradient in the properties such as, for example, tensile strength. These polymer fibers are deposited on a rotating cylinder. Depending on the rotation speed, the degree of orientation is changing as can be seen with scanning electron microscopy (SEM), but not with the eye. Because SEM-imaging destroys the sample, we employ our system for non-invasive measurement of the process parameters after manufacturing.

Fig. 2 *Sample of an electro spun fiber mat. The sample consists of polymer fibers with diameters of 2-5 µm. Due to the fabrication process the fibers are oriented predominantly in one direction, not visible to the eye.*

Fig. 2 shows an image of such a sample and Fig. 3 the measured MM image matrix, which resembles that of an ideal diffusor. However, in the data we find a signal, for example, in the matrix entry M [4,1]. Its value depends on the degree of polarization as well as the orientation of the sample.

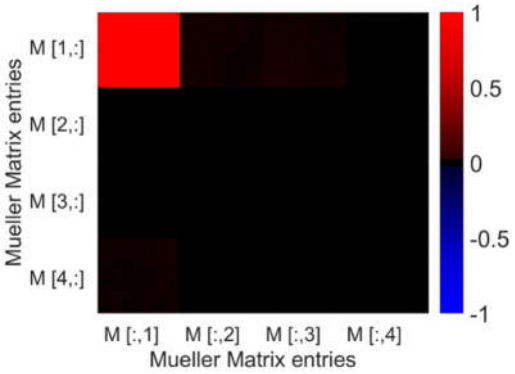

Fig. 3 *MM image matrix of the electro spun fiber mat. The matrix looks homogenous, similar to that of an ideal diffusor (see right part of Fig. 1), as expected from Fig 2.*

The signal is small but reproducible and seems to be correlated with the process parameters. With this signal the overall orientation of the fibers in the sample can be determined.

5 Conclusion and Outlook

We presented a method to extract information from a sample based on Mueller matrix polarimetry. The system can measure the MM *in vivo*, i.e. in a fast way, without using moving parts. Polarization states are generated and measured electronically by applying a voltage to liquid crystal retarders. Samples of electro spun fiber mats are investigated to verify the potential of the system to obtain additional information on orientation of small constituent structures. The results suggest that it is possible to reliably analyze these samples in a non-destructive way.

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