Towards multimodal melanoma depth determination with optoacoustics and optical coherence tomography

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We produced polyvinyl alcohol hydrogel phantoms including polystyrol microspheres and melanin to mimic human skin. Measurements with a self build optoacoustic setup and OCT on the same layered sample proved the feasibility of a combined device.

1 Introduction

Malignant melanomas are one of the most deadliest types of cancer. In Germany alone, 24,500 new cases of melanomas are expected in 2016 [1]. One of the most important figures in skin cancer staging is its thickness. If the penetration depth exceeds 1 mm the risk of the dermo-epidermal junction being breached and thus the likelihood of metastases is notably higher. Despite malignant melanomas being common and hazardous no device has yet emerged for the safe in vivo thickness determination. Here we attempt to combine optoacoustics (OAs) [2] and optical coherence tomography (OCT) [3] for this purpose. Both methods are well suited to assist histopathologists in measuring infiltration depth of melanocytic skin lesions in vivo. Combining in vivo data and the histopathology standard could help minimizing the errors in tumor assessment of malignant melanomas in the future.

2 PVA hydrogel phantoms

The imitation of human skin for combined measurements of OAs and OCT requires a tissue phantom to be matched acoustically as well as optically. Due to the high water content of skin and living tissue in general, hydrogels are well suited to emulate their acoustic properties, see Fig. 5. By addition of scattering and absorbing agents the optical properties of the sample can be tuned.

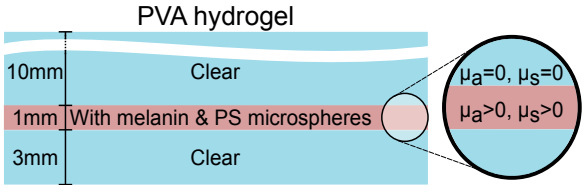

Fig. 1 *Sketch of layered hydrogel tissue phantom. The first 10 mm thick layer (blue) is transparent. Only the 1 mm thick layer containing melanin and polystyrene (PS) microspheres (red) contributes to the signal for both modalities. μ_a and μ_s represent the absorption and scattering coefficient of the sample, respectively.*

3 Optoacoustics

Optoacoustics is a measurement technique which combines the optical contrast of absorption with the high resolution of ultrasound signals. When a short laser pulse is absorbed, a fraction of the energy is converted into pressure by thermoelastic expansion. From the excited source volume this mechanical stress wave travels in all directions and can be detected. The detector, in our case, is based on a 9 µm thick piezoelectric PVDF film, see Fig. 2. Optically transparent indium tin oxide (ITO) conductors are sputtered with a thickness of ∼50 nm on both sides of the film with an overlapping circular region. This enclosed volume becomes a piezoelectric capacitor which is sensitive to pressure variation.

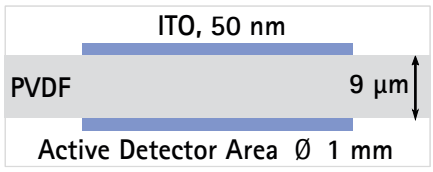

Fig. 2 *Sketch of PVDF-based OA detector.*

The detector transforms the acoustic signal to a voltage, which is amplified and recorded. The OA transient contains information about the geometry of the absorber. While in the near field the pressure profile resembles the absorbed energy distribution, acoustic diffraction transforms the profile in the far field [4]. The leading compression peak and the trailing rarefaction dip correspond to the beginning and end of the absorbing layer, respectively.

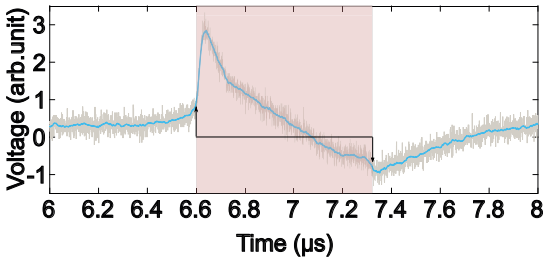

Fig. 3 *OA signal: raw data in light gray and smoothed data in blue. Red box: absorbing layer (guide to the eye).*

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4 Optical coherence tomography

OCT is an interferometric technique which uses short coherent light to investigate the sample. For Fourier domain OCT the depth profile is encoded in the phase of the backscattered light. The correlation of the sample and the reference arm yields a pattern which is Fourier transformed to a depth profile (A-scan). By scanning in one direction a cross-sectional image (B-scan) is obtained. We use a spectral domain OCT imaging system at 1325 nm central wavelength with an axial resolution of 5.5 µm in air. The maximal penetration depth of the signal in skin is approximately 1.3 mm, highly depending on the skin structure (e.g. a thick stratum corneum layer results in a high reflection attenuating the signal in the layers below). Since OCT allows for non-contact, non-invasive, and label-free imaging it is widely used in biophotonics and especially in medicine. Live in vivo images provide structural information of pathologic changes in tissue. We use OCT as a modality for determination of skin infiltration depth of malignant melanoma.

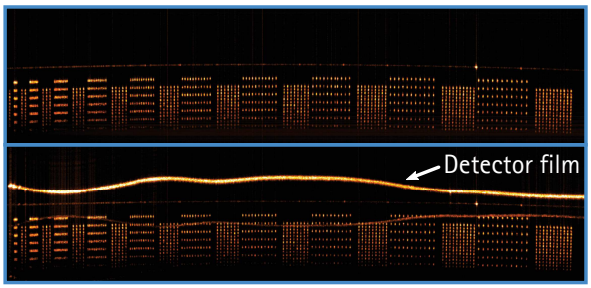

Fig. 4 *OCT image of a measurement standard (top) with and (bottom) without the OA detector film on top. Losses caused by the detector film are less than 10 %.*

5 Combined Measurement

Resulting from the layer symmetry of the sample, OA measurements yield the same result independent of their lateral position. As can be seen in Fig. 5 the resulution of the OCT is high enough to resolve individual clusters of scatterers. The OA signal, on the other hand, averages laterally over several millimeters, thus potential clusters of absorbers are not visible. In the phantom preparation process water is dispersed on the layers before they are stacked. Since the refraction indices of water and hydrogel differ, thin films of water remaining between layers result in increased reflection, highlighting the boundary in the OCT. The aim of our work is to detect boundaries on the basis of changes in scattering and absorption only. Thus, in the next step, we are working on removing the water films to obtain a more realistic phantom.

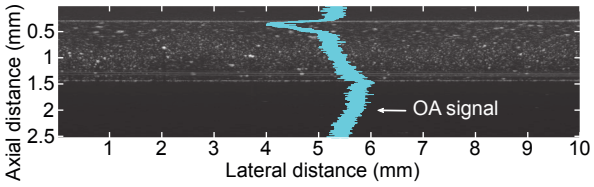

Fig. 5 *Combination of OCT and OA measurement on a hydrogel tissue phantom.*

6 Summary and Conclusions

We successfully created layered PVA hydrogel phantoms including PS microspheres as scatterers and melanin as absorber agent. By using the high resolution OCT and the self build OA device we managed to overlay the measurements and thus combined the fundamentally different contrast agents of the two modalities. Future challenges will be the calibration of the individual modalities to obtain the absolute depth and the integration into one single device. Following the validation of the technique on phantoms, clinical measurements are intended.

Acknowledgments

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References

[1] *Krebs in Deutschland 2011/2012* (Robert Koch-Institut (Hrsg) und die Gesellschaft der epidemiologischen Krebsregister in Deutschland e.V., 2015). URL `http://edoc.rki.de/docviews/abstract.php?id=4119`.

[2] L. V. Wang and S. Hu, "Photoacoustic tomography: in vivo imaging from organelles to organs," Science (New York, N.Y.) **335**(6075), 1458–1462 (2012).

[3] T. Gambichler, I. Plura, M. Schmid-Wendtner, K. Valavanis, D. Kulichova, M. Stücker, A. Pljakic, C. Berking, and T. Maier, "High-definition optical coherence tomography of melanocytic skin lesions," Journal of Biophotonics **8**(8), 681–686 (2015). URL `http://dx.doi.org/10.1002/jbio.201400085`.

[4] E. Blumenröther, O. Melchert, M. Wollweber, and B. Roth, "Detection, numerical simulation and approximate inversion of optoacoustic signals generated in multi-layered PVA-H based tissue phantoms," (2016). (unpublished), `arXiv:1605.05657`.