Micromachined Millimeter-Wave Near-Field Probe for Skin Cancer Diagnosis

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A reliable tool for skin cancer screening could help to cope with the increasing numbers of malignant skin tumors (>76 000 new cases of malignant melanoma in the USA in 2014, 2.7% yearly increase) by enabling higher patient throughput and early diagnosis and thus saving the lives of many patients while decreasing the cost for the healthcare system. The permittivity of cancer tissue differs from healthy tissue, thus microwaves reflection measurements, can be used for skin cancer diagnosis [1]. In this project a millimeter-wave near-field probe based on micromachined, metallized silicon-core, tapered dielectric rod waveguide interfaces was developed. The probe operates from 90 to 106 GHz and, unlike conventional open waveguide probes, its sensitivity and sensing volume are well adapted to early diagnosis of skin cancer. Fig. 1 shows a schematic of the probe as well as a photograph of a fabricated prototype.

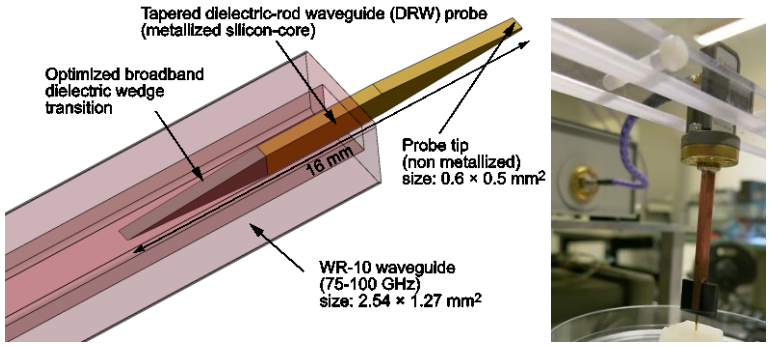

Fig. 1: (a) Millimeter-wave near-field probe developed for early stage skin cancer diagnosis [2]; (b) Photograph of fabricated prototype.

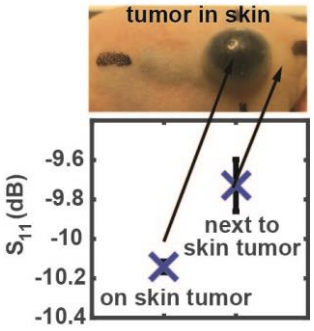

Fig. 2: Results of second round of murine skin tumor model measurements.

As a first probe evaluation step, prototype measurements on tissue-mimicking samples had been conducted [2] and it was verified that the probe combines high sensitivity and sub-wavelength resolution.
Furthermore, standardized dermatological tests with measurements on chemically induced skin irritation were conducted under the supervision of a dermatologist. The probe's measurement results were compared to a commercial instrument which evaluates the skin barrier damage; results show that the millimeter-wave probe is able to monitor the recovering of the skin from the irritation over long time [3, 4].
To demonstrate the probe's capability of identifying malignant melanoma skin tumors, measurements on murine tumor models were conducted. First a murine model that represents realistic skin tumor growth had to be established through three rounds of experiment. For the model 1 x 10^6 B16F10 murine melanoma cells in 20 µl PBS were injected into the skin of female athymic Nude-Foxn1^{nu} mice and grew into tumors with a diameter up to 1 cm within 7 to 9 days. The results are currently analyzed and are planned to be published as a journal publication. Preliminary results from the second round of experiments on murine skin tumor models (Fig. 2) will be presented at the *41th International Conference on Infrared, Millimeter, and Terahertz Waves (IRMMW-THz)* in Copenhagen in September 2016 [5].

[1] Töpfer, F. and Oberhammer, J., "Millimeter-Wave Tissue Diagnosis: The Most Promising Fields for Medical Applications," *IEEE Microwave Magazine*, vol. 16, no. 4, pp. 97–113, May 2015.
[2] Töpfer, F., Dudorov, S., and Oberhammer J., "Millimeter-Wave Near-Field Probe Designed for High-Resolution Skin Cancer Diagnosis," *IEEE Transactions on Microwave Theory and Techniques*, vol. 63, no. 6, pp. 2050–2059, Jun. 2015.
[3] Töpfer, F., Emtestam, L., Oberhammer, J., "Dermatological verification of micromachined millimeter-wave skin-cancer probe," *2014 IEEE MTT-S International Microwave Symposium (IMS 2014),* 1-6 June 2014 (Oral presentation: finalist for Best Student Paper Award)
[4] Töpfer, F., Emtestam, L., and Oberhammer, J., "Long-Term Monitoring of Skin Recovery by Micromachined Microwave Near-Field Probe," *IEEE Microwave and Wireless Components Letters* (submitted).
[5] Töpfer, F., Emtestam, L., and Oberhammer, J., "Diagnosis of Malignant Melanoma by Micromachined Near-Field Millimeter-Wave Probe," *41th International Conference on Infrared, Millimeter, and Terahertz waves (IRMMW-THz)*, Copenhagen, 2016, pp. 1-2 (accepted for oral presentation).

Impression on attending the IMS, career plans and the impact of the fellowship

The International Microwave Symposium in Phoenix in 2015 was the third IMS that I attended. Every time I am impressed by the high quality of the presented research. I highly value the conference as an outstanding opportunity to (re)connect with other researches in the field and to engage in fruitful discussions and exchange thoughts and experiences.
It was a great honor to receive the IEEE MTT-S Graduate Fellowship award for my research. It is a great motivation to continue research and development in the field of medical applications of microwaves and reassured me that valuable ideas are recognized and can attract ideal and financial support.
In the future I want to continue to use my engineering knowledge and experiences to develop solution that benefit patients, doctors and the healthcare system. As a first step, after my PhD project I will participate in the Clinical Innovation Fellowships Program, during which I, together with a multidisciplinary team, identify clinical needs by field observation directly in a hospital department. Based on these, our team will develop an innovative solution to a medical problem for which my experience from the PhD project provides a perfect background. I strongly believe that the recognition through the IEEE MTT-S Graduate Fellowship helped me to stand out from the other applicants for this program and to be chosen as a Clinical Innovation Fellow Candidate and that it will continue to have a positive impact on my career.