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Flexible POFF sensors for decubitus prevention

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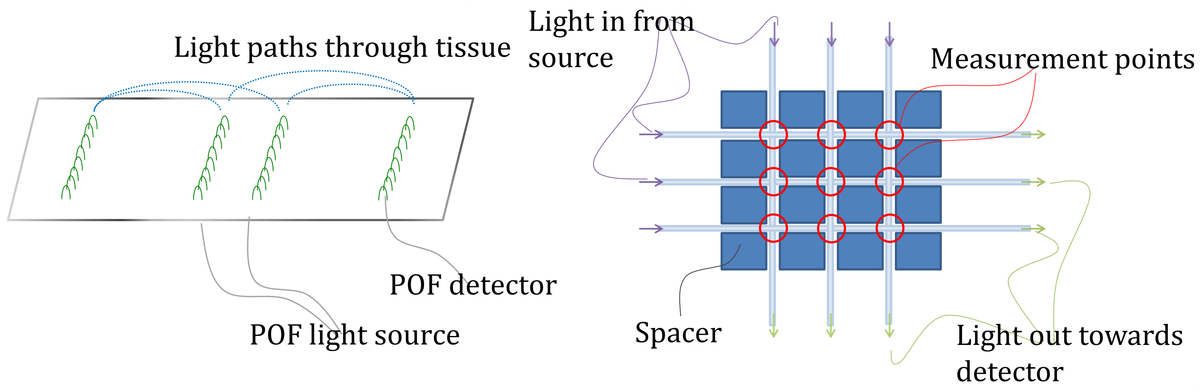
EMPA Materials Science & Technology

ETH Eidgenössische Technische Hochschule Zürich Swiss Federal Institute of Technology Zurich

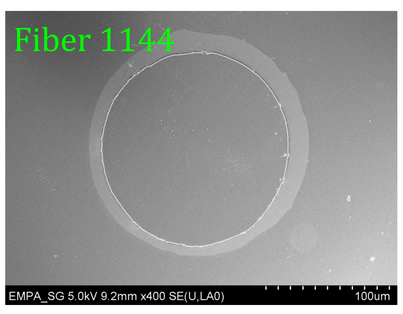
Introduction

Decubitus ulcers are still widely spread among paraplegics due to incomplete understanding of the mechanisms of tissue breakdown. Among others, threshold values for minimum oxygen saturation, blood perfusion and maximum load on the tissue over time are unknown. These are to date considered to be main causes of pressure ulcers. To help develop prevention protocols, textile low-friction measurement set-ups need to be developed for long-term measurements. Here, we present a sensor design based on polymer optical fiber fabrics (POFFs) for the prevention of decubitus ulcer formation.

Schematics for both sensing setups

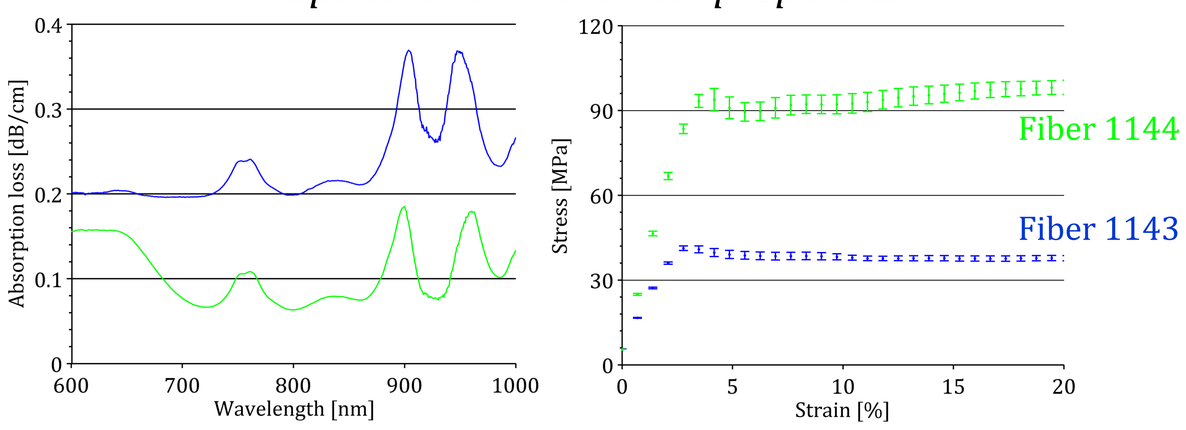


Bi-component fibers for perfusion and SpO_2 measurements



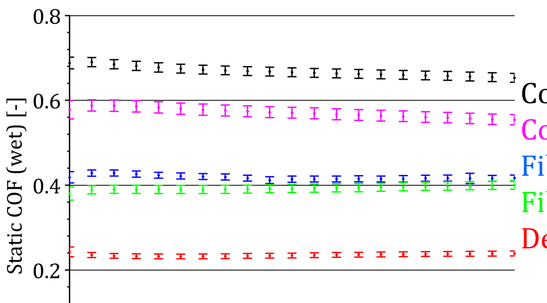
The fibers 1143 and 1144 are co-extruded at 300 and 400 m/min respectively, thus allowing for fast and continuous production. Both core and cladding are commercially available. The fluorinated polymer for the cladding makes the fiber highly resistant to environmental influences and allows for total light reflection inside the fibers' core.

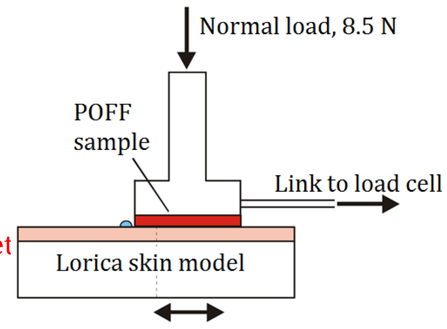
Optical and mechanical properties



Textile Friction Analysis (TFA)

The optical fibers were embroidered onto a newly-developed bedsheet (Empa/Schoeller) to determine the static coefficient of friction (COF) in wet and dry conditions to validate low friction compared to standard textiles. This could prevent the occurrence of additional pressure spots.

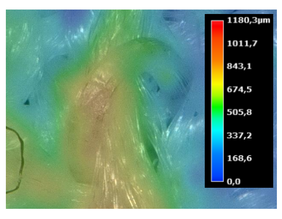


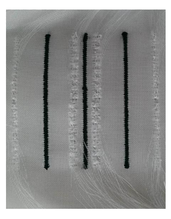


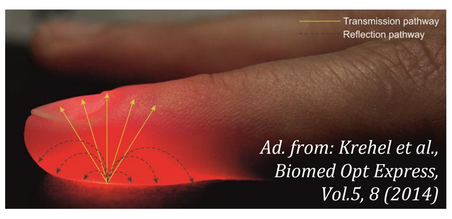
Ad. from: Derler et al.,Tribol Int, 46 (2012), 208-214

Prototype and functionality of light reflectance sensor

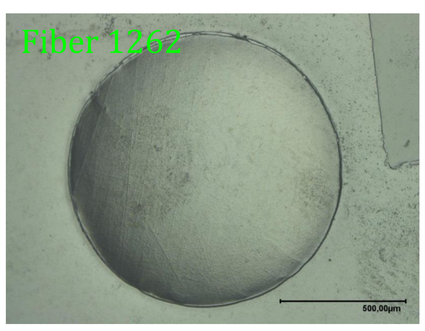
The high flexibility of the optical fibers allows for tight bends which then out-couple light into the tissue. Using two wavelengths, the ratio of oxygenated and deoxygenated hemoglobin can be determined. The sensor is used in reflection mode to be feasible on all body parts.

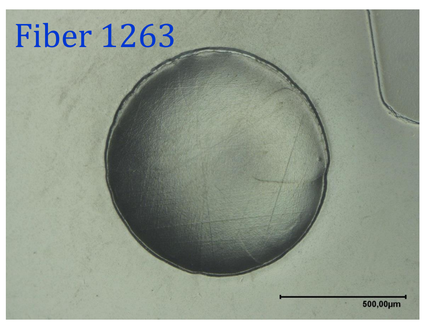






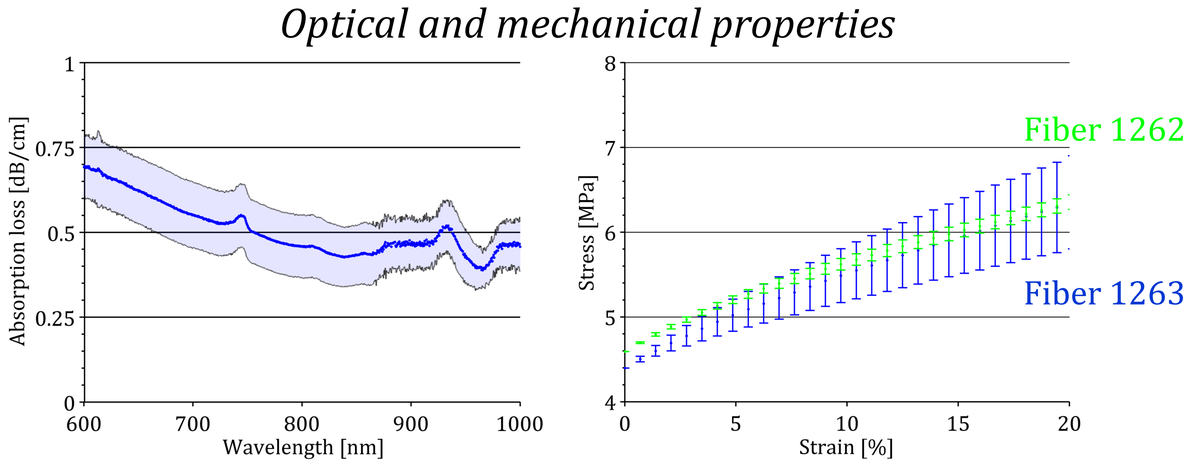
Mono-component fibers for pressure measurements





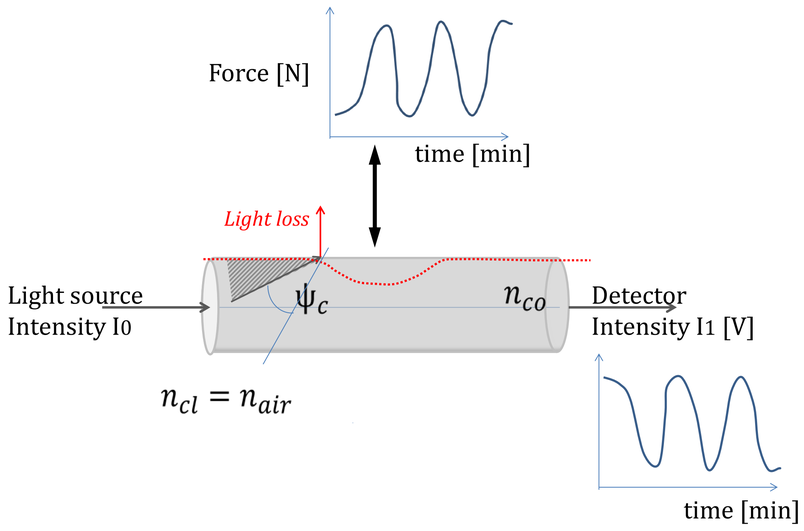
The fibers are extruded from a commercial block copolymer containing urethane and siloxane units. As a mono-component fiber without cladding, they are highly susceptible to light-outcoupling as schematically pictured below.
The fibers' diameters and mechanical properties vary with extruding temperature, cooling conditions and roll-off speed. Additionally, the chain length of the siloxane block has been varied. With longer chains, the pressure sensitivity increased dramatically.

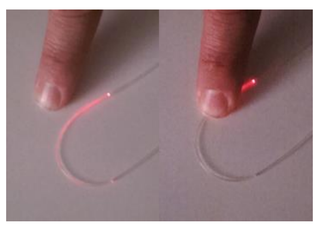
Optical and mechanical properties

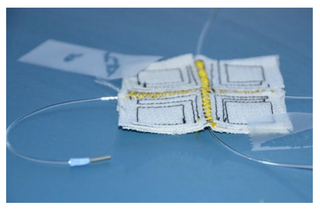


Prototype and functionality of pressure sensor

The polymer optical fibers can be used as pressure sensors as changes in the cross-section of the fibers lead to light intensity changes at the detector. Specifically, the light is out-coupled at the introduced micro-bends. Such, with calibrated fiber sensors, the applied load can be measured.







Conclusion and Outlook

Both blood pulsation and pressure have been logged in preliminary demonstrations with the proposed optical fibers developed at Empa. These show sufficient flexibility as well as strength as they can be embroidered on commercial textile machinery. Additionally, they maintain their light-guiding properties. Here we presented the mechanical and optical properties as well as friction coefficient of newly-developed polymer optical fibers. These measurements show that the optical fibers can be recommended for decubitus prevention long-term measurements due to their overall performance.

We would like to thank Benno Wüst for his invaluable insights into the practical aspects of fiber extrusion and his investment during fiber production as well as Eugen Zgraggen for his help with setting up the attenuation measurements.

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