SHORT TERM SCIENTIFIC MISSION (STSM) SCIENTIFIC REPORT

This report is submitted for approval by the STSM applicant to the STSM coordinator

Action number: CA17107
STSM title: Smart textiles with optical fibre implementation for in-situ measurement of friction, compression, deformation
STSM start and end date: 20/01/2020 to 08/02/2020
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PURPOSE OF THE STSM:

(max.200 words)
The stay at Empa lasted three weeks. The aim was to meet the researchers working on the manufacture of polymeric optical fibers in this laboratory. I was able to understand how they manufacture the different optical fibers and the different technologies. As a reminder, fibres can be made by melt-spinning, wet-spinning, moulding.

The goal was also to share my textile knowledge. So I explained to them the different textile manufacturing processes, as well as the different possibilities to insert optical fibres for each process.
I also had to understand the fibre coupling process they were using, the different tools used to characterize optical fibres and the use of electronics to process information from fibre optic sensors.

The LPMT is located in Mulhouse on the UHA campus of the textile engineering school ENSISA. ENSISA is an engineering school with five specialties including the specialty "Textile and Fibers ». LPMT is specialized in the development and characterization of materials and manufacturing processes for fibrous structures, from the nanometric to the macroscopic scale. The LPMT works in collaboration with Empa on projects involving optical fibers.

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DESCRIPTION OF WORK CARRIED OUT DURING THE STSMS

(max.500 words)
For several years, Empa has been developing polymeric optical fibers (FOPs) of different diameters, materials and mechanical and optical properties (developed later in the text) to design their own sensors using these FOPs. Several applications have been explored:

- Respiration : supervision and aid
- Respiration : lung volume assessment
- Cardiac output : measurement of hearthbeat and rate
- Blood pressure
- Blood : flow, perfusion of tissues, hemoglobin volume, saturation of oxygen in tissue and arteries
- Pressure on tissue, loading of cutaneous tissue layers
- Shear stress on and in tissues
- Mobility and gait analysis

Empa produces different types of polymeric optical fibers using different methods. The technique they use most is polymer melt spinning. The molten or solution polymer is first pushed through a spinneret with up to 100 holes of about one millimeter in diameter, through which the flow rate must be as uniform as possible. Another technique they use is moulding. A mould is filled with polymer, the support is closed and heated so that the polymer solidifies. So the polymer is completely amorphous because it's not stretched. The shape can be a very thin hollow cylinder to make an optical fibre for example. Empa uses Poly (siloxane-co-urethane), PMMA, PC, PDMS.

Fiber optic-based systems consist of a light source, a transducer and a detector. When the transducer (optical fiber) is disturbed (deformation, compression,...) the luminous flux inside the fiber is modified. This modification of the flux changes the light path of the light and thus increases the light loss (intrinsic or extrinsic). The detector (photodiode) detects the drop in luminosity at the output of the fibre by a decrease in the light power (overall or only certain wavelengths). The computer receives this information and converts this difference in light power into a mechanical quantity defining the disturbance. For example, if the fiber undergoes bending, the computer finds the angle of curvature in relation to the measured light power.

Empa has a wide range of equipment for characterizing materials such as optical fibers. They also possess laser diodes of different wavelengths, as well as different photodiodes associated with these wavelength. For light power measurement they have access to two multimeters. They own is the P-9710 from Gigahertz-Optik. These two devices, coupled with light power measuring heads, allow the measurement of optical power from a continuous or pulse source. They can display the light power of a defined wavelength. Finally, by connecting it to an oscilloscope it is possible to record light variations over a period of time.

To connect the fiber optics with the LED and photodiode, Empa uses a ThorLabs SMA905 connector. This connector is either used with a BFT1 ThorLabs clamp.

The LPMT (my laboratory) has the advantage of being a textile laboratory and therefore has several textile production machines. Weaving machines, knitting machines, braiding machines, etc. can be found here. With my experience I have already been able to present this machine park to Empa researchers and the various possibilities for inserting optical fibers into a textile.

DESCRIPTION OF THE MAIN RESULTS OBTAINED

The results obtained on the integration of POFs in textiles were presented through an oral presentation. This presentation covered all the different textile processes for inserting an optical fiber into a textile. For each process, a list of advantages and disadvantages was listed. Ideas and important points were also added for each process. Some processes are potentially feasible and others are not. Among the feasible processes are weaving, knitting, braiding and embroidery.

Weaving allows the optical fibers to be inserted in warp and weft, which makes it possible to cross optical fibers if necessary. Weaving is a very difficult process for the fibres because there are many high tensions applied to the fibres. As weft, drawbacks are frictions between the reed and the cladding of the optical fibre, and between textile fibres and the optical fibre. It's difficult to have an access to the fibre and there are microbending of the optical fibre inside the textile. But it is a quick and simple process.
Some possibilities can be identified such as the type of yarn selection (patterning by Jacquard or harnesses) and the type of weft insertion (shuttle, rapier, ...)
3D weaving is also possible. The optic fibre can be inserted between the 2 layers of warp to be protected and doesn't have microbending. And the optic fiber can bend over the warp layer to have a more easy access for the connection.

Knitting is another way to make textile surfaces. The advantages are the easy modification of the needles bed so the textile width. The possibility to insert the optic fibre inside the textile by laying in and the possibility to knit a 3D structure. And locally integrate the optical fibre for a few number of loops. But the machine needs long rolls of filament and the loop generation creates sharp angles. So there are outcoupling of the light in unnecessary areas.

Stitching is a process to integrate the optical fibre on the textile and not inside. The advantages are the deposition angle of the fibre material. It can vary between 0° and 360° in the plane of reinforcement. Very little development is required. There is a low waste and optimum material utilization. And it's possible to process different materials. But the problems are the tension on the optic fibre due to the sharp angles and the friction between the fibre and the needle.

Finally, braiding is a textile process to make ropes. It's possible to insert fibres inside as core. These fibres can be optical fibres, copper wires, ... It's possible to make partly open-braided yarn to have an access to the core yarn. And it's a fast process for different diameters. But there are tension and compression on the optic fibre inside. So the idea with this process is to use the braiding like a cladding to protect the fibre and reduce the pressure from outside. It can be useful when the optic fibre is sticky and for the integration in process like weaving, knitting, ...

FUTURE COLLABORATIONS (if applicable)

Before I return to Empa, I should work at the LPMT on the fiber-optic coupling. Indeed, coupling is a key point in smart textile design because the connector represents a bridge between the light source, the optical fiber and the photodiode. If the connections are not correct, it will be difficult to measure a reliable signal so have a reliable sensor.