A bioinspired flexible optical sensor for force and orientation sensing

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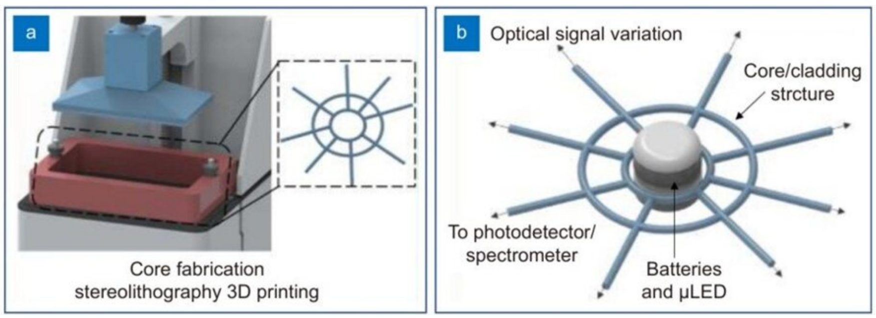

Figure 1. (a) Schematic representation of the core/cladding fabrication using stereolithography 3D printing technique. (b) Representation of the batteries and µLED assembly in the structure. Credit: Compuscript Ltd

Recently, flexible optical waveguides made from elastic polymer have been intensively explored due to their excellent physiomechanical properties and sensing performance together with low cost, reliability and potential for large scale fabrication. Typically, elastic polymer waveguides with a core-cladding structure are fabricated using molding, coextrusion or dip coating methods. By measuring the output intensity of the waveguide, the exerted force or deformation can be obtained.

For instance, a soft prosthetic hand equipped with multiple flexible optical sensors can feel the shape and softness of tomatoes. The other prominent example is a stretchable distributed fiber-optic sensor enabled glove, which can reconfigure all types of finger joint movements and external presses simultaneously.

It is worth noting that most of the reported flexible optical sensors use a one-dimensional structure, which makes it difficult to sense the force and orientation simultaneously. To address this issue, scientists can employ fiber array to construct a diffuse light field, which can be decoupled through machine learning techniques, or use two flexible fibers with a crossed-over layout, to form a multiaxis sensor. However, the relatively large size of these sensors may limit their practical applications in wearable sensors or space-confined scenarios.

In a recently published paper in *Opto-Electronic Advances*, Carlos Marques and his colleagues at University of Aveiro and Federal University of Espírito Santo report a bioinspired multifunctional flexible optical sensor (BioMFOS) as an ultrasensitive tool for force (intensity and location) and orientation sensing. Inspired by spider webs, the authors designed and fabricated a frame structure with radial and frame elements using so-called micro-opto-electro-mechanical systems.

In this work, polydimethylsiloxane (PDMS) and photocurable resins that have high refractive index contrast (1.43 VS 1.50), excellent viscoelasticity and high transparency over a wide spectral range, are used as the cladding and core, respectively. As shown in Fig. 1(a), the photocurable resin core is fabricated using stereolithography 3D printing technique. To form a core/cladding structure, the photocurable resin core was placed inside a container filled with the PDMS resin, and followed by a thermal curing. As shown in Fig. 1(b), the core/cladding structure with eight radial elements is integrated with a PDMS packaged battery-LED assembly, which works as both light source and proof mass.

In this case, the force applied at different locations of the BioMFOS can be detected through the optical signal variation on the sensor due to its viscoelastic response. The as-fabricated BioMFOS has a small dimension (about 2 cm) and a light weight (0.8 g), making it suitable for wearable application and clothing integration.

Experimentally, the BioMFOS can detect forces in the μN range, making it promising in a wide range of critical applications. By analyzing four radial element's signals, the spatial resolution is about 0.02 mm. Compared with inertial measurement unit, the BioMFOS achieved a correlation coefficient higher than 0.9, indicating the capability of the orientation detection in 3D plane, such as movement analysis and classification applications. For example, when a BioMFOS is positioned on the top of the user's hand, the finger positions can be recognized based on the sensors' signal variations. As it does not need additional accessories and is not directly connected to the user's joints, the BioMFOS provides comfort for the user.

Moreover, the authors demonstrate an application of cloth-integrated BioMFOS for trunk orientation and respiration rate sensing. This advantageous result indicates that the BioMFOS can be employed for the continuous assessment of elderly patients with fall risk as well as activity monitoring in different healthy or injured subjects.

To mitigate the impact of transverse forces or pressures applied in the top plane of the BioMFOS on the 3D orientation assessment, a protective cover was added to the sensor structure, which makes the BioMFOS robust and reliable for practical applications. Therefore, the BioMFOS opens new avenues for developing novel human-machine interfaces, high performance robotic tactile units, compact biomechanical analysis devices, and remote health care systems.

More information: Arnaldo Leal-Junior et al, Multifunctional flexible optical waveguide sensor: on the bioinspiration for ultrasensitive sensors development, *Opto-Electronic Advances* (2022). DOI: 10.29026/oea.2022.210098

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