Highly sensitive and fast response strain sensor based on evanescently coupled micro/nanofibers

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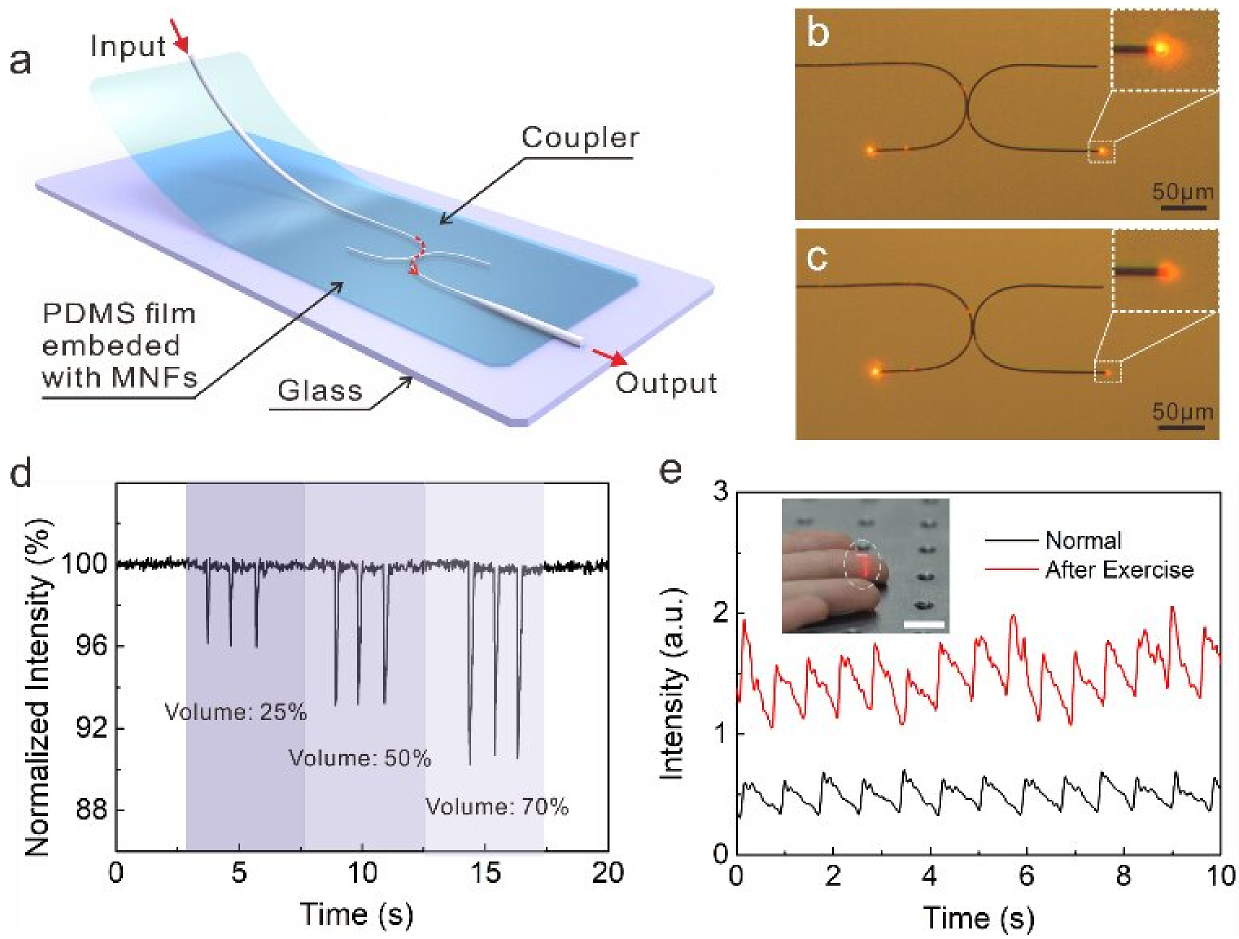

Working principle of the strain sensor based on MNF coupler. (a) Schematic diagram of a strain sensor structure. (b), (c) Optical micrographs of an MNF coupler before and after slightly changing of the gap, respectively. The diameter of the MNF is about 900nm, and the bending radius is 50μm. (d) The device response to a metronome at three different volumes. (e) Measurement of the real-time fingertip pulse wave under normal conditions (72 beats per minute) and after exercise (85 beats per minute). The inset shows a photo of the sensor attached to the fingertip to test the pulse of the fingertip, and the scale bar is 1cm. Credit: Compuscript Ltd

A new publication from *Opto-Electronic Advances* discusses a highly sensitive and fast response optical strain sensor.

Strain sensors play an important role in many applications such as flexible electronics, health monitoring, and soft robotics due to their superb response to mechanical deformations. At present, the reported strain sensors mainly focus on high stretchability and high sensitivity under large deformation for motion detection, yet low sensitivity under micro-deformation (≤1%) may limit their applications in micro-displacement detection and weak physiological signal monitoring.

Recently, various types of electric strain sensor based on microstructures such as islands structures, percolations and microcracks have been demonstrated for physiological signals detection. However, the complicated processing and high sensitivity to electromagnetic disturbances bring challenges to their practical applications. Alternatively, fiber based optical sensors offer attractive advantages compared with their electronic counterparts, including inherent electrical safety, immunity to electromagnetic interference, and small size.

As a combination of fiber optic and nanotechnology, micro/nanofibers (MNFs) have been attracting increasing research interest due to their potential in renewing and expanding fiber optics and flexible sensors in micro/nano scale. Especially, optical coupler based on evanescently coupled MNFs is a promising structure for highly sensitive optical sensing, as the coupling efficiency is strongly dependent on the ambient refractive index, the coupling length and the gap between the two adjacent MNFs. Recently, a highly sensitive and fast response optical strain sensor with two evanescently coupled optical micro/nanofibers (MNFs) embedded in a polydimethylsiloxane (PDMS) film is proposed.

The strain sensor exhibits a gauge factor as high as 64.5 for strain ≤ 0.5% and a strain resolution of 0.0012% which corresponds to elongation of 120 nm on a 1 cm long device. As a proof-of-concept, highly sensitive fingertip pulse measurement is realized. The properties of fast temporal frequency response up to 30 kHz and a pressure sensitivity of 102 kPa-1 enable the sensor for sound detection. Such versatile sensors could be of great use in physiological signal monitoring, voice recognition and micro-displacement detection.

The authors of this article propose a highly sensitive and fast response optical strain sensor, as shown in Figure 1a. Each U-shaped MNF has a diameter of 0.9 μm and bending radius of 50 μm. As the evanescent field decays exponentially outside the MNFs, the coupling efficiency is very sensitive to the gap between the two MNFs. Thus, any displacement between two MNFs will be reflected upon the change of optical intensity at the output port, thereby realizing highly sensitive strain sensing.

The whole structure is embedded in a PDMS film of appropriate thickness to ensure that the strain is transduced to the sensor with high fidelity. The PDMS film can isolate the sensing region from the air, thereby avoiding unpredictable signal interference caused by dust deposition and other external environmental changes. Figure 1b and c show that such a coupler is sensitive to gap widths, as the output intensity changes dramatically when gap width changes slightly. The specially designed MNFs structure and the flexibility of PDMS endow the sensor with high sensitivity and good ductility.

The sensor achieved a gauge factor of 64.5 in the range of 0–0.1% strain, and a fast temporal frequency response up to 30 kHz for sound detection. The sensor can also perform sound vibrations detection (Figure 1d) and real-time monitoring of human fingertip pulse (Figure 1e). In addition, the sensor has properties as simple device structure, low requests for light source and detector. Moreover, taking advantage of wavelength-insensitive device response, halogen tungsten lamp and spectrometer used in the experiments can be replaced by cost-effective devices, such as an LED and photodiode, respectively, which is favorable for wearable weak physiological signal sensing system.

The proposed new sensor would open a simple route to low-cost, sensitive multifunctional flexible sensors with great potential in medical health monitoring, voice recognition, and micro-displacement detection.

More information: Wen Yu et al, Highly sensitive and fast response strain sensor based on evanescently coupled micro/nanofibers, *Opto-Electronic Advances* (2022). DOI: 10.29026/oea.2022.210101

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