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Liquid metal gives transmission lines a softer touch

A fibre with liquid-metal core and soft outer shell can be woven into textiles and used to sense multiple compression and stretching events simultaneously.

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The ability to obtain information on the spatial and temporal distribution of mechanical stimuli, includingcompression, tensile, torsional and bending stress, is important in the development of applications related to health monitoring, human–machine interactions and soft robotics. One-dimensional sensing probes based on fibres or cables are desirable for such purposes because they can easily be integrated into large-area textile fabrics. If a single fibre is capable of detecting multimodal deformations — with information on deformation mode, amplitude, time and location — then only one or two output ports at the fibre ends are required. In such a case, there is no need to have complex addressing circuits, which can be difficult to achieve in flexible fibrous structures like textile fabrics. Such fibres can also potentially be made in kilometre lengths and could thus be used in very-large-area sensing applications, for example, in bridges or railway tracks.

Previously, radio-frequency transmission lines together with time-domain reflectometry have been explored to detect multimodal deformations[1,2]. It has also been shown that sensing networks based on optical fibre gratings can measure multi-point distributions of strain, stress and temperature using time-domain and wavelength multiplexing schemes[3]. However, these one-dimensional sensing probes are made of rigid dielectric materials or solid metals, and are easily damaged in a soft structure that experience repeated large deformation. Writing in *Nature Electronics*, Fabien Sorin and colleagues[4] at the École polytechnique fédérale de Lausanne now report a stretchable micro-structured fibre that contains several liquid metal conductors embedded in a soft dielectric elastomer and can be used to simultaneously sense multiple compression and stretching events (Fig. 1a).

The fibre architecture — including the materials, cross-sectional features and length — was designed so that the fibre's impedance, shielding, and loss meet the requirements for radio-frequency time-domain reflectometry of a transmission line. The fibres can also be fabricated in lengths of several metres, and with uniform cross-sectional designs, using a thermal drawing technique. The resulting soft and stretchable transmission fibres can be used as one-dimensional sensing probes that are capable of detecting the mode, magnitude and position of multimodal deformations, either singularly or in combination with simultaneous stretching and compression events (Fig. 1b).

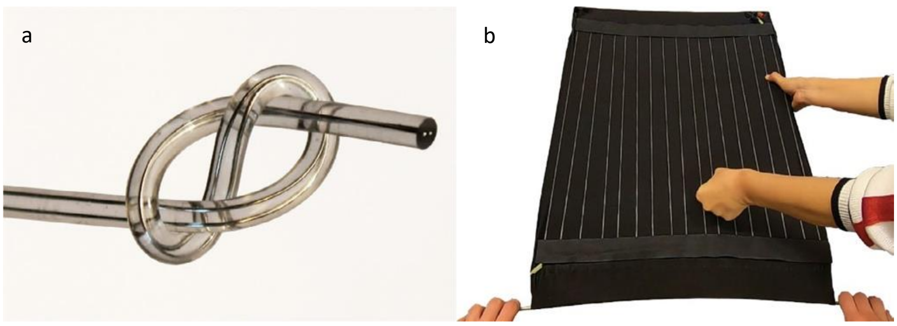

Fig. 1 | Soft and stretchable transmission lines for time-domain reflectometry. a, A soft transmission line with liquid metal core and soft elastomeric shell. **b**, A single transmission line integrated into a textile with a single output port can multiplex stretching and compression deformation simultaneously. Figure reproduced with permission from ref. [4], Springer Nature Ltd.

While traditional rigid transmission lines have been explored for multiplexed sensing, their low dynamic strain sensitivity, due to the low deformability of the solid metal and dielectric material, has limited their applications. By introducing a soft, deformable liquid metal and soft elastomer, Sorin and colleagues have largely overcome this difficulty. The approach also provides a signal sensitivity that is enhanced over 200 times compared with conventional rigid transmission lines. In addition, only a single interface port is used per fibre for the detection of spatial and temporal point distribution of complex mechanical deformation events, in a similar way to optical fibre grating probes. However, with the metal–elastomer fibre probes, deformation events occurring anywhere along the soft fibre can be detected by wave reflection, whereas for the optical fibre grating probes the location detection of events is limited to where the gratings are written in the fibre. The metal–elastomer fibre has the ideal characteristics for integration into a large piece of textile fabric using established textile manufacturing processes.

Currently, the spatial resolution of the distributed fibre probe varies depending on the distance of the pressure points to the interrogated end, ranging from 4 cm at 0.2 m to 20 cm at 5 m. Furthermore, the force resolution is 0.2 N and a strain resolution of 0.25% occurs in an example one-metre fibre probe. However, as the fibre probe is new, further optimization of performance can be expected. One additional concern is related to the use of liquid metal in the fibres. The electric resistance of liquid metal is low, so high current in the fibre may cause Joule heating, which could affect the probe performance if used for prolonged periods of time. Moreover, and for wider application, leakage of the liquid metal due to fibre damage will need to be prevented.

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