COMMENTARY

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Fibre integrated circuits towards intelligent wearable electronics

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The advancement of wearable electronics is accelerating the evolution of devices toward multifunctionality and system-level integration [1]. Current fibre devices already demonstrated multiple discrete functions, such as energy harvesting and storage, sensing, and display, thereby laying a foundation for future intelligent wearable platforms [2]. Nevertheless, the essential signal processing components in such a system still depend on externally connected rigid silicon-based chips. This limitation fundamentally contradicts the flexible and conformal nature of fibres and severely impedes the realization of truly integrated smart fibre systems [3,4]. The critical bottleneck stems from the intrinsic curved geometry and limited surface area of fibres, which hinder the high-resolution fabrication of dense, multifunctional circuits necessary for on-fibre information processing.

Recently, a breakthrough by Peng's group published in *Nature* has addressed this fundamental challenge [5]. The authors developed a transformative fibre integrated circuit (FIC) based on a multilayer spiral architecture, fabricated through an innovative strategy combining high-precision patterning on a flat elastic polymer substrate with a modified rolling process that transformed the planar circuits into a fibre geometry. By fully utilizing the radial dimension, this architecture achieved an extraordinary integration density of 10^5 transistors per centimeter, thereby enabling standalone signal processing and computing functions within a single fibre.

As a representative demonstration, the authors fabricated a 300-μm-diametre FIC incorporating logic circuits. Microscopic imaging confirmed uniform and well-defined circuit patterns with linewidths as narrow as to 5 μm (Figure 1a). Fluorescence tomography further visualized the internal multilayered architecture, revealing spirally arranged layers along the radial direction, with circuits wrapping 360° around the circumference to form a three-dimensional interconnection network (Figure 1b, c). Notably, this fabrication strategy exhibited remarkable scalability, allowing for the production of metre-long FICs with preciously tunable diameters through adjustments in substrate dimensions and layer thicknesses (Figure 1d, e).

Furthermore, the FIC demonstrated outstanding flexibility and durability that are unattainable with conventional rigid chips, attributed to its innovative modulus-graded heterostructure design. This architecture alternated high-modulus parylene buffer layers with soft polydimethylsiloxane interlayer, effectively dis-

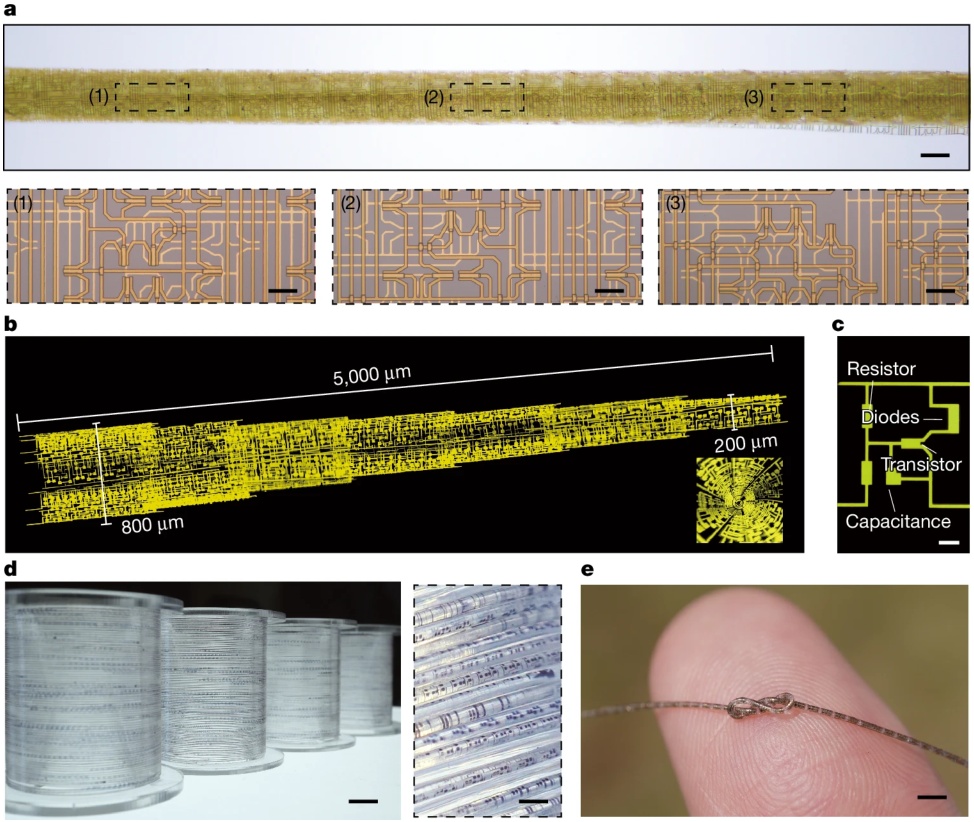

Figure 1 Photographs showing the structure of FICs. (a) Photograph of a FIC with exclusive-or circuits on the fibre surface (scale bar: 200 µm) and enlarged views (scale bars: 40 µm). (1), (2) and (3) show the uniformity of the circuits in the FIC. (b) Reconstructed three-dimensional fluorescence photomicrograph showing the connectivity of the microdevices in a FIC. The circuit can be distributed 360° around the fibre circumference. (c) Fluorescence photomicrograph showing an active driving circuit unit inside a FIC, suggesting that a wide variety of devices can be integrated into the fibre. Scale bar: 40 µm. (d) Photograph of FICs being produced at a large scale. The enlarged photograph shows the continuity of circuits in the FICs. Scale bars: 1 cm (left); 1 mm (right). (e) Photograph of a FIC being knotted and placed on a thumb, exhibiting the flexibility and structural integrity of the FIC. Scale bar: 2 mm. Reproduced with permission from Ref. [5].

sipating and redistributing external stress. Consequently, the FIC withstood extreme mechanical deformations, including compression under a 15.6-ton truck, 10000 cycles of bending and abrasion, 30% stretching, and twisting up to 180° cm^{-1}.

Functionally, the FIC executed digital and analogue computational tasks on par with commercial silicon-based chips, such as logic gates, sequential circuits, and waveform generators. Beyond these standard operations, the incorporation of organic electrochemical transistors enabled neuromorphic computing, achieving a recognition accuracy of 99.8% on standard image–classification tasks. Further, the authors realized fully integrated closed-loop systems that incorporated power supply, sensing, data processing, and display modules within a single fibre, yielding self–sufficient intelligent fibre prototypes. These advanced capabilities underpinned several transformative applications, including high-density neural probes featuring *in-situ* signal amplification for high-fidelity recording, smart textiles woven embedded with pixel-level addressable displays, and machine-washable tactile gloves capable of programmable haptic feedback.

Overall, this work represents a paradigm shift in fibre electronics, transforming fibres from passive functional carriers into intelligent platforms endowed with autonomous information processing capabilities. By serving as a versatile and robust computational core, the FIC addresses a key missing link in realizing truly self-sufficient fibre-integrated systems. This advancement provides a foundational framework for next-generation wearable devices, implantable electronics, and human-machine interfaces, thereby propelling fibre electronics toward a new era of functional integration and system-level intelligence.

Conflict of interest

The authors declare no conflict of interest.

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