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PROCEEDINGS

Scalable, Mechanically Resilient, and Electrochemically Optimized Liquid Metal Micro-Wire Electrodes for Flexible Neural Interfaces

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ABSTRACT

Gallium-based liquid metals, distinguished by their intrinsic fluidity and exceptionally high electrical conductivity, have emerged as a highly promising material platform for next-generation flexible neural interfaces. However, their translation into practical neural devices still faces persistent challenges, particularly in scalable microwire fabrication, robust interfacial encapsulation, and long-term validation of mechanical fatigue resistance. To overcome the fundamental limitation imposed by the high surface tension of gallium—which critically impedes the reproducible formation of sub-50-μm microwires—a polyurethane coating-assisted drawing technique was employed. By optimizing key process parameters, including PU solution concentration, dip-coating speed, and axial stretching rate, precise control over microwire diameter was achieved, yielding stable liquid-metal microwires as fine as 30 μm. Subsequently, carbon nanotube fibers were integrated as compliant electrode substrates; electrochemical performance was enhanced through the conformal electrodeposition of Pt/IrO_x coatings, resulting in significantly improved charge injection capacity and outstanding coating stability—no delamination or performance degradation was observed even after 10^8 biphasic current pulses at 200 μC/cm². The electrodes also exhibited robust in vitro stability under accelerated aging conditions (55 °C phosphate buffer saline solution, 9 days). Crucially, bending fatigue evaluation confirmed that 100-μm-diameter Ga-based microwires retained both structural integrity and stable electrical resistance (change <15%) after 10^6 cycles at a bending radius of 6 mm. Collectively, this work establishes a scalable, mechanically resilient, and electrochemically optimized pathway for liquid-metal microwire electrodes in flexible neural interfaces.

KEYWORDS

Neural electrode; liquid metal gallium micro-wire; electrochemical performance; anti-fatigue performance

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