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Transparent Electroactive Actuators for Organ-on-Chip Platforms

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Micro-physiological systems (MPS) hold the potential for advancing drug research by emulating realistic *in vitro* human (patho)physiology models. These systems replicate organ microenvironments, delivering stimuli similar to those experienced by organs *in vivo*. Active biomechanical cues, like shear force and tensile stress, profoundly influence cell activity and can alter biochemical responses. The critical factors encompass the nature, duration, magnitude, and frequency of these cues [1]. A currently popular solution to provide biomechanical stimulation employs pneumatic actuation, which is powerful and multifunctional, but bulky, expensive, and inconvenient to use. Electroactive polymers (EAP), also known as artificial muscles, are gaining attention as a potential alternative for improved versatility [2]. Ionic polymer-metal composites (IPMCs) are a class of ionic EAPs which operate at low voltage and exhibit large displacement [3]. They are intrinsically suitable for cell culture media as their operating principle is based on electrolytes (Fig. 1A). However, IPMCs employ metallic electrodes, which eliminate the optical transparency essential in fundamental biological experiments.

In this study, we present the design, fabrication, and characterization of a selectively transparent IPMC for utilization in MPS to apply controllable mechanical stimuli to tissues. A multiphysics-based finite-element model was constructed and validated basing on literature data [4] to estimate the maximum tip displacement of IPMC cantilevers. The model was used to study several cantilever configurations to determine the best electrode patterning topology for the transparency, stiffness, and tip displacement trade-off. The optimized designs were implemented in wafer-scale cleanroom-compatible fabrication (Fig. 1B-C). The novel fabrication process involved sequential patterning of planar Au electrodes on polydimethylsiloxane (PDMS) substrates, and covalent bonding of a pair of such Au-patterned PDMS substrates to an ionomer (Nafion) through silanization (Fig 1B). Preliminary electro-mechanical characterization of the performance of the selectively transparent IPMC cantilevers (Fig. 1D) and biocompatibility tests indicate a potential for integration and use in MPS and organ-on-chip platforms.

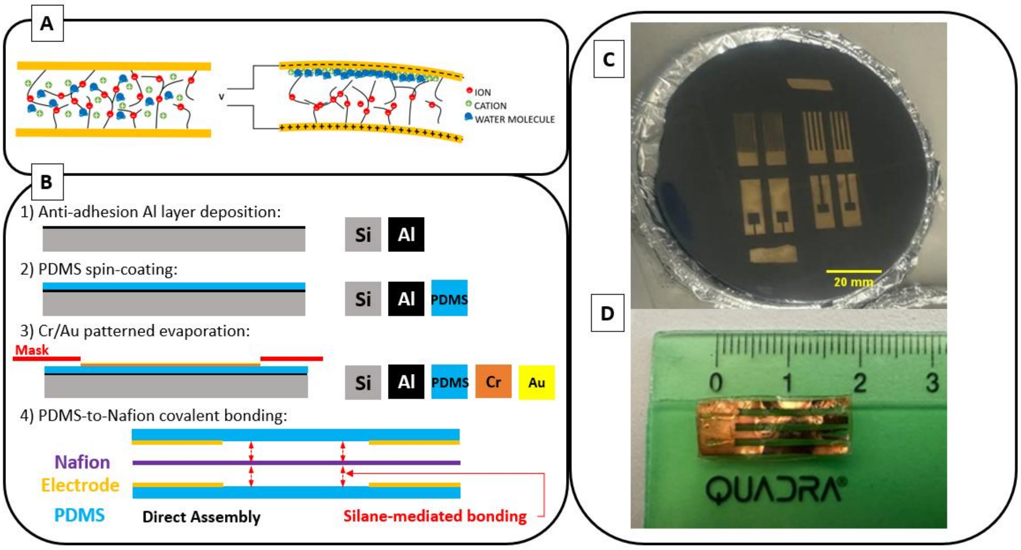

Figure 1. *A) Schematic of IPMC electro-mechanical transduction mechanism. B) Fabrication steps. C) Electrodes patterned on PDMS-coated 4-inch Si wafer by shadow masking of Cr/Au e-beam evaporation. D) Released IPMC actuator.*

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