Shear-direction-sensitive mechanoelectric transduction in a soft ionic paste under anisotropic interfacial boundary conditions

Pensini, Erica

Department of Civil, Environmental and Water Resources Engineering, College of Engineering, University of Guelph, 50 Stone Road East, Guelph (ON), N1G 2W1, Canada

epensini@uoguelph.ca

Soft ionic materials can generate electrical signals under mechanical deformation, but the origin of these responses is often difficult to assign because bulk piezoelectricity, interfacial polarization, leakage, and electrochemical effects may all contribute. Here, we report a water-rich arginine–dodecanoic acid (ARG–DA) soft ionic paste that exhibits reproducible, shear-direction-dependent mechanoelectric transients when confined between grooved aluminum electrodes. The system was designed as a simple two-electrode sandwich cell in which unidirectional surface texturing imposes anisotropic interfacial boundary conditions.

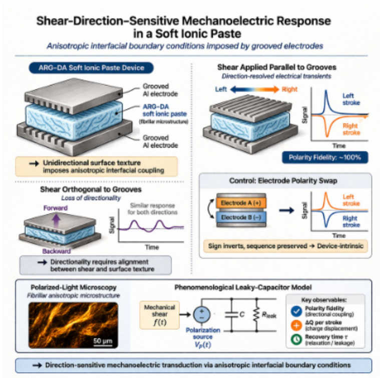
Open-circuit potential and chronoamperometry measurements show that, when shear is applied parallel to the electrode grooves, opposite stroke directions generate opposite-signed electrical transients. In contrast, when shear is applied orthogonal to the grooves, the response remains detectable but loses its direction-resolved character. This collapse of directionality under misaligned boundary conditions indicates that the observed behavior is governed by anisotropic interfacial coupling rather than by an orientation-independent bulk response of the paste. A polarity-swap control, performed by reversing the electrode assignment, inverts the sign convention while preserving the association between stroke direction and response sequence, confirming that the effect is device-intrinsic.

Cyclic voltammetry within a narrow operating window shows smooth, largely featureless loops whose magnitude increases with scan rate and stabilizes after conditioning. This behavior is consistent with a predominantly polarizable interface with finite leakage, rather than with a dominant Faradaic process in the measurement range. Polarized-light microscopy further reveals a fibrillar mesoscale microstructure, suggesting a plausible structural basis for anisotropic engagement between the paste and the textured electrode surface.

To interpret the data conservatively, we use a minimal phenomenological framework in which the device is treated as a mechanically driven polarization source in parallel with capacitive and leakage pathways. Within this picture, three experimentally accessible observables are especially useful: polarity fidelity, stroke-integrated charge, and recovery time. These metrics capture, respectively, the extent of directional coupling, mechanically induced charge displacement, and electrical relaxation after deformation.

The results show that direction-sensitive mechanoelectric transduction can be achieved in a simple hydrated soft ionic paste without invoking a specific microscopic bonding mechanism. More broadly, they highlight how electrode texture and interfacial boundary conditions can be used to encode directional mechanical information in soft matter systems, which is relevant to tactile sensing, low-frequency motion detection, and interface-enabled mechanoionic devices.

Keywords:
mechanoelectric transduction, soft ionic paste, interfacial polarization, anisotropic boundary conditions, shear direction sensing



Shear-direction-sensitive mechanoelectric response of an arginine-dodecanoic acid soft ionic paste between grooved aluminum electrodes. Parallel shear resolves stroke direction, whereas orthogonal shear loses directionality, consistent with anisotropic interfacial polarization.