Hybrid Piezoresistivity and Piezocapacitivity of Architected Porous Nanocomposites

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Abstract

Electronic skins (e-skins) that mimic the mechanical softness and tactile sensations of human skins crucial for future prosthetics and humanoids. However, despite decades of research, soft capacitive pressure sensors still face two persistent challenges – a rapid decrease in pressure sensitivity with increasing pressure and interference from lateral stretching on pressure readings.(1) Our group pioneered the Hybrid Response Pressure Sensor (HRPS) (2) and Stretchable Hybrid Response Pressure Sensor (SHRPS) (3) by leveraging the synergistic piezoresistivity and piezocapacitivity of optimally doped porous nanocomposites (PNC). Using commercially available Ni foam as a template, we manufactured CNT-doped-Ecoflex PNC through dip-coating and curing of the composite, followed by etching away the Ni foam. Our HRPS exhibited unprecedented pressure sensitivity at high pressures, and the ultra-high pressure sensitivity of SHRPS can trivialize its response to stretch. As a demonstration, SHRPS has been mounted on an inflatable robotic end effector to safely and effectively check human pulses and potentially blood pressure without the need for a cuff. Through simplified circuit models and electromechanical analysis, we have uncovered the fundamental mechanisms of HRPS and SHPRS and obtained analytical predictions of their behaviors.(4, 5) Additionally, we fabricated architected porous nanocomposite (APNC) based on micro-architected Ni foams produced by digital light processing (DLP) and hydrogel infusion method.(6) We discovered that the APNC-based architected stretchable hybrid response pressure sensor (ASHRPS) demonstrated even higher pressure sensitivity than the SHRPS. We explain this discovery through combined micro-CT and computational analyses.(7) We hope to collaborate with mechanicians specializing in architected materials and AI tools to develop a design framework for creating ASHRPS e-skins. Architected electromechanical materials hold significant potential for soft electronics and robotics.

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