

Next-Generation Neuromorphic Devices for Bioinspired Sensory Perception

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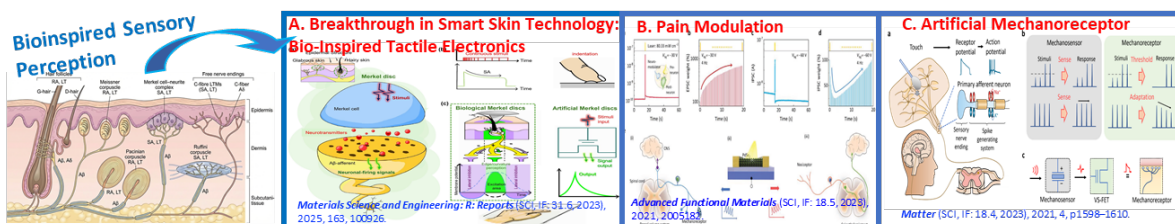
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Recent advances in nanomaterials and micro/nanofabrication technologies have enabled the development of neuromorphic electronic platforms capable of emulating biological sensory perception. These nanoengineered devices offer significant potential for next-generation intelligent prosthetics and bioinspired robotic systems. In this work, van der Waals heterostructure field-effect transistors (VHFETs) based on diverse 2D nanomaterials are introduced as device-level platforms for implementing perception-like functions. [1-4]

MoS₂/h-BN/graphene-based VHFETs exploit atomic interfaces and charge-trapping mechanisms to reproduce key characteristics of biological mechanoreceptors, [2] including stimulus-dependent adaptation under sustained mechanical inputs, analogous to sensory adaptation and fatigue in human tactile systems. In parallel, defect-engineered PdSe₂ transistors are developed to emulate photonic nociceptors, [3] where controlled oxygen adsorption and desorption at selenium vacancy sites enable tunable doping and dynamic charge transfer. This leads to threshold-triggered responses and sensitization behaviors analogous to biological pain perception, with programmable temporal dynamics enabled by reversible defect modulation. Furthermore, VHFETs with engineered access regions (VHFET-AR) are designed to emulate Merkel discs, slowly adapting tactile mechanoreceptors responsible for spatial discrimination. [4] These devices exhibit essential synaptic functions, including spike-dependent plasticity, inverse notch signaling, and lateral inhibition, enabling hardware-level implementation of tactile perception mechanisms.

Collectively, these nanoengineered neuromorphic transistors demonstrate how advanced materials engineering, heterostructure design, and defect modulation can encode complex temporal sensory dynamics within compact solid-state platforms. When integrated with flexible substrates, these devices offer a pathway toward bioinspired electronic skin and prosthetic technologies capable of perception, adaptation, and intelligent response.

Keywords: 2D materials, floating-gate transistors, neuromorphic devices, artificial synapses.



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