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ABSTRACT:

Opto-Electronic Synapses from "All Carbon" Graphene-like (sp²C)/Diamond (sp³C) Junctions for Neuromorphic Computing: Filamentary Diffusion or Interface-Type Memristors?

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Electronic devices emulating biological functions are essential to advance brain-inspired neuromorphic computing, capable of efficient data processing. Integration of allotropic sp²-/sp³-bonded carbon platforms evoked realization of neuromorphic devices viz. memristors as "artificial" synapses. This work reports nonvolatile heterojunctions comprising graphene-like (sp²C-rich) layers on poly-diamond (sp³C-rich), significant for their reduced complexity and nanoscale footprint. Specific architecture includes: (1) boron-doped carbon nanowalls (BCNW/diamond), (2) diamond/BCNW/diamond, (3) CNW/diamond, (4) rGO/diamond, while (5) nanodiamond/diamond, (6) diamond foil/BCNW, and flexible laser induced graphene are evaluated for permutational comparison, synthesized by MPACVD except reduced graphene oxide, rGO. The "all carbon" memristors exhibited lower switching voltages for non-volatile operation with multiple conductance states recognized via continuous high and low resistance, refers to adaptability in response to synaptic weight, high switching ratio ~10⁴-10⁵, and long retention 10⁴ s, indicating long-term potentiation under electrical (and optical) bias. Additionally, devices (1-3) exhibited quasi-linearity and symmetry with high endurance when subjected to identical input pulses, essential for online neural network training. The underlying resistive switching originated from redox of C-C double bonds at reorganizational sp²-sp³ hybridized interface induced by H-terminated diamond paired with oxygen ion movement and local sp²C clustering revealed by in-situ Raman and I-V carrier transport. These devices have potential applications in logic operations, artificial neural network, and multimodal perception systems [1, 2].

[1] S. Gupta, M. Sawczak, M. Narjczyk, K. Bury, R. Bogdanowicz, APL Electronic Devices 2, 016111:1-26 (2026).

[2] S. Gupta, K. Bury, P. W. May, Diamond and Related Materials, 164, 113511 (2026).