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Ion Modulation and Ionic Coupling Effect in Neuromorphic Vision Network

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DESCRIPTION

Machine vision technology is now becoming reliant on reconfigurable image sensors for real-world object recognition and comprehension. It has recently been demonstrated that the neural network image sensor, which imitates the neurobiological functions of the human retina, can simultaneously sense and process optical images. However, these Artificial Neural Networks (ANNs) that truly function like a human retina would be able to make a paradigm-shifting leap in compactness and function with highly tunable responsivity and non-volatile image data storage in the neural network. Sensory nodes are becoming more and more common in neuromorphic vision networks, but the data they produce is frequently unstructured and redundant for machine-learning algorithms. This is because the processing units, which typically execute digitally using von Neumann architecture, are physically distinct from the sensory units, which operate primarily in the analog domain. Because of this, a large amount of data must be transferred to local processing units or cloud-based systems, which results in high energy consumption, latency, insufficient storage space, and communication bandwidth. Contrarily, the parallelism of the human visual system makes it possible to combine image sensing and processing functions, allowing it to carry out intricate tasks in real time. Devices based on bulk materials and two-dimensional (2D) materials, such as Variable-Sensitivity Photodetectors (VSDP), Dual-Gate Photodiodes (DGP), Two-Terminal Photo-Memories (TPM), and Gate-Tunable Vision Sensors (GVS), have been developed to address this issue. However, bias-dependent dark current with high power consumption, volatile photocurrent for neural networks, or a complicated integration preparation process and low photo-responsivity (DGP, GVS) are common problems for these neural network sensors. 2D materials, as a technology, are now advanced and mature enough to be used over wafer scales in complex integrated device and circuit level systems, which can further be easily integrated with silicon readout/control electronics. In this context, 2D materials offer superior features for neuromorphic vision hardware because they demonstrate strong light-matter interaction in a broad spectrum, ease of fabrication and integration, and the possibility of static and dynamic tunability of the potential profile within a device. Using layered metal sulfides (MoS_2, WS_2) as the 2D semiconductors, we present a two-terminal photovoltaic detector based on metal/2D-semiconductor/metal (M/S/M) structures in this study. We used WDS characterizations, the Kelvin Probe Force Microscope (KPFM), and the Sentaurus-TCAD simulation in a series of experiments to gain an understanding of the atomic mechanism responsible for the reconfigurable and non-volatile response of MoS_2 M/S/M devices. By creating an in-plane electric field of approximately 10 MV/cm and applying voltage biases to the M/S contact, we were able to observe the *in-situ* distribution of sulfur atoms in the MoS_2 channel. It demonstrated that the sulfur atoms were uniformly distributed throughout the channel prior to applying voltage pulses. The channel's distribution of sulfur atoms is depicted by the red signal on the WDS map. Prior to electric pulse programming, the WDS map and elemental spectrum show uniform sulfur distribution across the MoS_2 channel. However, a negative voltage pulse with amplitude of -10 V was applied; it is a clear absence of sulfur atoms near the anode indicates the migration of sulfur vacancies in the MoS_2 channel.

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CONFLICT OF INTEREST

The author declares there is no conflict of interest in publishing this article.

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