Graphene-Based Memristive and Photomemristive Nanosensors for Energy-Efficient Information Processing

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INTRODUCTION

The emergence of advanced low-dimensional (LD) materials of the graphene family opens up unique possibilities for fast processing of electrical and optical signals in a wide spectral range from ultraviolet (UV) to infrared (IR) and terahertz radiation. Non-volatile resistive states in memristors fabricated on the basis of two-dimensional (2D) crystals, quasi-one-dimensional (1D) nanoribbons and quasi-zero-dimensional (0D) quantum dots are accessible for control by light, electric or magnetic field due to polarization and rearrangement of sp^2-sp^3 hybridization of carbon atoms, as well as due to photoinduced phase transitions[1-7]. LD materials have unique structural and electronic properties required for the development of fast and energy-efficient memristive devices for nano-information technologies[8]. Graphene/graphene oxide-based memristors, obtained by local reduction of graphene oxide using electron beam irradiation, exhibit nonlinear behavior and well-controlled resistive states at low bias voltages[9]. Devices based on LD materials have fast resistive switching, fast photoresponse, and high photosensitivity. Graphene-based devices, due to a well-controlled redox process, demonstrate the dynamic behavior required for neuromorphic computing directly in the sensor, which reduces the energy and time costs associated with data processing[7]. Neuromorphic computing in a photomemristor-based sensor makes it possible to create a compact, autonomous, and energy-efficient system for detecting, storing, and recognizing visual information in real time for use in self-driving transport, personalized medicine, and other applications.

EXPERIMENTAL/THEORETICAL STUDY

LD materials such as 2D graphene, graphene oxide, diamane, transition metal chalcogenides and 0D layered quantum dots have been used to fabricate memristive and photomemristive heterostructures for modeling and creating electronic and optical vision systems for neuromorphic data processing.

RESULTS AND DISCUSSION

It is shown that graphene materials can be used for intelligent visualization in a wide optical range with preliminary information processing in the nanosensor itself. Intelligent sensors with embedded neural networks based on photomemristors can be made of biocompatible flexible graphene materials and used to create autonomous energy-efficient neuromorphic vision. This opens up the possibility of classifying and recognizing objects in a trained nanosensor, similar to the processing of optical signals in the retina.

CONCLUSION

Non-volatile memristive states in heterostructures based on LD-graphene family materials can be dynamically controlled electrically and optically in a wide UV-IR range, which allows for the creation of intelligent broadband devices with low power consumption. A photomemristive sensor with an embedded neural network provides energy-efficient detection, storage and processing of information similar to biological systems, which can be used to develop autonomous artificial neuromorphic sensor systems.

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