Optoelectronic Synapses based on Semiconductor Nanostructures towards Physical Reservoir Computing

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Abstract

With the advancement of artificial intelligence (AI) and edge computing, physical reservoir computing (PRC), which enables efficient and flexible processing of time-series data, has been attracting increasing attention. In this talk, we introduce the development of optoelectronic synaptic devices inspired by the human visual system and their applications in PRC. These devices are expected to function as in-sensor PRC systems capable of directly processing time-series optical inputs, and hold potential for next-generation low-power AI optical devices.

First, we present an optoelectronic synaptic device based on a composite film of ZnO nanoparticles (NPs)[1,2]. The ZnO NP arrays exhibit a slow photoresponse behavior due to oxygen adsorption and desorption processes, and this characteristic was exploited to achieve synaptic-like operations. Using this device, we demonstrated the classification of 4-bit optical inputs and verified its application in handwritten digit recognition through PRC. These results show that even a simple material system can enable advanced information processing.

Furthermore, in pursuit of sustainable, low-power devices, we developed an optoelectronic synapse based on dye-sensitized solar cells (DSCs) with TiO_2 NPs[3-5]. This device exhibits slow response characteristics derived from photoelectrochemical reactions and has been confirmed to show synaptic behavior. In addition, the device demonstrated its functionality as an optical sensor capable of classifying human motion.

In this session, we will explain in detail the operating principles, design processes, and performance evaluations of these devices in PRC applications. We will also discuss a new perspective on PRC systems that can adapt to temporal variations in light wavelengths.

References:

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