

Innovations for Neuromorphic Computer: Insulators, Semiconductors and Superconductors for Base Elements of Brain-Inspired Neural Networks

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Abstract: With the growing energy demands of modern computers based on the von Neumann architecture, the need for more energy-efficient computing solutions has become increasingly urgent. This challenge has stimulated a shift toward non–von Neumann computing paradigms, particularly those inspired by the brain’s neural network architecture. Artificial neural networks (ANNs), which emulate the structure and function of biological neurons and synapses, have gained significant attention in this context. These networks require innovative functional nanostructures designed using advanced insulating, semiconducting, and superconducting materials, offering the potential for dramatic reductions in energy consumption and addressing key limitations of conventional von Neumann systems.

In this work, we present the results of modeling, design, and investigation of artificial neurons and synapses based on smart functional nanostructures composed of hybrid layered superconductor/insulator and superconductor/magnetic metamaterial systems. The results highlight their potential in superconducting spintronics and their promise for enabling a new generation of energy-efficient computing technologies.

Keywords: Insulator, Spintronics, Neuromorphic Computing, Artificial Neural Networks, Hybrid Nanostructures.