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Modeling, creation and optimization of artificial neural networks based on Mott insulator

Keywords: *Hardware neural network, quantum materials, simulation*

Context

For half a century, the information technology revolution has been closely associated with the development of computing. However, all computers are built according to a so-called Von Neumann architecture, where processors and memory are separate blocks. This results in high energy consumption for the processing of massive data. Researchers are working on alternative architectures to develop a more energy-efficient artificial intelligence. The most promising architecture is based on the mammalian brain, which can be 10,000 times more energy efficient than current computers. Currently, intense international competition is growing to realize hardware-based artificial neural networks using artificial synapses and neurons made from innovative materials.

In this context, a team of researchers from IMN has discovered a new property of Mott insulators. This property makes it possible to realize a new type of non-volatile multi-level memories (similar to artificial synapses) and an artificial neuron of the Leaky-Integrate-and-Fire (LIF) type with these materials. The IMN team very recently obtained substantial funding from the Region/CNRS/Nantes University, enabling to finance PhD theses and Post-Docs in order to create the first hardware neural network demonstrator based on Mott insulators. This project aims to lay the foundations for energy-efficient artificial intelligence using these innovative materials.

PhD project

The PhD thesis will focus on an important part of this project. The main objective is to realize, test and model artificial neurons and artificial neural networks based on Mott insulators. The thesis will consist of three parts. 1) Sizing and realization of artificial neurons: the student will define the optimal design of the individual components for their integration into a functional neural network. For this, he might carry out multi-physics simulations, will deposit thin layers by reactive magnetron sputtering and will characterize the produced devices by electrical transport, SEM, TEM, Raman, AFM, XRD… 2) Electrical tests of neurons and neural networks: the student will have to define the protocol for programming artificial neurons, targeting excellent reproducibility of the component characteristics. Within the framework of the overall project, he will also participate in the electrical testing of the neural network fabricated using the optimized components. These tests will be carried out on existing IMN equipment and on a specific probe station acquired as part of the project. 3) Modeling of neurons and the neural network: the student will create a model of the individual neurons behavior which will be integrated into a simulation of the neural network. This will allow him to extrapolate the behavior of the tested network, and to simulate wider / deeper networks.

Required profile

The candidate must be a graduate of an engineering school and/or hold a Master 2 Research whose training focuses mainly on nano/micro-electronics: electrical measurements, production of components, modelling, neural networks or related fields. The PhD thesis subject requires a significant amount of experimental work, and a good level in materials science and solid state physics

is necessary. We are looking for a highly motivated student with a strong interest in new applications for microelectronics. Interpersonal skills, dynamism, rigor and ability for team work as well as autonomous work will be appreciated. Applicants must be fluent in English and/or French. In addition, well-written English will be highly appreciated. A first internship experience in component modelling research, neural networks and/or electrical characterizations is expected.

Scientific environment

The candidate will mainly work at the Institut des Matériaux de Nantes Jean Rouxel (the IMN) (https://www.cnrs-imn.fr/). It is one of the main materials research centers in France. It now brings together more than 120 researchers (chemists, physicists, materials engineers from the CNRS and Nantes University), administrative and technical staff, and 80 research contractors. Deposition and annealing equipment are available at the IMN, as well as many characterization techniques (XRD, SEM, HR-TEM, XPS, electrical measurements at the single chip level). He/she will work in the "Physics of Materials and Nanostructures" team. The attached doctoral school is the ED3M whose themes cover physics and chemistry in the broad sense. More information: https://ed-3mg.doctorat-paysdelaloire.fr

Funding

Doctoral contract from Nantes University (approximately €2050 Gross/month) from 01/10/2024 onwards.

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Send a detailed CV including at least two people to contact, a cover letter, grades and ranking in Master 1 and 2.