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Study of Mott materials for neuromorphic applications using a simple circuit model

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Mott insulators are materials which should have metallic properties according to tight-binding calculations, but are found to have insulating properties instead. This discrepancy between theory and experiments can be explained with the failure of the independent-electron approximation to account for Coulomb interactions, which are not negligible in such materials. When this contribution is included in the calculation of the electronic structure, like in the Hubbard model, the half-filled band splits and a gap in the density of states opens up, explaining the insulating behavior. However, Mott materials such as transition metal-oxides, can be made to behave like metals under certain conditions, for example when the material is heated up by application of a voltage. The resistive collapse that follows the application of the bias voltage and signals the insulator-to-metal transition is of particular interest, since it occurs at room temperature, paving the way for the use of Mott materials in a variety of applications, such as next generation memories and neuromorphic devices.
In this presentation we describe the insulator-to-metal transition using numerical simulations based on the Mott resistor network, a phenomenological model that makes no use of microscopic equations and instead describes the sample as a circuit of resistors governed by classical laws. This makes the model easy to understand and tinker with. We showcase the ability of the model to reproduce experimental results, while also allowing to study the resistive collapse with greater temporal resolution than that afforded by the instrumentation. Finally, a comparison is made between the dynamics of the resistive collapse and neuronal dynamics, showing how it may be possible to use Mott materials to build neuromorphic devices that mimic the behavior of biological neurons.

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