Out-of-equilibrium Mott insulators to metal transitions: from fundamental issues to applications in non-volatile memories and in artificial intelligence

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The study of strongly correlated materials in nonequilibrium conditions has developed into one of the most exciting branches of condensed matter physics. These systems have already fascinating properties at equilibrium, such as high temperature superconductivity. Driving them out of equilibrium might yield even richer physics, of which only a small fraction has been discovered so far. Mott insulators correspond to the archetype of correlated systems. The famous Mott insulator to metal transitions (IMT), driven at equilibrium by on-site electron repulsion or electronic doping, has sparked a huge interest over the last fifty years. Interestingly, recent developments have unveiled the possibility to trigger out-of-equilibrium IMT in Mott insulators, by applying either ultra-short laser pulses [1] or electric fields [2]. The transition driven by electric field turned out to be a universal feature of canonical Mott insulators [3,4,5]. In these compounds, an abrupt drop of electrical resistance occurs above a threshold electric field E_{th} typically in the 1-10 kV/cm range. This Electric Mott Transition (EMT), volatile for fields slightly above E_{th}, becomes non-volatile at larger electric fields. These EMT allows envisioning applications in the emerging field of Mottronics (domain aiming at using Mott insulators properties in microelectronics) such as non-volatile Mott memories [6]. Moreover, it was recently demonstrated that the volatile Electric Mott transition can be used to implement the three basic functions Leaky, Integrate and Fire expected for artificial neurons [7], paving the way of their use in Hardware Neural Networks. In parallel, significant progresses have been recently achieved in the understanding of the nature of the phases associated with the non-volatile states and of the microscopic mechanisms driving the EMT's. These recent advances, as well as the remaining opened theoretical issues, will be presented and discussed.

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