Electrical Transport in Novel Materials with Perspectives in Neuromorphic Computing

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Résumé :

The evolution of the transistor, from its first conception in the 1920s to its ultimate manifestation in today's integrated circuits, tells in part the history of research in the device physics community. While research in the latter part of the 20th century often focused on developing new devices with novel materials, the approaching end of Moore's law has ushered in a new emphasis on novel computing paradigms that push this community to focus on integrating new devices within what were once considered outlandish architectures. The research presented in this habilitation thesis defense follows along this main evolution in device physics.

Starting with research exploring a novel silicon MOSFET, the Schottky barrier MOSFET, that in the 1990s was proposed as an alternative to conventional CMOS, my investigations of this device ranged from understanding the fundamental electronic transport over a wide range of temperatures. The most interesting results, nevertheless, are at low temperatures where transport involving single or small clusters of atoms modulate the transport allowing for spectroscopy, and observations of quantum interference.

The discovery of high temperature superconductivity in 1986 in novel ceramic oxides ushered in a flurry of research on these and related materials. One remarkable discovery was colossal magnetoresistance in magnetic oxides in which the interplay between electronic, magnetic and structural degrees of freedom continues to give rise to research surprises. In this context, I explored the quantum corrections that arise in the model LaSrMnO3 manganite thin film and show how one can obtain the phase coherence length.

Finally, as the community has migrated from exploring devices for possible applications towards novel architectures, the final part of defense will explore how novel computing paradigms. A first approach explores the use of conventional C-element circuit in a stochastic computing setting to demonstrate Bayesian inference. Next, I explore an analogy between second order phase transitions and overfitting in the extreme learning algorithm. A third project presents how a Schottky barrier nanowire dressed with redox molecules can be used as a memristor. Finally, I conclude with my research perspectives where I plan to exploit my knowledge of device physics and statistical mechanics to realize bio-inspired hardware.