Electron Transport in Graphene based 2D Crystals for Novel Electronic Devices

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Abstract

Reproducing electronic device functionalities that have been successfully realized, and gainfully employed for many decades in traditional semiconductor devices made of Silicon, or III-V heterostructures is a difficult long-term survival strategy for 2D crystal material electronic device applications. They sure are the most sensitive tests of the physics of transport, electrostatic control, and electronic properties of the materials. However, for realistic long-term applications, 2D crystals must transcend the traditional device paradigm and exploit what is truly unique in them.

Novel features of the electron transport properties and electrostatic control will be the driver for realistic electronic device applications of graphene and related 2D crystal semiconductors. An immediate, and potential `opening' for realistic application for logic devices is in ultra low-power tunneling transistors [1]. For tunneling transistors, Graphene and the transition metal dichalcogenides (TMDs) such as MoS_2, WS_2, etc due to their atomically thin nature have the potential to achieve what is considered very difficult with traditional 3D semiconductors [2]. The physics, and material challenges of 2D crystals for in-plane tunneling transistors [3], and out-of-plane interlayer tunneling transistors such as the proposed SymFET [4] and the THIN-TFET [5] will be discussed. Recent experimental progress in the realization of the proposed devices, such as the SymFET [6], and graphene nanoribbon TFETs [7] will be presented, and their performance compared to the predicted and desired characteristics.

There is danger in clubbing too much under the umbrella of `already understood', or 'simple' physics. Case in point: the low-field transport properties of TMD semiconductors are poorly understood. Because of the potential for low dangling bonds, they are considered attractive for scaled traditional transistors as well [8], as has been experimentally demonstrated [9]. However, carrier mobilities in these crystals suffer from very strong coupling to surroundings, which simultaneously are a challenge, and an opportunity for boosting the performance [10]. Mobilities *far exceeding* current numbers are predicted in the near future, based on the analysis [11]. Finally, the contribution of *d-orbitals* to the electronic band-edge states are predicted to be key to exploiting *correlated* effects in these semiconductors, seeding ideas for devices that transcend the current state of the art.

References

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