Quantum Transport in Condensed Matter

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Abstract: Properties of materials, which are in condensed forms of atoms and/or molecules, are governed by states and motions of electrons moving through by virtue of quantum tunneling. In periodic lattices of solid those electronic states are described by well-known band theory which is at the core of understanding of materials properties in general and the basis of semiconductor technology. Electronic states in band theory are characterized by the propagating wave vector. However, in recent efforts to tackle strongly correlated electrons, especially those of transition metal oxides including high temperature copper oxides (cuprates) , scientific interest is more on local aspect, i.e. local atomic arrangement and energy scheme (spectroscopy) in local scale as well. This trend has been stimulated by various experimental capabilities, particularly those of STM and STS. Typical examples of such interest in ”locality” governing properties of macroscopic materials are 1) strongly correlated systems, 2) surfaces and interfaces, and 3) molecular assemblies [1].

In this presentation, recent progress in exploring new possibilities in molecular solids [2, 3] will be focused, including spin liquids, Dirac fermions and p-d coupled systems. It turns out that theoretical backbones of these developments are validity of tight-binding approximation based on molecular orbitals for describing electronic states of apparently very complicated molecular systems. In the cases of p-d coupled systems, there are clearly different cases where d electrons are localized playing roles as localized spins or mixed with p electrons of molecules as in single component molecular metals. (It is interesting to note that cuprates and FePn superconductors are also classified in this way.) Studies on metalloproteins will also briefly be touched upon in this context.

[1] H. Fukuyama, in “Frontier in Materials Research", Springer Series "Advances in Materials Research" Ed. K. Nakajima, T. Sakurai & Y. Fujikawa, p.11-28.
[2] Various articles in Chem. Rev. 104 (2004).
[3] H. Fukuyama, J. Phys. Soc. Jpn 75 (2006) 051001.