MAR05-2004-002338

Abstract for an Invited Paper
for the MAR05 Meeting of
the American Physical Society

Theory of Quantum Hopping In Metallic Polymers and Applications in Electronics[1]

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The low frequency electromagnetic response of highly conducting polymers (e.g., polyaniline and polypyrrole) in a metallic state[1], when analyzed within the standard theory of metals, is provided by an extremely small fraction of the total number of available electrons ~ 0.1 % (in contrast to ~ 100 % for common metals such as Cu, Ag, or Ni) but with anomalous long scattering time $> 10^{-13}$ s (~ 100 times longer than for common metals). We show that a chain-linked network of metallic grains (the polymer's crystalline domains) connected by resonance quantum tunneling through strongly localized states in surrounding disordered medium produces this behavior. The small fraction of electrons is assigned to the low density of resonance states and the long scattering time is related to the narrow width of energy levels in resonance. Recently a new interesting phenomenon, an electric field effect, was reported for the doped highly conducting polymers. Upon applying the gate voltage of a few volts the conductivity of the polymer film drops by a several orders of magnitude[2]. This observation is in conflict with the fact that the electric field cannot penetrate into a conductor further that the 'lattice constant', and therefore its effect on the polymer film of ~ 100 nm thickness should be negligible. We suggest that the field effect in doped conducting polymers is an electric field induced conductor-nonconductor transition described by the chain-linked granular model in the presence of mobile ions. The ion motion under the gate voltage is breaking the interdot percolation network by removing critical hoping sites and as a result producing the conductor-nonconductor transition. The experimental evidences for the present mechanism of field effect in conducting polymers are presented.

1. R.S. Kohlman *et al.*, *Phys. Rev. Lett.* **78**, 3915 (1997).

2. A.J. Epstein *et al.*, *Curr. Appl. Phys.* **2**, 339 (2002).

[1]Supported in part by ONR