HOPPING CHARGE TRANSPORT IN AMORPHOUS ORGANIC AND INORGANIC MATERIALS WITH SPATIALLY CORRELATED RANDOM ENERGY LANDSCAPE

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A general feature of amorphous organic materials is a long range spatial correlation of the random energy landscape $U(\mathbf{r})$ [1]. Correlation arises because of the influence of the molecules having permanent dipole or quadrupole moments. For dipolar materials the energy correlation function has a form $C(\mathbf{r}) = \langle U(\mathbf{r})U(0)\rangle \propto 1/r$, while for the quadrupolar materials $C(\mathbf{r}) \propto 1/r^3$. Spatial correlations provide particular field dependence of the hopping carrier drift mobility $\mu(E)$ in organic materials [2]. Typically, in organic materials the density of states (DOS) has a Gaussian form. For the Gaussian DOS power law correlation function $C(\mathbf{r}) \propto 1/r^n$ gives the mobility field dependence $\ln\mu(E) \propto E^{n/(n+1)}$. This is the reason for the ubiquitous observation of the Poole-Frenkel mobility field dependence $\ln\mu(E) \propto E^{1/2}$ in amorphous organic materials [1]. Important property of the Gaussian DOS is the eventual development of the quasi-equilibrium (non-dispersive) transport regime for any temperature. In this regime the carrier mobility does not depend on time for $t \to \infty$.

In inorganic materials typical kind of DOS is an exponential one $\rho(U) \propto \exp(U/U_0)$, $U < 0$. In the recent paper [3] it was found that such DOS could be observed in some organic materials as well. Until now the charge transport in the correlated exponential DOS is not studied. In the drastic contrast with the case of the Gaussian DOS, low temperature transport with $\alpha = kT/U_0 < 1$ for the exponential DOS demonstrate highly non-equilibrium dispersive regime where carrier mobility monotonously decreases with time.

For the non-dispersive transport in correlated exponential DOS with $\alpha = kT/U_0 > 1$ we obtained an exact solution for the 1D case. The simplest relations can be found for the close vicinity of the transition to the dispersive regime $\alpha \to 1$. For example, for the power law correlation function $C(\mathbf{r}) \propto 1/r^n$ the carrier drift mobility depends on E as $\mu \propto E^n$. For the short range correlation having characteristic length a we have $\mu \propto \exp(eaE/kT)$.

We also discuss an approximate treatment of the dispersive transport with $\alpha < 1$. In the limit of weak E the mobility depends on the thickness L of the transport layer as $\mu \propto L^{1-1/\alpha}$, exactly as in the case of the multiple trapping model of charge transport. However, in comparison to the multiple trapping model, the dependence of μ on E is much stronger; for example $\mu \propto E^{1/\alpha-1}\exp(eaE/\alpha kT)$ for the short range correlation.

References

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