Analysis of the Meyer-Neldel rule in organic thin-film field-effect transistors

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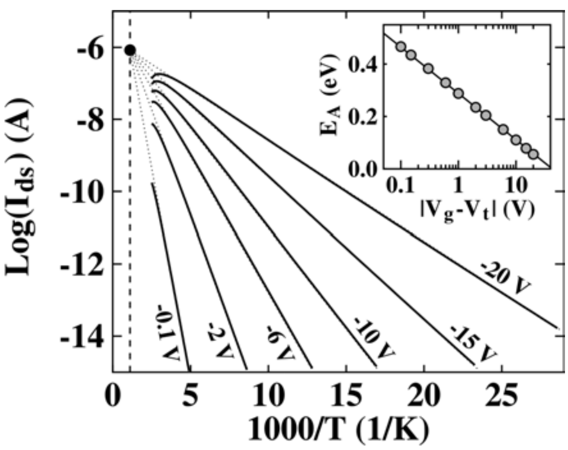
The Meyer Neldel rule (MNR) [1] is an observation occurring in a variety of research fields ranging from diffusion processes (where it is called the compensation effect) to electrical conductivity. In general, the MNR is the observation of a thermal activation energy depending on a parameter and the existence of a temperature (the isokinetic temperature, T_{MN}) where the dependence disappears. In other words, the non-parallel Arrhenius plots of the process all pass through a single point. The MNR is often observed in organic materials, see for example the works of the Eindhoven group [2].

For thin-film transistors (TFTs), the activation energy of the drain-source current depends on the gate bias [3]. However, for a certain temperature this bias-dependence disappears and the current becomes bias independent. The figure gives an example of such a situation.

For amorphous-silicon TFTs, Shur and Hack have developed a model to explain the gate-bias dependence of the charge carrier mobility. We extend the theory and show how also the observation of the Meyer-Neldel rule can be explained by this model. The model is based on the existence of deep traps with a distribution exponentially decaying over energy, $N_T = N_{T0} \exp(-E/kT_2)$. One parameter in this is the distribution energy kT_2, which represents the slope in a logarithmic plot. We show that there is a direct link between the isokinetic temperature T_{MN} and T_2. As such, Arrhenius plots directly reveal information about the trap distribution and are important in the evaluation of the quality of the material and device. Moreover, a model is developed to determine the minimum requirements for the observation of the MNR.



Example (simulation) of the MNR in the drain-source current of TFTs. Each curve represents an Arrhenius plot of the current for a certain gate bias as indicated. The solid dot is the Meyer-Neldel point. The inset shows the as-measured activation energy as a function of bias. The dashed lines are guides for the eye.

For sexithiophene (αT6) TFTs we demonstrated the link between traps on one side and non-linear transfer curves, bias-dependent mobility, non-linear IV curves, stressing (increase of the threshold voltage over time) and (non-exponential) current transients on the other side [4, 5].

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