Using the Seebeck coefficient to determine charge carrier concentration, mobility, and relaxation time in InAs nanowires

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The Seebeck coefficient is an extremely useful quantity for characterizing semiconductor materials. I would like to present a method for determining charge carrier concentration, mobility, and relaxation time in semiconducting nanowires based on carefully analyzing the Seebeck coefficient. The idea is to first deduce the Fermi level from the Seebeck coefficient data, and in a second step the charge carrier concentration using the Fermi level. If additional data on the electrical conductivity, obtained at the same conditions, are at hand, the mobility can be obtained as the ratio of conductivity and charge carrier concentration. In particular compared to gate-voltage-dependent measurements of the mobility, this procedure has the advantage that it does not require an estimate of the capacitance. Furthermore, since the Seebeck coefficient is only sensitive to transported charge carriers (and not to the total number like in case of gate-voltage-dependent measurements) the method is insensitive surface effects. Analyzing the data of a degenerately doped InAs nanowire we found that the mobility shows a dependence on the Fermi level. Although uncommon, this is in full agreement with the general description. It turns out, that this Fermi level dependence of the mobility is caused by both the non-parabolicity of the InAs Gamma-valley and by the energy dependence of the electron relaxation time. From the Fermi level dependence of mobility one can finally obtain the relaxation time. Using this Seebeck-coefficient-based approach of analyzing the characteristics of an n-type InAs nanowire we found:

1.) that electron mobility shows a pronounced Fermi level dependence if the Fermi level is located within the conduction band; 2.) that electron mobility for this InAs nanowire is around 2000 cm²/Vs at room temperature; and 3.) that in the temperature range between 210 K and 336 K the relaxation time can be approximated as the product of a constant times a power-law energy dependence.