Dependence of Electron Mobility on Dopants in Heavily Doped Semiconductors

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Abstract

At high doping concentrations the transport of conduction electrons is predominantly determined by charged-impurity scattering. Experiments have shown that the electron mobility is different for various dopants. It was found that the mobility in As-doped Si was significantly lower than that in P-doped Si for doping concentrations higher than 10^{18} cm^{-3}. Also, the mobility of minority electrons in B-doped Si was substantially higher than the majority electron mobility in n-type Si for carrier concentrations above 10^{17} cm^{-3}. All attempts in the past to explain these differences failed. There is no theoretical model to date which is able to explain the completely different temperature-dependent behavior of minority electrons in p-type silicon and majority electrons in n-type Si.

We introduce a new theoretical approach to study the dependence of the low-field electron mobility on the atomic number of the dopants in doped semiconductors. We describe the charge distribution of the impurities within the Thomas-Fermi theory in the energy functional formulation. Taking into account many-particle interactions the total scattering cross section as a function of the atomic and electronic number of the impurities is derived. Monte Carlo simulations including all important scattering processes have been performed for silicon in the doping concentration range from 10^{15} cm^{-3} to 10^{21} cm^{-3}. The agreement with experiments is excellent. Our results confirm not only the experimental data of the mobility enhancement of minority electrons by a factor of 2.5 compared to majority electrons in degenerated silicon but also the generally lower electron mobility in arsenic-doped silicon compared to phosphorus-doped silicon.

KEYWORDS: electron mobility, ionized impurity scattering, Thomas-Fermi theory, doped semiconductors,minority- and majority electron transport