EPR-INDUCED CHARGE TRANSPORT IN HIGHLY DOPED n-TYPE SiC

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Paderborn, 8/31/2000

Electron paramagnetic resonance (EPR) methods are powerful techniques for the determination of defect structures. For the study of small or low resistivity samples (epitaxial layers, diodes, etc.) electrically detected electron paramagnetic resonance (EDEPR) offers several advantages over conventionally detected EPR: it delivers information on microscopic defect structure with an enhanced detection sensitivity and the expensive microwave detection technique becomes superfluous. Up to now it has been successfully used for the investigation of amorphous and porous semiconductors as well as irradiated crystalline semiconductors. However, in the case of non-irradiated crystalline samples it was not clear which concentrations of donors and acceptors were needed for the observation of an EDEPR signal. The aim of this work was to deepen our knowledge of the EDEPR method, in particular for the case of highly doped crystalline semiconductors, in order to be able to predict the optimal conditions for its use. For this purpose, different n-type bulk and epitaxial silicon carbide samples with high nitrogen concentrations were studied by means of electrical characterization techniques, EPR and EDEPR.

To begin with, electrical investigations were conducted which aimed at the determination of the defect concentration and compensation as well as the dominating charge transport mechanism at the low temperatures typical for EDEPR investigations. Furthermore the influence of microwave irradiation was investigated. Studies of the temperature and magnetic field dependence of the resistivity showed that hopping was the dominating conduction process at low temperatures for partly compensated samples with a nitrogen concentration N_D in the range of $10^{18}cm^{-3} < N_D < 10^{19}cm^{-3}$.

The EDEPR signal was measured in the dark and was found to correspond to a resisitivity decrease at spin resonance conditions in contrast to the case of the donor acceptor recombination. The order of magnitude of the EDEPR effect at optimum conditions was $\Delta\rho_{EPR}/\rho \approx 10^{-3}$. Experimental studies of the EDEPR signal behaviour with parameters such as temperature, microwave power, modulation frequency and defect concentration provided the necessary information to discuss the microscopical processes responsible for the resistivity decrease at spin resonance conditions.

In contrast to an earlier proposed mechanism, namely the transfer of the EPR energy to the hopping electrons by the combined action of the exchange interaction and the spin-orbit interaction, we discuss a heating of the sample at resonance conditions as responsible for the resonant resistivity decrease. At resonance the spin system absorbs microwave energy, which is transferred to the surroundings by relaxation processes. As a result, the crystal is heated at resonance conditions. An experiment was carried out on purpose to see whether the sample temperature increases indeed at resonance. A direct measurement of the resonant temperature change was performed. In fact a temperature increase at spin resonance conditions was found.

In samples with a nitrogen concentration of about $(1\text{-}3)\bullet 10^{18}cm^{-3}$ two additional EPR lines were found, as compared to the hyperfine triplet spectra (I=1 for ^{14}N) for low defect concentrations. The additional lines were situated exactly in the middle between two nitrogen hyperfine lines. Such additional lines have been reported before, and their origin has been subject of controversy. Not two but six additional EPR lines, the position of which corresponds to +/-1/4, 1/2 and 3/4 of the hyperfine splitting of nitrogen at the quasicubic position, were found in a further sample. The experimentally determined temperature dependence of the resistivity of these samples showed that hopping dominates the conductivity at low temperatures. Thus, it is shown that the additional EPR lines arise from a donor-electron hopping between two or four nitrogen donors, respectively.