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Donor-Acceptor Complexes in ZnO

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One of the main obstacles to the technical application of many wide-gap semiconductors represents the difficulty to achieve reliable and sufficient p-type or n-type doping. Possible causes are the electrical compensation of dopants by native defects or other impurities present in the material. For the II-VI semiconductors CdTe, ZnTe, and ZnSe it has been shown [1,2] by perturbed Gamma-Gamma angular correlation spectroscopy (PAC) that the concurrent presence of In donors and group-V acceptors leads to the formation of neighboring donor-acceptor pairs. In case of ZnO, the affinity to form donor-acceptor complexes may help to overcome the limitations of p-type doping of this material as outlined in the theoretically proposed concepts of cluster-doping [3] or co-doping [4].

Here, we report on PAC results obtained by co-doping experiments of ZnO using the donor ^{111}In and different group-V acceptors. Fig. 1 shows a PAC spectrum obtained after the implantation of ZnO with ^{111}In and P and after annealing at 850 K. Besides the lattice electric field gradient (EFG) due to the wurtzite structure of ZnO (nQ Lattice = 31 MHz), two additional EFG caused by the formation of In-defect complexes are observed. They are characterized by two slightly different nearly axially symmetric EFG with $nQ1 = 175(1)$ MHz ($\text{Eta} = 0.1$) and $nQ2 = 155(2)$ MHz ($\text{Eta} = 0$). Due to the wurtzite structure of ZnO having different nearest neighbor distances along the c axis and in the basal plane, respectively, even for identical defect complexes two different EFG are expected to occur. The magnitudes of the EFG observed here are similar to that of the EFG known for In-acceptor complexes in other II-VI semiconductors [1,2]. The nature of the defects in ZnO and the efficiency of different co-doping procedures will be discussed.

The results of first PAC experiments on the formation of donor-acceptor complexes using group-VII donors in ZnO utilizing the radioactive donor ^{77}Br will be discussed, as well.

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