STUDY OF DOPANT (Al, B) INCORPORATION DURING PVT GROWTH OF p-TYPE SiC CRYSTALS

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The availability of p-type highly conductive SiC bulk crystals with low defect densities is an important issue for the further development of SiC power electronics. Furthermore, defined p-doping at very low levels is a prerequisite for the preparation of semi-insulating, highly resistive SiC substrates for high frequency applications, where vanadium acts as deep donor for the compensation of residual acceptor levels. P-conduction is commonly established by Al or B doping. For the achievement of homogeneously doped p-type SiC Crystals in lateral and longitudinal directions a thorough understanding of the dopant incorporation both at low and high concentrations is necessary.

Difficulties in p-type doping arise on one side from the lack of an suited gas source, which, if constantly applied, will provide in principle homogeneously doped bulk crystals, as can be seen in n-type doping, where N_2 as a gas source is commonly used. On the other side, the amount of incorporated species and related electrical activity of p-dopants under PVT conditions is not clear. In this paper, p-type doping is performed by applying solid sources. Here several aspects are critical: First, the depletion of the dopant source has to be avoided. Second, segregation phenomena can provide local accumulation of dopants species resulting in inclusions or polycrystalline growth conditions. Third, as the temperature field at the growth interface changes with growth time, also the conditions of dopant incorporation can change. All of these aspects can lead to inhomogeneous doping up to the order of several magnitudes. Finally, temperature field and applied source strongly influence the overall doping level, which has also to be taken into account.

In our investigation several SiC bulk crystals were grown by the physical vapor transport (PVT) technique. The dopant was provided either by adding solid compounds as B_4C or Al_4C_3 to the undoped SiC source material or by doping the SiC powder during synthesis with varying amounts of B or Al, respectively. For reference purposes also some nominally undoped crystals were grown to take into account the residual impurities of the growth system. Wafers as well as longitudinal cuts were prepared from the crystals. Characterization was performed by doping level mapping via absorption measurements. Further investigation was performed by Hall measurements, GDMS and SIMS analysis. Also, a detailed study of the samples by optical microscopy was performed to analyze crystal quality and doping-induced defects like inclusions or grain boundaries.

We will present results on p-type SiC samples, doped with Al or B, with charge carrier concentration in the range from 10^{15} cm^{-3} to $5\cdot10^{18}$ cm^{-3} as measured by absorption and Hall effect. Several correlations in respect to growth parameters are revealed: The dopant incorporation of Al or B, respectively, is several times higher during crystallization on the silicon face with respect to the carbon face. At very high doping levels polycrystalline growth can occur on either face. For highly doped growth, the generation of voids and mesoscopic pipes and, in the case of B doping, inclusions of probably eutectic B-Si-C compounds, were observed. Doping inhomogeneities up to the order of one magnitude can arise from the variation of growth temperature and the structural evolution of the source during growth. Inhomogeneous doping is shown to be distinctive at low doping levels, especially for Al doped growth. For B doped growth, the range of dopant incorporation in dependence of growth conditions will be presented. Finally, implications of this study for PVT growth conditions with reduced dopant non-uniformities are discussed.

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