Experimentally Determining the Magneto-resistance Tensor of Unintentionally Doped (010) β-Ga$_2$O$_3$ (AGSR_96)

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The beta-phase of gallium oxide (β-Ga$_2$O$_3$) is a promising material for next generation power electronics due to its ultra-wide bandgap of 4.5 – 4.8 eV and ease of high-quality bulk growth with melt-growth techniques. The crystal structure of β-Ga$_2$O$_3$ is monoclinic with C2/m space group. Due to the low symmetry of the material, possible anisotropy in charge transport can be expected. Therefore, in this work, four-point probe and Hall effect measurements were performed on unintentionally doped (010) β-Ga$_2$O$_3$ bar-shaped substrates diced along [001], [100]$^*$ and [001]$^*$ directions to determine the elements of material’s magneto-resistance tensor. No notable anisotropy has been observed in the electrical conductivity as the difference in the in-plane resistivity was within 3%. The measured Hall voltage was corrected for non-ideal effects such as misalignment, Seebeck, Nernst, and Righi-Leduc effects. Among the four, misalignment of contacts was found to be the dominant non-ideal effect. At room temperature, Hall electron concentration and mobility were ~ 7-8 × 10$^{16}$ cm$^{-3}$ and 130 – 140 cm$^2$ V$^{-1}$s$^{-1}$, respectively. The results of Hall electron mobility among the samples were within 4 – 10 %. The larger difference in mobility could be attributed to the direction-dependent electron-phonon coupling strength in β-Ga$_2$O$_3$. Due to the monoclinic structure of β-Ga$_2$O$_3$ and orthogonal coordinate system required for the magneto-resistance tensor calculations, the elements of the tensor denote the values along one crystallographic axis (c or a) and a direction orthogonal to it (a$^*$ or c$^*$). Using the experimentally measured values for ca$^*$b – system, we found the values for c$^*$ab – system using a matrix transformation. A 3 % difference was observed between the experimentally measured values and the ones obtained through the matrix transformation.