# MOCVD Epitaxy and Doping for β-$Ga_2O_3$ and $(Al_xGa_{1-x})_2O_3$
# (Invited)

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Ultrawide bandgap (UWBG) gallium oxide ($Ga_2O_3$) represents an emerging semiconductor material with excellent chemical and thermal stability. It has a band gap of 4.5-4.9 eV, much higher than that of the GaN (3.4 eV) and 4H-SiC (3.2 eV). The monoclinic β-phase $Ga_2O_3$ represents the thermodynamically stable crystal among the known five phases (α, β, γ, δ , ε). The breakdown field of β-$Ga_2O_3$ is estimated to be 6-8 MV/cm, which is much larger than that of the 4H-SiC and GaN. These unique properties make β-$Ga_2O_3$ a promising candidate for high power electronic device and solar blind photodetector applications. Single crystal β-$Ga_2O_3$ substrates can be synthesized by scalable and low cost melting based growth techniques. Metalorganic chemical vapor deposition (MOCVD) growth technique was used to develop high quality β-$Ga_2O_3$ thin films and its ternary alloy $(Al_xGa_{1-x})_2O_3$. Control of background and n-type doping in β-$Ga_2O_3$ will be discussed. Record carrier mobilities of 184 $cm^2/V\cdot s$ at room temperature and 4984 $cm^2/V\cdot s$ at low temperature (45 K) were measured for β-$Ga_2O_3$ thin films with room-temperature doping concentrations of $2.5\times10^{16}$ and $2.75\times10^{16}$ $cm^{-3}$, respectively [1]. Growth and fundamental understanding of $(Al_xGa_{1-x})_2O_3$ are still lacking. The limit of Al incorporation in beta-phase $Ga_2O_3$ has not been understood or experimentally verified, although it was predicted up to 60% of Al composition could be incorporated into β-$Ga_2O_3$. N-type doping capability as a function of Al composition in $(Al_xGa_{1-x})_2O_3$ is another important fundamental question. Carrier transport properties in $(Al_xGa_{1-x})_2O_3$ will be discussed.

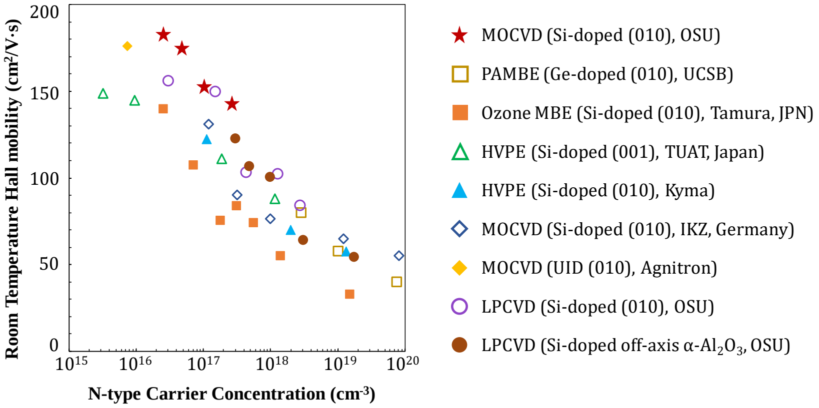

Fig. 1 Results from this work as compared to state-of-the-art: room temperature carrier mobility vs. carrier concentration for (010) β-$Ga_2O_3$ films.

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[1] Z. Feng, AFM Bhuiyan, M. R. Karim, H. Zhao, Appl. Phys. Letts, 114, 250601 (2019).