

MOCVD Epitaxy of β -Ga₂O₃ Thin Films with Record Mobilities

Zixuan Feng^{1,*}, A F M Anhar Uddin Bhuiyan¹, Md Rezaul Karim¹, Yuxuan Zhang¹ and Hongping Zhao^{1,2,†}

¹Department of Electrical and Computer Engineering, The Ohio State University, Columbus, OH 43210, USA

²Department of Materials Science and Engineering, The Ohio State University, Columbus, OH 43210, USA

*Email: feng.890@osu.edu

†Corresponding Author Email: zhao.2592@osu.edu

β -Ga₂O₃ with an ultra-wide bandgap of 4.5-4.9 eV and capability of n-doping promises its applications for high power electronics. β -Ga₂O₃ is predicted to have high breakdown field (6-8 MV/cm) with room temperature mobility of ~ 200 cm²/Vs. The Baliga figure of merit (BFOM) of β -Ga₂O₃ for power electronics is predicted to be 2 to 3 times higher than that of GaN and SiC. More advantageously, the availability of high-quality native Ga₂O₃ substrates produced from melt growth techniques is critical for large scale production. High voltage (>1 kV) devices, as well as RF devices with 27 GHz cut-off frequency, have been demonstrated recently [1, 2]. Nevertheless, development of high-quality β -Ga₂O₃ thin film growth technology is the cornerstone for high-performance device applications. Epitaxy of β -Ga₂O₃ has been investigated via different methods, including MBE, MOCVD, LPCVD, PLD, ALD and etc. Recently, MOCVD grown β -Ga₂O₃ has exhibited record high electron mobilities in both unintentionally doped (UID) [3] and Si-doped films [4].

In this work, we continue optimizing the MOCVD β -Ga₂O₃ homoepitaxial process on (010) Ga₂O₃ crystal orientation, and expand our investigation of β -Ga₂O₃ MOCVD growth along different orientations including ($\bar{2}01$), (001) and (100). Key growth parameters, including growth temperature, growth pressure, Ga/O molar ratio, and substrate preparation, were investigated. For films grown on semi-insulating Fe doped (010) Ga₂O₃, the epi-film exhibit low background doping. From secondary ions mass spectroscopy (SIMS) depth profile, impurities such as hydrogen (H), carbon (C), chlorine (Cl), iron (Fe) were all below the detection limit. With low intentional Si doping, we demonstrated (010) β -Ga₂O₃ films with controllable doping between 10^{16} to 10^{19} cm⁻³. From temperature dependent Hall measurements and analysis taking into account various carrier scattering mechanisms, we extracted a very low compensation level of $N_a < 1 \times 10^{15}$ cm⁻³. Peak electron mobility reaches ~ 9500 cm²/Vs at $T \sim 45$ K for an unintentionally doping (010) β -Ga₂O₃ film. We demonstrated record high room temperature mobility of ~ 194 cm²/Vs with $n = 8 \times 10^{15}$ cm⁻³. The superior transport properties of the MOCVD grown (010) β -Ga₂O₃ films demonstrated high purity MOCVD epitaxy process with low defects densities.

For films grown along different crystal orientations, we use scanning electron microscopy (SEM) and atomic force microscopy (AFM) to characterize the surface morphologies, which have shown significant dependence on substrate orientation. Film growth rate, doping incorporation and transport properties are investigated.

In summary, we demonstrated superb electrical transport properties from MOCVD grown (010) β -Ga₂O₃ thin films with high purity and low defect densities. Growth mechanisms will be investigated for films grown along other orientations. The results from this study will provide fundamental understanding of the material properties of β -Ga₂O₃, which determines its potential for power device applications.

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