Gallium Oxide Bulk Crystal Growth, Epilayer MOCVD, Substrate Processing, and Characterization for Ultrawide Bandgap Semiconductor Devices

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Abstract: Gallium oxide (β-Ga_2O_3) has emerged as the leading ultrawide bandgap (UWBG) semiconductor and is generating considerable interest for next-generation power electronics. β-Ga_2O_3 has a high critical electric field, a range of shallow n-type dopants, and is the only UWBG semiconductor that can be crystallized from a melt at an industrial scale. This poster will discuss our group's research on β-Ga_2O_3 bulk crystal growth, substrate processing, and epitaxy to manufacture epiwafers suitable for device fabrication. We will also highlight characterization techniques implemented throughout processing for evaluation of the material structure-processing-property relationships to scale-up and improve the quality of the β-Ga_2O_3 materials.

Our group utilizes the Vertical Bridgman (VB) technique to grow bulk β-Ga_2O_3 crystals from a melt. VB requires careful control of temperature gradients, cooling, and translation to grow single crystals without cleaves, grain boundaries, or other major defects. After growth, we orient and slice the crystals into individual wafers. β-Ga_2O_3 has a low-symmetry crystal structure, and we have observed that the orientation/miscut significantly affects the material properties. Next, our group has developed a chemical-mechanical polishing (CMP) process for β-Ga_2O_3 utilizing low pH colloidal silica slurry. This process efficiently removes subsurface damage and produces a smooth surface finish with average surface roughness values consistently <0.1 nm.

As part of our AFRL programs, we also partner with companies to process β-Ga_2O_3 substrates from crystals they grow using other methods, such as edge-defined film-fed growth (EFG) and Czochralski (Cz). Finally, we collaborate with multiple research groups to grow β-Ga_2O_3 homoepitaxy layers and are currently developing a hot-wall metalorganic chemical vapor deposition (MOCVD) capability in our lab. The substrates and epiwafers are characterized using several techniques, including high-resolution x-ray diffraction (HRXRD), atomic force microscopy (AFM), white light interferometry (WLI), etch pit density (EPD) mapping, and a "Pre-Epi Surface Evaluation" method for assessing subsurface damage.