Summary of Identification of β-Ga_2O_3 Knowledge Gap Exercise

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Motivation

During the course of the workshop, it was clearly shown that tremendous progress has been made in the field of β-Ga_2O_3 in the last two years and that the community is eager to embrace the research challenges that are unique to this family of materials. New transport modeling and defect analysis has spurred device advances and materials synthesis developments. We are now seeing high-critical field strength devices, e-mode device operation > 600 V, and field-plated devices with > 750 V lateral breakdown. Homo-epitaxial growth and hetero-epitaxial alloy growth has been demonstrated by several techniques to achieve large ranges of doping concentrations with several dopants to enable high current density > 500 mA/mm and low ohmic contact resistance < 0.5 Ω·mm. Commercial availability of bulk crystals for research purposes was clearly indicated by Tamura Corp. and Northrop Grumman Synoptics showed significant progress toward developing substrates.

Despite all of this, substantial research is required to fully realize the promise of this exciting material. The purpose of this document is to provide a summary of the knowledge gaps identified during the focus sessions and group discussion on 12 DEC 2016 during the 2nd AFRL Workshop on β-Ga_2O_3 in Arlington, VA.

Exercise Summary

The research community was well represented in a wide range of technical interests including, but not limited to, modeling, materials synthesis, defect characterization, electronic transport, and devices. During the group discussions, it was agreed that the top two considerations for this material system will be thermal issues and materials availability. While great strides have been made to improve materials access, co-design of electrical, mechanical, and thermal properties will be an overarching theme for all research activities. Advanced microscopy and materials analysis communities were under represented, but will be critical to the success of this research. Engaging the application community early on to identify novel uses for β-Ga_2O_3 will also be critical for success as well as guide the efforts of researchers.

Significant modeling efforts are required to link atomistic simulation of high-field band structure with accurate phonon effects to incorporate missing extreme electric field and thermal gradients that will be encountered in commercial simulators.

A full understanding of defect complexes and behavior under high fields and thermal gradients is required. Defect analysis and characterization is required to study the migration of dopants and other elements in β-Ga_2O_3 and related alloys. The role of oxygen and oxygen vacancies must be clarified.

Dielectric development and their interfaces with the β-Ga_2O_3 host substrate as well as ohmic and Schottky contact development are in their infancy.

In the early stages of this material system, the impact of extreme environmental conditions such as high-temperature, oxidizing or irradiating environments are not known.

In terms of device applications, it was noted that mobility is fundamentally lower than high-performance RF materials and that the carrier saturation velocity occurs under extreme fields implying that for normal voltages, the devices will never operate outside of the gradual channel approximation. However, it was also noted that devices can be scaled to force the high electric fields to achieve saturation velocity at lower voltages and that novel device uses favoring the high-field strength even though mobility is low should be investigated.

Even though power switching and high-efficiency RF applications dominated the discussion, it is clear that other applications may exploit the unique properties of β-Ga_2O_3. Solar-blind UV detectors have previously been demonstrated and were noted as a possible application as well as novel optical gain media based on self-trapped holes in β-Ga_2O_3. And finally, β-Ga_2O_3 substrates were originally developed as a transparent conductive oxide for the growth of GaN optical devices suggesting novel integration approaches for RF, EO, and power switching applications on a common substrate.