Development of a High-Purity, High-Concentration Ozone Delivery System for MBE and Growth of β-Ga_2O_3

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Each year, research in oxide materials and devices increases and molecular beam epitaxy (MBE) serves as a critically important tool for the synthesis of these materials. The ever-increasing interest in oxide materials is attributable to the wide range of potential uses of these materials in applications including power electronics, structural buffer layers, gate dielectrics, superconductors, 2D electron gases, ferroelectrics, ferromagnetics, electrical isolators, and optically transparent conductive layers. For many of these applications, a key challenge for MBE growth is adequately oxidizing compounds to achieve desirable properties.

Molecular oxygen and oxygen plasma have been used extensively in the growth of oxide materials but have limitations including reactivity and growth rate. An alternative to these approaches is to use a stronger oxidizer such as ozone. However, using ozone as a source gas in MBE presents challenges related to generating, storing, and injecting ozone that is of both high purity and high concentration. Additionally, ozone has inherent challenges with toxicity and chemical instability.

To address these practical issues in safely implementing ozone in MBE, a distillation system has been integrated to a novel delivery system with key features including: delivery of high-purity, high-concentration ozone; wide-ranging, precise pressure control for the injected ozone gas; and comprehensive safety controls. Growth pressures have been actively controlled from $5x10^{-9}$ to $5x10^{-5}$ Torr with high precision and highly-linear ramp rate control. Additionally, to maximize process flexibility, this system provides for automated, rapid switching between injecting molecular oxygen, low-concentration ozone (15-25 wt%), and high-concentration ozone (~90 wt%).

Finally, this ozone system has been used in the growth of β-Ga_2O_3 epitaxial films. Details of the growth interactions will be discussed. The resulting epitaxial films were measured using techniques including RHEED, AFM, high-resolution XRD, and ellipsometry.

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