Innovative Gallium Oxide MOCVD Reactor

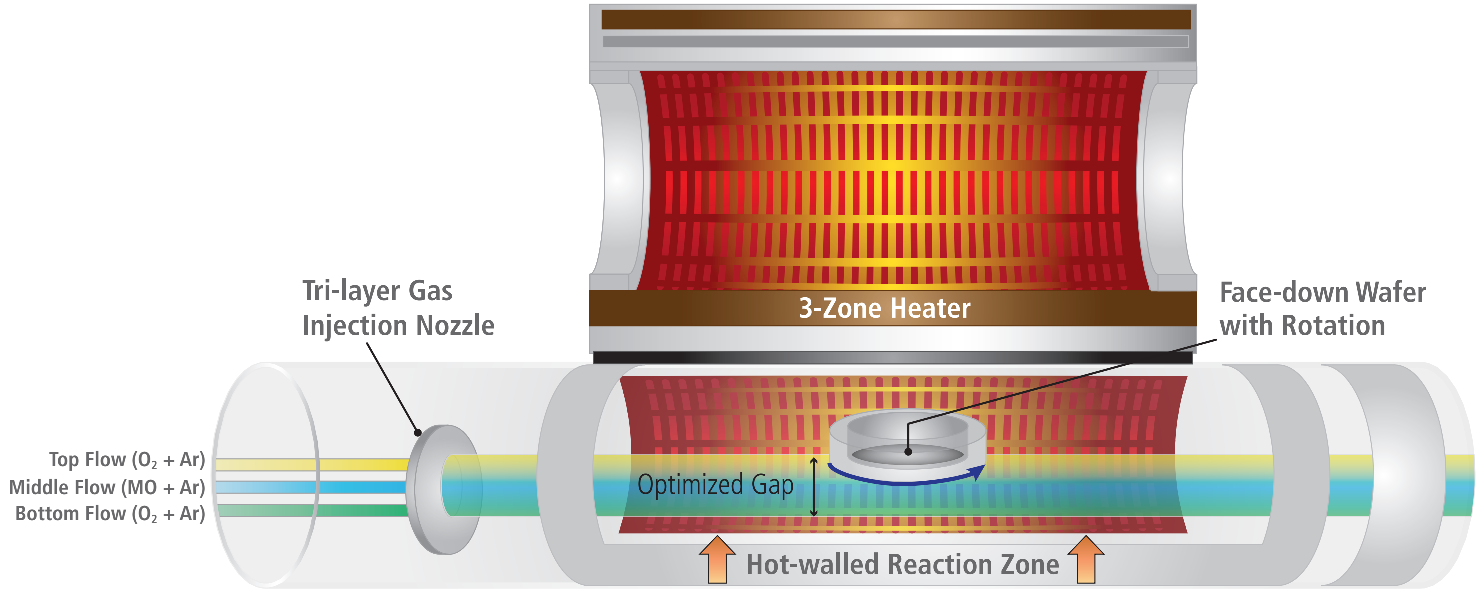

Figure 1: Taiyo Nippon Sanso FR2000-OX - Optimized Gallium Oxide MOCVD Reactor

Taiyo Nippon Sanso's FR2000-OX gallium oxide (GaO_x/Ga_2O_3) MOCVD reactor (Figure 1) has three important design features that enable state-of-the-art gallium oxide epitaxy:

- A hot-walled reaction zone
- A face-down wafer mounting configuration
- A tri-layer gas injection nozzle

The hot-walled reaction zone is maintained by a three-zone electric furnace heater, which offers a **long component lifetime** and **lower cost of ownership**. GaO_x MOCVD reactor design requires the selection of materials that are **resistant to oxidation**. The hot-walled reactor design is also **better matched to the thermodynamics** of the GaO_x materials system and **promotes uniform heating** of the substrate, which reduces warpage and deformation. In addition the hot-walled reaction zone promotes complete decomposition of hydrocarbons thereby **reducing hydrogen (H) and carbon (C) incorporation** in the GaO_x thin film. The FR2000-OX MOCVD also is compatible with ***in situ* reactor cleaning technology**, which is more effective in a hot-walled reactor.

The face-down wafer mounting configuration and tri-layer gas injection nozzle reduce particulate contamination and parasitic gas phase reactions. The tri-layer gas injection nozzle is designed for high flow velocity, which limits parasitic gas phase reactions and **promotes higher growth rates**.

TAIYO NIPPON SANSO

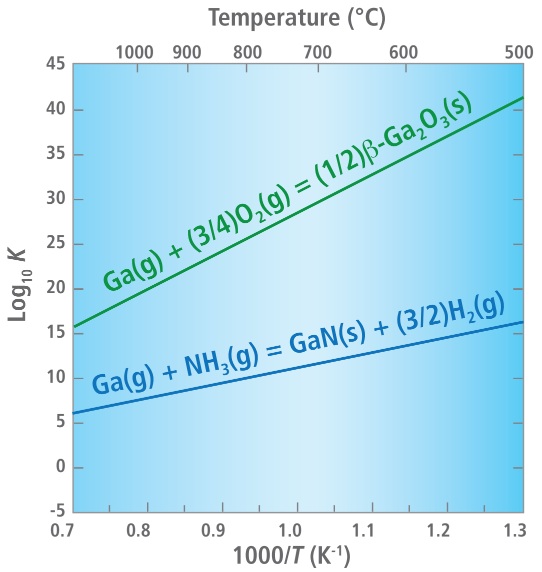

Figure 2: Equilibrium Constants, *K's*, as a Function of Temperature for Growth Reactions of ß-Ga_2O_3 and GaN MOVPE.

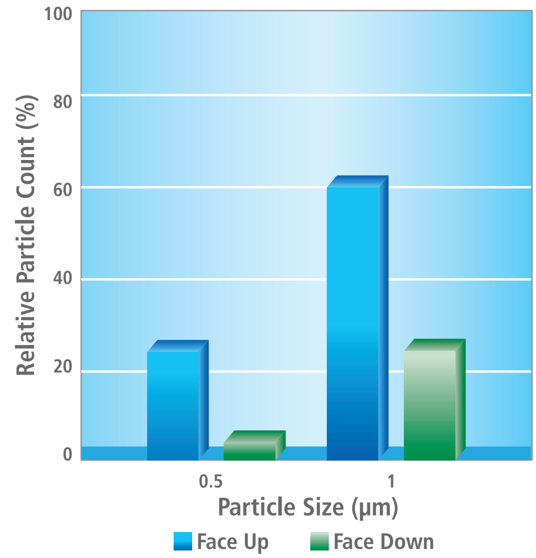

Figure 3: Particle Reduction with Face-down Wafer Configuration.

The equilibrium constant diagrams (Figure 2) for gallium nitride (GaN) and Ga_2O_3 illustrate how the chemistry and thermodynamics for the two materials systems are very different (Y. Kumagai and K. Goto, Journal of the Japanese Association for Crystal Growth Vol. 48, No. 3 (2021) 48-3-05). The **different thermodynamic driving force for the GaO_x materials requires special care** and consideration for GaO_x MOCVD reactor design.

Taiyo Nippon Sanso has extensive experience in designing MOCVD systems with face-down wafer configuration for arsenide-phosphide (As/P) and GaN epitaxy. Particulate reduction is of paramount concern for all large area epitaxial processes, and Figure 3 illustrates how a face-down wafer configuration offers advantages for **reduction of particulate contamination** during epitaxy.

Collaboration with Tokyo University of Agriculture and Technology (TUAT)

Professor Yoshinao Kumagai of Tokyo University of Agriculture and Technology (TUAT) and his group have led the development of growth techniques for wide bandgap oxide semiconductor crystals, such as gallium oxide and indium oxide, mainly using hydride vapor phase epitaxy (HVPE)-based crystal growth techniques. The Kumagai group developed the early thermodynamic models for GaO_x deposition (Ken Goto *et al.* 2021 Jpn. J. Appl. Phys. 60 045505). Taiyo Nippon Sanso has been collaborating with TUAT to develop GaO_x MOCVD technology. Taiyo Nippon Sanso placed its first GaO_x MOCVD system in Professor Kumagai's laboratory in 2022. Joint efforts are ongoing to demonstrate the full capabilities of Taiyo Nippon Sanso's FR2000-OX gallium oxide (GaO_x/Ga_2O_3) MOCVD reactor, including $(Al_xGa_{1-x})_2O_3$ epitaxy.