RESEARCH BRIEF

PROCESS SENSING AND SIMULATION FOR GaN-BASED SEMICONDUCTOR ELECTRONICS

The potential

Gallium nitride (GaN) films are the basis for the next generation of radar electronics, promising to increase power densities by a factor of 10, extend operational frequency and temperature range, and provide higher reliability than existing gallium arsenide (GaAs) devices. As a result, GaN-based devices will be lighter, smaller, and more robust, giving them broad applicability.

The development of GaN technology is important to Northrop Grumman Electronic Systems, which has accordingly made a significant investment in new materials growth equipment and process technology for GaN.

The challenge

While we are starting to see GaN-based optoelectronic device technology in a broad range of applications in solid state lighting and displays, microwave electronic devices demand considerably higher material quality in GaN epitaxial films and GaN-based alloys. In turn, this requires a deeper understanding of chemical mechanisms, optimized equipment design for materials growth, and sensing and process metrology methods to control the growth process for manufacturing. While these components have become mainstream in current silicon technology and manufacturing, the materials complexity in GaN-based electronics generates what is in some ways a more difficult challenge, and in an industry which is at an earlier stage of its evolution.

The research

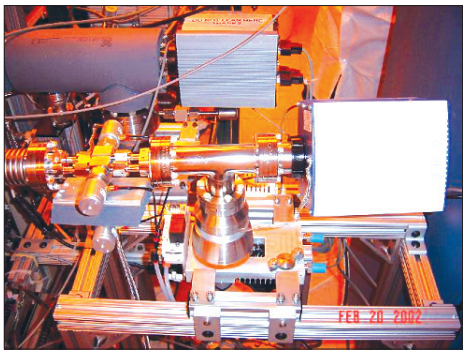
Several years ago Northrop Grumman (NG) put together a GaN materials growth team, including onboard experts and new PhD hires. They also recognized the need for an even broader research base to underwrite their GaN materials development, to know what is going on in the processes, equipment and consequent materials and device structure.

In Fall 2001 NG initiated a joint project to exploit ISR's skills in chemical process sensing, metrology, modeling and simulation, equipment design, and process control. The ISR researchers have a significant history of successful research and collaboration in applying their expertise in these areas to semiconductor manufacturing equipment and processes for the silicon technology industry.

ISR's contribution

ISR research groups have made major contributions to NG's GaN technology.

Dr. Rubloff's work has applied in-situ chemical sensing for advanced process control goals, achieving:



In-situ real-time process sensing of the GaN MOCVD using downstream mass spectrometry.

- Real-time thickness metrology for thickness control of the critical nanoscale AlGaN cap layer at a precision of 0.2nm out of only 20 nm total thickness (i.e., 1 percent)
- Chemical signatures which are useful predictors of material quality
- Real-time identification of contaminaton sources and equipment faults, as a fault detection component of advanced process control

Dr. Adomaitis' research has exploited modeling, simulation, and design optimization to reactor and process design, leading to:

- Major advances in gas delivery system design for enhanced uniformity across the wafers
- Modeling tools to analyze the consequences of equipment and process design before they are built and tested
- Innovative design concepts motivated by modeling and simulation investigations

Impact

This joint research has become a critical technology to NG, which sees it as a key component of its future technology leadership.

NG now uses and relies on ISR's methods routinely in its development process. Sensor-based metrology is exploited to automatically terminate the growth of the AlGaN cap layer, a nanostructure which is a direct determinant of device performance. Furthermore, the same sensor is employed to identify substandard material quality and equipment faults in real time. Gas delivery and process models are used by Northrop Grumman engineers to investigate possible improvements in system and process design.

ISR's contributions and collaboration are recognized as an important component of NG's profound advance in the field, helping to move the company from the status of non-player to a position of competitive leadership in GaN-based materials and process technology for microelectronics systems. Judging by public announcements and publications, the company is now the industry leader in GaN-based process uniformity, layer thickness control, and advanced process control.

ISR is very cognizant of the importance with which NG views contract research and development support, and we are enthusiastic to assist in such efforts as we have successfully done before.

This research is being done as a component of Northrop Grumman's membership in the ISR Industrial Affiliates Program (IAP).

Awards

ISR Ph.D. student Soon Cho received a Student Paper Award for "Real-Time, In-Situ Metrology to Drive Real-Time Advanced Process Control" at Sematech's Advanced Equipment Control/Advanced Process Control Symposium in 2003.

Research team

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