get it right®

AIXTRON

Advanced Multiphysics Modelling Reduces Cost of Ownership of LED Production Equipment

THE CHALLENGE

- Reducing the high manufacturing cost of LEDs to help accelerate widespread LED adoption
- Providing accurate control of layer composition and thickness of chemical reactors and basic deposition process technology for MOVPE
- Proving ability to reduce the cost of ownership of LED production equipment

THE STORY

"AIXTRON has used CFD-ACE+ for more than ten years for our modelling needs. The advanced multiphysics modelling capabitility of CFD-ACE+ helps evaluate the impact of key process and reactor design parameters on performance criteria like the uniformity of layer thickness and composition on wafer and from wafer to wafer, the growth efficiency and the robustness of the process. At AIXTRON, upfront modelling analysis has become an integral part of any development project that involves the reaction chamber of an MOVPE reactor."

THE BENEFITS

- Aixtron reduced the cost of ownership of production scale MOVPE reactors
- Lowering the ownership cost of MOVPE reactors in turn reduced the cost of LED manufacture
- Employing modelling and simulation is key to reducing the technological risk and the time-to-market for product innovations

AIXTRON AG, headquartered in Aachen, Germany, is a leading provider of deposition equipment to the semiconductor industry. Established in 1983, the company's technology solutions are used by a diverse range of customers worldwide to build advanced components for electronic and opto-electronic applications based on compound, silicon, or organic semiconductor materials. These components in turn are used in fiber optic communication systems, wireless and mobile telephony applications, optical and electronic storage devices, computing, signaling and lighting, as well as a range of other leading-edge technologies.

Example of architectural lighting with white LEDs.

HIGH MANUFACTURING COST: KEY BARRIER TO WIDESPREAD LED ADOPTION

The lighting industry is experiencing a fundamental change as revolutionary as the introduction of digital cameras has been to photography. Light Emitting Diodes (LEDs), either based on compound semiconductors or novel organic polymers – referred to as OLEDs, Organic Light Emitting Diodes – are substantially more energy efficient in converting electricity into light, last longer, and are more versatile due to their small size than the traditional incandescent light bulb. In addition, LED lighting contributes to energy conservation and reduces CO2 emission.

The High Brightness LED market grew at an impressive 25-30% average annual growth rate from 2001 to 2006 and is expected to continue, with a market projection of $9 billion by 2011. In spite of recent productivity advances, the major roadblock to their widespread adoption remains the high manufacturing cost of LEDs.

MODELLING AND SIMULATION OF THIN FILM DEPOSITION PROCESSES FOR MOVPE WITH ESI GROUP'S CFD-ACE+ MULTIPHYSICS CFD SOFTWARE

LEDs based on compound semiconductors are by far the most common type today, and are usually composed of multiple thin layers of so called III-V semiconductors. The method of choice for making LEDs is Metal Organic Vapour Phase Epitaxy (MOVPE), a deposition technique using gaseous metalorganic and hydride species. The precursors are supplied to the MOVPE reaction chamber with a flow of carrier gas at a process pressure below atmosphere, and the monocrystalline solid thin film is formed on heated substrates at temperatures from 600°C to 1400°C, depending on material and application.

AIXTRON AG develops, manufactures and markets chemical reactors and basic deposition process technology for MOVPE, a highly precise chemical process used for the production of optoelectronic devices. The accurate control of layer composition and thickness, which can be as low as a few nanometers, with uniformity requirements on multiple substrates of less then +/- 1% deviation from the mean value, poses a formidable challenge to reaction chamber and process design.

Multiphysics modelling and simulation of semiconductor deposition processes has become an indispensable tool to meet accuracy requirements of the sensitive MOVPE process. AIXTRON

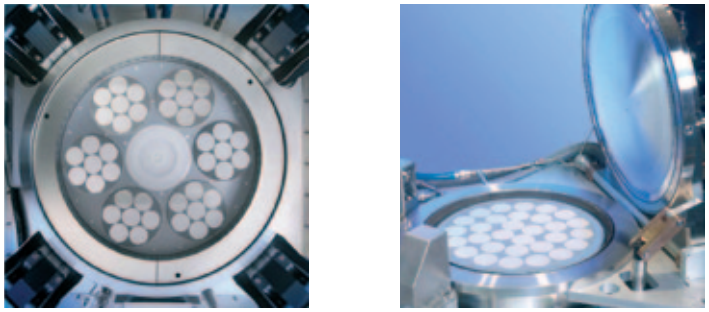

Figure 1: The AIX 2800G4 HT Planetary Reactor® in 42x2" configuration (bottom left) and the Crius 30x2" Close Coupled Showerhead Reactor (bottom right) are integrated in the IC Platform system (top).

has been using ESI Group's CFD-ACE+ multiphysics CFD software for nearly ten years to provide guidance during conceptualization, hardware development and process tuning. Today's industrial requirements to reduce the cost of LED manufacture call for production scale MOVPE reactors with lower cost of ownership. This goal is accomplished by larger and larger reaction chambers accommodating an increased number of wafers, reduced gas consumption per wafer area and increased throughput at enhanced process performance. Modelling and simulation play a key role in reducing the technological risk and the time-to-market for product innovations. The impressive increase in reactor wafer load capacity over the past few years speaks for itself. Figure 1 shows AIXTRON's flagship MOVPE reactors for the production of GaN based green, blue and white LEDs, the Planetary Reactor for 42x2" wafers (or 11x4" and 5x6" equivalently) and the Close Coupled Showerhead system for 30x2".

The modelling approach is based on the numerical computation of mixed convective laminar gas flow coupled with heat transfer and multi-component diffusive gas species transport. For the growth of group-III Nitrides this basic approach is supplemented by advanced mechanisms including complex gas phase reactions and even gas phase nucleation, i.e. the formation of nano-size particles by interaction between low volatile reaction by-products, and the deposition of nitride semiconductor layers on the substrate surface. The models were developed in a joint collaboration with STR Inc. and incorporated into CFD-ACE+ via user subroutines and user defined scalars.

The gas inlet of a MOVPE reactor chamber is one of the key components and essentially determines process performance and versatility. Primarily using a rigorous CFD based multiphysics modelling approach, a novel gas injector (figure 3) was developed for a new generation AIXTRON Planetary Reactor® with 42x2" wafers, which is currently the world's largest production scale reactor for processing GaN based LEDs. The gas injector features multiple gas inlets for advanced deposition uniformity control, symmetric and uniform gas flow to guarantee wafer-to-wafer reproducibility, and thermal control of the injector to prevent premature gas phase reactions.

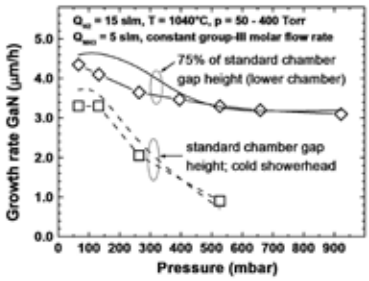

Figure 2: Pressure dependence of GaN growth rate in the 6x2" Close Coupled Showerhead Reactor, comparing two different hardware sets, (a) bare, cold showerhead and (b) covered warmer showerhead with reduced chamber height. Model prediction (lines without symbols) and experimental data (lines and symbols).

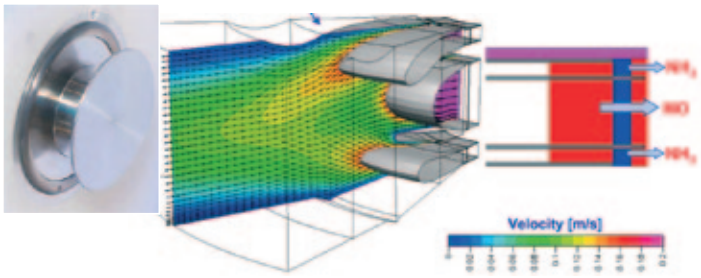

Figure 3: CFD modelling of a novel gas injector used in the AIXTRON Planetary Reactor®.

ABOUT ESI GROUP

ESI is a world-leading supplier and pioneer of digital simulation software for prototyping and manufacturing processes that take into account the physics of materials. ESI has developed an extensive suite of coherent, industry-oriented applications to realistically simulate a product's behavior during testing, to fine-tune manufacturing processes in accordance with desired product performance, and to evaluate the environment's impact on product performance. ESI's products represent a unique collaborative and open environment for Simulation-Based Design, enabling virtual prototypes to be improved in a continuous and collaborative manner while eliminating the need for physical prototypes during product development. The company employs over 750 high-level specialists worldwide covering more than 30 countries. ESI Group is listed in compartment C of NYSE Euronext Paris. For further information, visit www.esi-group.com.

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