BATTLE CARD

MICRO & MINI LED | MOCVD

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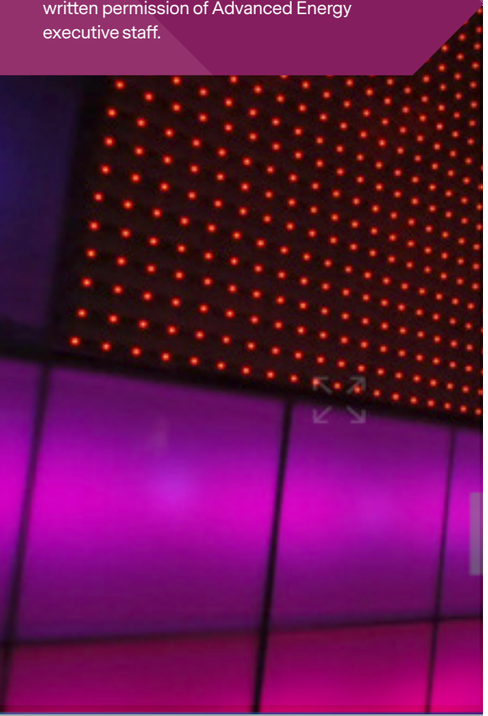

SOLUTION OVERVIEW

The manufacturing of mini and micro LED (Light Emitting Diode) technology involves several steps, including the Metal Organic Chemical Vapor Deposition (MOCVD) process. Our solutions offer precise temperature monitoring to ensure high accuracy in heating regulation via power control.

The MOCVD process plays a crucial role in the manufacturing of Micro and Mini LED displays, allowing for precise control over the epitaxial growth of LED structures. This process enables the production of high-quality LEDs with small pixel sizes, making them suitable for applications such as high-resolution displays, augmented reality devices, and other emerging technologies.

Advanced Energy's UV 400 and UVR 400 pyrometers allow greater control of the process temperature to a variation of +/- 3°C. By directly measuring wafer surface temperature, this improved method allows more accurate control of the wafer temperature leading to improved yield. These systems set a new standard for LED production processes showing reliable results in monitoring the MOCVD process.

An overview of further AE solutions for temperature measurement in semiconductor epitaxy processing applications is given at the end of this document.

UV 400 | UVR 400

Target Markets/Customers

We want to focus on two types of customers, MOCVD Reactor Manufacturers and the Reactor operators (=LED Manufacturers).

Manufacturers:

- Aixtron
- Veeco
- Agnitron Technologies (USA)

Operators:

- Epistar (TW)
- Lumileds (The Netherlands and USA)
- Nichia (JP)
- AMS OSRAM (Europe)

Audience – who to engage and when

- Customer type: OEMs (system integrators and MOCVD reactor manufacturers). End-users such as operators of MOCVD reactors (LED / Epitaxy manufacturers).
- Who to enage: There is no particular level of hierarchy that we want to focus on. We need to contact the technical decision makers and those people who are responsible for the yield in the MOCVD process.
- Customer size: The size of the customer is not important. Of course, long term supply contracts are of major interest, but also small size enterprises can be beneficial customers as well.
- When to engage: Generally there are two major opportunities. We can try to engage during the technical evaluation phase when a new manufacturing plant is designed, or we can engage during regular business operations. Depending on the reactor type our system can be integrated at any time.

BUT: The transition from traditional LED to mini LED is happening now! This situation opens a "sweet spot" for our technology as most of the reactors for traditional LEDs can be upgraded to the production of mini LED.

Business Benefits

- Improve yield via accurate true wafer temperature measurement.
- Measure temperature directly on the GaN layer using UV wavelength instrumentation to obtain reliable wafer temperature via PL (Photo Luminescence) wavelength correlation.
- Capture real-time reflectance measurement using a fast pulsing light source.
- The UV 400 supports the transition from traditional LED manufacturing to mini LED production. For the production of Mini LEDs the traditional reactors can be upgraded, regarding Micro LED the reactors often need to be replaced completely.
- IP-safe technology. The UV 400 can be combined with most common MOCVD reactors and provides IP safe software integration in customers communication network.
- Customers can use the UV 400 to upgrade their reactors without getting the manufacturer involved. We do not offer an integrated solution.

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Qualifying Questions

- Is the customer the manufacturer or the operator of MOCVD reactors? This question is ideally clarified in advance to a customer contact.
- Who decides which measurement technology is implemented in the reactor? This question is more important than it initially seems. We need to clarify if the used reactor is able to be equipped or upgradable with our device. Some MOCVD reactor manufacturers use their own or pre-installed measurement technology and therefore we need to evaluate the situation in advance.
- Does the customer need a direct temperature measurement of the GaN layer during the process?
- Does the customer need any additional measurement technology or features? For example is the temperature of the pocket layer required as well?
- What are the process settings. What is the frequency or the speed of the reactor to make sure the temperature measurement is accurate? What is the temperature range that needs to be covered and is there a critical process temperature that needs special attention?
- Process settings, frequency, temperature range (min/max temperature and critical process temperature)
- Are there special requirements regarding the technical set-up. Is there a special device/reactor geometry that needs to be taken into account?
- Standard product version or any customized adaptions needed? Experience shows that most customers need individual adjustments of the measurement technology used.
- Does the customer need a special communication system integration performed by us?
- Can we provide cross selling opportunities shown on page 4?

Customer Challenges

1. MOCVD is a complex process that has relatively low yields which are typically leading to higher costs.
2. The direct measurement of the GaN layer is crucial for higher yields. The temperature directly influences the quality of the grown layer and the subsequent components, the LEDs.
3. Micro and Mini LEDs require higher quality epitaxy and very tight uniformity across the wafer.
4. Every LED Manufacturer or MOCVD reactor operator has his own unique recipes for the epitaxy process. Those are the “crown jewels” and need to be IP safe.
5. The MOCVD reactor itself plays a decisive role in terms or its initial measurement equipment or the ability to be upgraded at a later point.

Key Features & Specs (high-level differentiators)

1. AE´s UV 400 device can help to improve the MOCVD process. The precise and accurate temperature control supports LED quality, increases yield and reduces costs.
2. The direct temperature measurement of the GaN layer allows precise adjustment of the heating system in the reactor and supports a more accurate growing of the GaN layer.
3. The UV 400 provides features to ensure exact control functions. For example reflectance measurements help to locate the wafer inside the rotating reactor at high speed. This also improves the accurate detection of the “true wafer temperature”.
4. AE´s UV 400 is an independent devise that is not fixed to a certain reactor type. This flexibility is unique in the market and beyond provides an IP safe data communication.
5. Some of the available reactors show a fixed set-up regarding initial equipment. Because of it´s customization capability the UV 400 can be used with any reactor type. This is also beneficial when considering reactors that need to be upgraded to handle other LED dimensions like the mini-LED.

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Competitor	Laytec	Veeco (own solution)	AK Optics (formerly known as BeiOptics)	K-Space Associates (US)
Their Positioning & Selling Points	▪ Laytec is designed in in many major MOCVD machines. ▪ Close association with Aixtron ▪ Small footprint. ▪ Strong technical support. ▪ Portfolio of pyrometers (400 nm and mid-IR), deflection monitor ▪ Product(s): Laytec Pyro 400, EpiCurve® TT system.	▪ Manufacturer of MOCVD Reactors, own UV temperature measurement solution. (400 nm and mid-IR) ▪ Product(s): RealTemp200, BlueTemp and deflection systems.	▪ Mid-IR and 400 nm capabilities ▪ Product(s): Viper-RTC MOCVD	▪ Full suite of pyrometers (UV and mid-IR), deflection monitor, band-edge. ▪ Thin-film characterization capabilities ▪ Product(s): kSA ICE, kSA 400
Our Differentiation & Comparative Positioning	The majority of AE´s competitors provide UV and mid IR solutions for the temperature measurement in the MOCVD process. At the moment the technology is in transition from traditional LED to mini-/micro LED. Here AE´s UV 400 comes into play. The UV 400 supports this transition by enabling the customer to use existing reactors, upgradable with the IP safe UV 400 technology from Advanced Energy. ▪ The **upgradeability** is ensured by the fact that our system is not exclusively linked to specific reactors. The UV 400 can be connected to most of the reactor types that allow separate measurement technology. ▪ **IP security** is ensured because AE´s UV 400 does not exclusively communicate with the reactor manufacturers interface or communication protocol. The UV 400 allows individual integration in customer´s communication system. ▪ The UV 400 is a budget friendly solution when changeover the reactors from traditional to e.g., mini LED. While upgrading a reactor with the UV 400 would cost around $ 35-45k, a complete new MOCVD reactor is connected to investments costs above $ 1M.			

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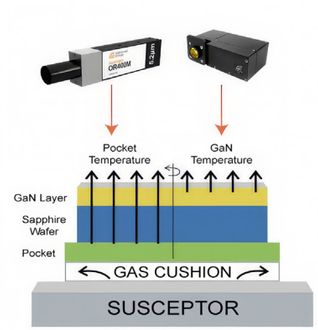
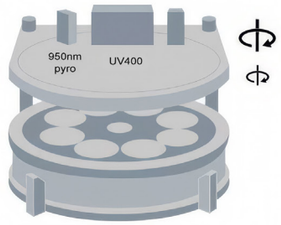
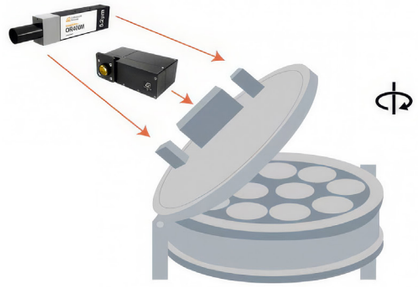
System Block Diagram





Rotation Style Reactor



Planetary Style Reactor

UV 400 & UV 400R	Sekidenko MXE	OR400M/401M	Sekidenko OR4000T/E	Sekidenko OR400T	Sekidenko 4100T
Digital pyrometers with extremely short wavelength for true Wafer Surface Temperature and Reflectance Instrumentation for GaN-based MOCVD epitaxy processes.	High-Speed, Non-Contact Optical Temperature Pyrometer with Integrated Reflectance Measurement and Emissivity Compensation.	Single-Channel Temperature Measurement Capability with Selectable/Fixed Emissivity.	Multi-Channel, Non-Contact Optical Fiber Temperature Pyrometer with Configurable Wavelength Range and Fixed-Emissivity Correction.	Compact, Single-Channel Optical Fiber Temperature Pyrometer for High-Volume Semiconductor Applications.	Multi-Channel, Non-Contact Optical Fiber Temperature Pyrometer with Configurable Wavelength Range.
MOCVD (Metal-Organic Chemical Vapour Deposition)					
RTP (Rapid Thermal Processing).	TCO (Transparent Conducing Oxides).	TCO (Transparent Conducing Oxides).	RTP (Rapid Thermal Processing).		
		EPI & GIGS (PV)	ALD (Atomic Layer Deposition)		
		TFD (Thin Film Deposition for PV)	PV-S (PV Cell Stringing)		

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