

Chinese burn into LED market driving MOCVD

Times are good for the two main metal-organic chemical vapor deposition system makers Aixtron and Veeco. Demand from China for their MOCVD tools is booming, thanks in part to hefty subsidies from the Chinese government. Mike Cooke reports.

China is coming to the end of its 11th five-year plan (2006–2010). Not only is the country advancing its industrial base, it wants to increase energy conservation, and one way is seen as being the use of 'green lighting', e.g. by installing LED-based street and traffic lighting. To support these ambitions, the Chinese state has set up four LED industrial areas, seven national LED Industrial Parks, and 21 showcase pilot cities.

It is estimated that the epitaxy and chip value component for LED production is about 70% of profits, while the remaining 30% comes from the packaging. China has until now been stronger in the lower-value packaging stage, but it wants to move in on the higher rewards of epitaxy through subsidizing MOCVD equipment purchases by CNY8–10m each (Chinese yuan/renminbi 'people's currency', CNY8–10m ~ \$1.2–1.5m, CNY6.7 ~ \$1). This subsidy can represent almost half of the equipment cost. Beneficiaries have been domestic firms, joint-ventures and foreign settlers.

Some reports put current orders for MOCVD equipment at up to 1600 sets. Sanan Optoelectronics announced recently that it plans to invest CNY12bn (about \$1.7bn) to build an LED manufacturing plant in Wuhu, and it plans to purchase 200 MOCVD systems over the next 3 to 4 years. Tsinghua Tongfang plans to invest CNY3bn over the next three years. Silan Microelectronics plans to buy 30 MOCVD tools and has raised CNY575m to expand LED production, along with replenishing its working capital. Elec-Tech in Shenzhen has made a

Table 1. Solid-state lighting legislation and subsidies (production-equipment related in China and Taiwan). Based on Sterne Agee 2010, World Bank 2009, OECD 2010, and LEDinside.

Country	Legislation	Subsidy	Ban	GDP rank
US	Yes	Yes	<2020	1
EU	Yes	Yes	<2012	2
Japan	Yes	Yes	2012	3
China	Yes	Yes	2017	4
Canada	Yes	Yes	2012	5
Russia	Yes	Yes	<2014	7
Australia	Yes	No	2010	8
Korea	Yes	Yes	2013	10
Taiwan	Yes	Expired	2012	16

Table 2. Residential light cost comparisons (Citigroup Global Markets June 2010, Sterne Agee 2010, BETAled, LEDinside, and Aixtron).

Residential lighting	LED	Incandescent	CFL
No. of lightsources	5–12	1	1
Cost of bulb	\$20–35	\$1–2	\$8–12
Power requirements	7–10W	60W	10–12W
Energy consumption (kWh/yr)	8	61	11
Annual electrical bill (at \$0.15/kWhr)	\$1.2	\$9.2	\$1.7
LED payback: no lifetime adjustment	—	<2.5yrs	<2.5yrs
LED payback: 3yr lifetime adjusted	—	<1yr	<1yr
LED payback: 5yr lifetime adjusted	—	<0.5yr	<0.5yr

Table 3. Commercial light cost comparisons (Citigroup Global Markets June 2010, Sterne Agee 2010, BETAled, LEDinside, and Aixtron).

Commercial lighting	LED	Incandescent	CFL
No. of lightsources	5–12	1	1
Cost of bulb	\$20–35	\$1–2	\$8–12
Power requirements	7–10W	60W	10–12W
Energy consumption (kWh/yr)	22	180	11
Annual electrical bill (at \$0.15/kWhr)	\$3.4	\$27.0	\$5.0
LED payback: no lifetime adjustment	—	<1yr	<2yrs
LED payback: 3yr lifetime adjusted	—	<4 months	<1/2yr
LED payback: 5yr lifetime adjusted	—	<1 quarter	<4mths

joint venture cooperative agreement with South Korean firm EpiValley to develop the Chinese LED market. US–Taiwan firm SemiLEDs began building a \$350m plant in Nanhai district of Foshan, Guangdong in March 2010. ▶

Overheating of the market, resulting in over-supply of LEDs, is a leading concern arising from such developments. Over-supply could lead to rapid price falls and the loss of profitability (and hence return on investment). The Chinese government is reportedly cognizant of the problem and is expected to address it in the national plan for the next five years (No.12). However, one may be skeptical that 'planned economies' will be any better at dealing with the temptations of semiconductor boom & bust than their 'free market' counterparts.

The Chinese government is not alone in subsidizing the LED industry for general lighting (Table 1), along with shutting down the production of much less efficient incandescent light bulbs through legislation.

Market reports

Of course, over-supply won't be a problem if new markets/demand can be found or developed. Although arguments can be made for LED lighting in terms of lower running and replacement expenses, the up-front cost for these components is still high (Tables 2 & 3). However, as LED costs come down, the balance will tip in favor of LEDs. For example, some Taiwanese firms are selling white light LED bulbs at \$12-15, compared with the \$20-35 LED bulb cost presented in Tables 2 & 3.

While general illumination may be the future for high-volume LED production (Figure 1), there are significant contemporary applications (Figures 2 and 3) in street, traffic and architec-

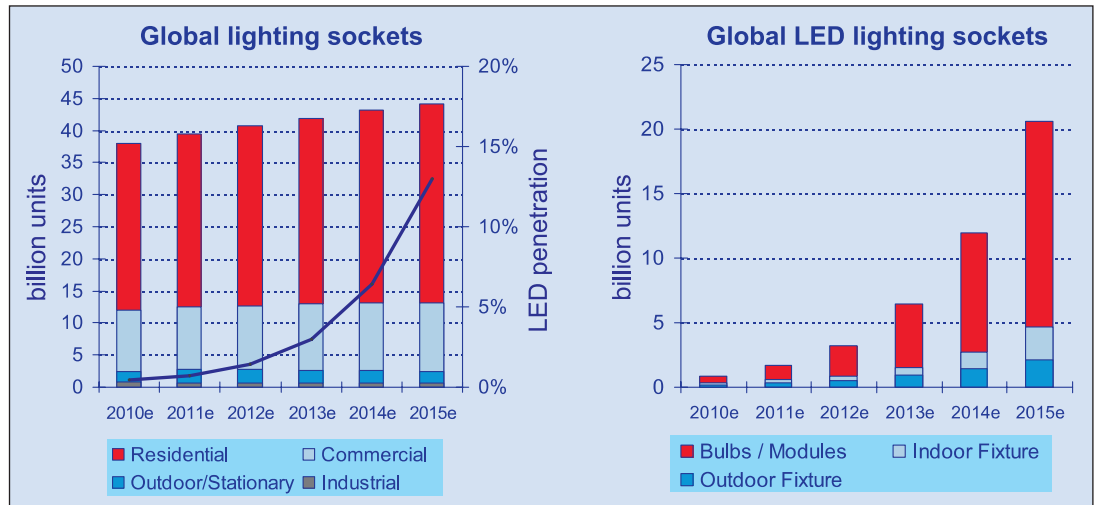


Figure 1. Solid-state lighting market estimates based on data from Sterne Agee 2010, Citigroup Global Markets June 2010, and Clinton Foundation.

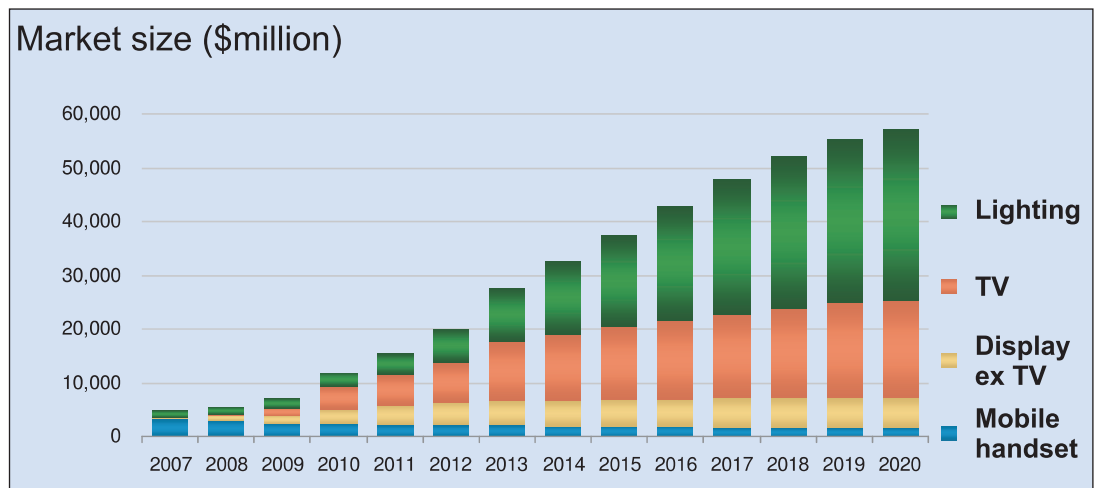


Figure 2. Morgan Stanley Research's projections for various LED markets. The expected compound annual growth rate (CAGR) for the total market is 21%, and for the lighting segment it is 31%.

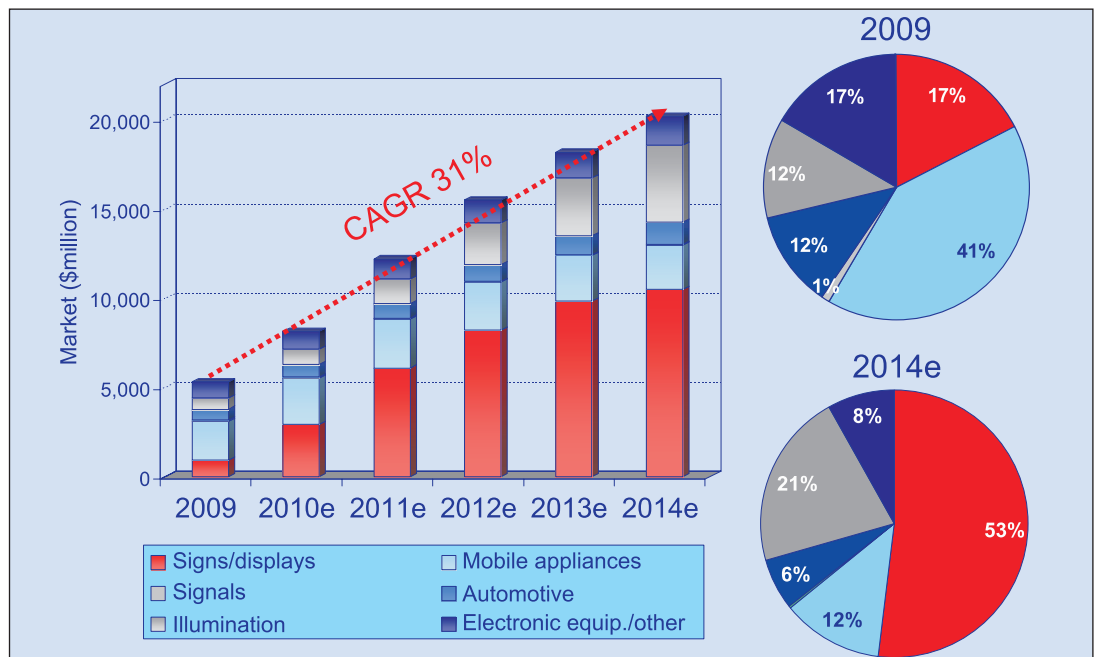


Figure 3. Strategies Unlimited February 2010 forecast for period up to 2014.

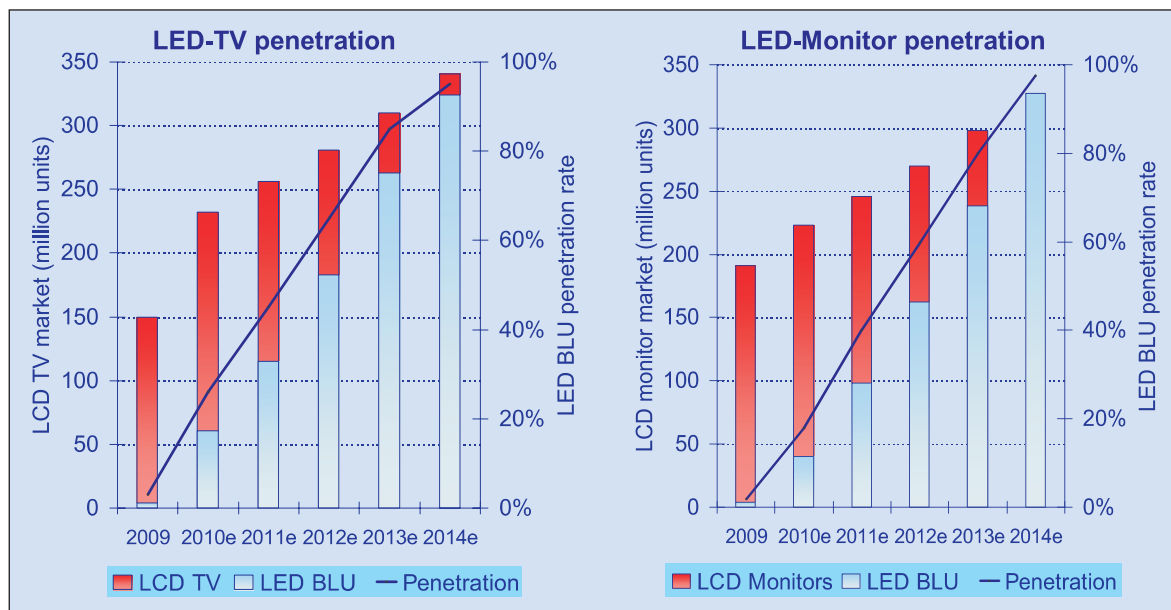


Figure 4. LED backlighting unit (BLU) market forecasts based on data from Aixtron and Display Search, Q2/2010.

tural lighting, and for TV/monitor LCD display back-light units (BLUs).

Much of the recent increase in LED demand has been associated with an expected switch from cold-cathode fluorescents (CCFL) to LED BLUs (Figure 4). Advantages of LED power LCD displays can include greater dynamic contrast, compactness (thinner screens), wider color gamut (especially with RGB lighting), less pollution on disposal, and lower power consumption.

BLU production seems to be the motivation of a number of the Chinese companies setting up LED facilities. One of these, Elec-Tech, is a supplier of household electronics (e.g. TVs) to the Wal-Mart retail giant in the USA.

Some market research firms (e.g. TrendForce) comment that there is a large degree of over-optimism in China for LED prospects. Some companies in China are entering the arena blindly without an accurate idea of the market or their place in it.

The great increase in Chinese MOCVD capacity is likely to suffer from a lack of qualified personnel, particularly at the R&D end of product introduction. This will have impacts on product quality, volume, yield, competitiveness, etc.

There also seem to be wide discrepancies in the market research estimates (Figure 5) — TrendForce sees there being plans for 1200 systems, with 300 coming in 2010; IMS Research says that 300 systems were installed in Q2/2010 and that there are expectations for more than 4000 systems to ship over the 2010–2013 timeframe, giving an increase in LED capacity of more than 300% over 2009–2014.

TrendForce adds that historical experience suggests that the number of actual systems will be less than those planned.

According to IMS, Aixtron and Veeco are increasing capacity to meet demand — targeting about 150 and 120 systems per quarter by the end of the year, respectively. Aixtron has about 60% market share and Veeco about 37%, worldwide. Aixtron leads in Taiwan and China, while Veeco is dominant in South Korea. Veeco puts its own market share at more than 40% 'and growing'.

The firm claims a bookings market share for Q2/2010 of 52%, while in revenue terms market share is around 30% in Q1, but increases to 42% in Q2. The company says that it sells to more than 80% of the world's LED makers. It has doubled its 2009 customer list and plans to ship to more than 35 manufacturers this year. Key Veeco customers include Osram, Bridgelux, Lumileds, Seoul Optodevice, and Sanan.

Aixtron points out that it has maintained a 60–70% market share over the period 2002–2009 (based on figures from VLSI Research and Gartner Dataquest). The only other significant MOCVD tool producer (~10%) over this period was Taiyo Nippon Sanso. Other companies have either fallen by the wayside or been acquired, such as Emcore by Veeco. Although Applied Materials is researching LED MOCVD production equipment with US government money (see May issue of Semiconductor Today, page 110), it does not yet have commercial tools available.

Sales highlights

Both Aixtron and Veeco have made a string of press announcements of sales in China since the beginning of the year.

Veeco has an impressive list of Chinese clients. Since January 2010, the company has announced sales destined for production at facilities owned by the firms Tsinghua Tongfang, Elec-Tech, Shanghai Epilight, Invenlux, Neo-Neon, and Sanan. Other Veeco sales announcements this year are in Taiwan (Arima, Epistar, Genesis Photonics) and Korea (Seoul Optodevice).

However, even some of the 'non-Chinese' sales are destined for installation at facilities in China. For example, Arima Optoelectronics is to install most of its new Veeco systems in Shanxi Province, northern China. ▶

▶ The Taiwanese firm has an agreement with the local government to form a new joint venture to manufacture LEDs for backlight applications.

Arima also has plans in Wujiang, Jiangsu Province, where some 10 MOCVD systems are expected to be installed by the end of the year, 10 more by mid-2011, and perhaps 150 over the next five years. Arima plans to convert an existing facility that it owns in Wujiang.

Veeco is making in-roads into Aixtron's dominance in China: Veeco is termed Tsinghua Tongfang's 'primary MOCVD supplier' for a new production facility in Nantong to be completed by the end of the year. The initial systems of a 'large' multi-tool order have been booked. The Chinese company evaluated the Veeco TurboDisc K465i MOCVD system at its R&D facility in Beijing.

Describing the system's benefits in terms of cost of ownership (CoO) and productivity, Tsinghua Tongfang vice president Wang Lianghai reports: "We have an aggressive plan to ramp production of LEDs primarily to address backlighting demand for TVs, and Veeco's technology, tool performance and customer support best matched our needs."

Elec-Tech has given Veeco its 'tool of choice' label for two new LED facilities in Wuhu and Yangzhou. As with Tsinghua Tongfang, initial systems from a large multi-tool purchase order from Elec-Tech's LED subsidiary Elec-Tech Optoelectronic Technology (Wuhu) have been booked.

"Our board of directors has approved our plan to purchase 130 MOCVD tools to ramp production capacity at our two LED factories," reports Elec-Tech's chairman Tony Wang. "Our goal is to become one of the top three LED companies by output and sales revenue in China within two years, focusing primarily on the general lighting and BLU market, but on other applications as well," he adds.

Wang also describes Veeco as his firm's "preferred and primary supplier for the vast majority of the 130 MOCVD systems", citing low CoO and high productivity as leading factors in the decision.

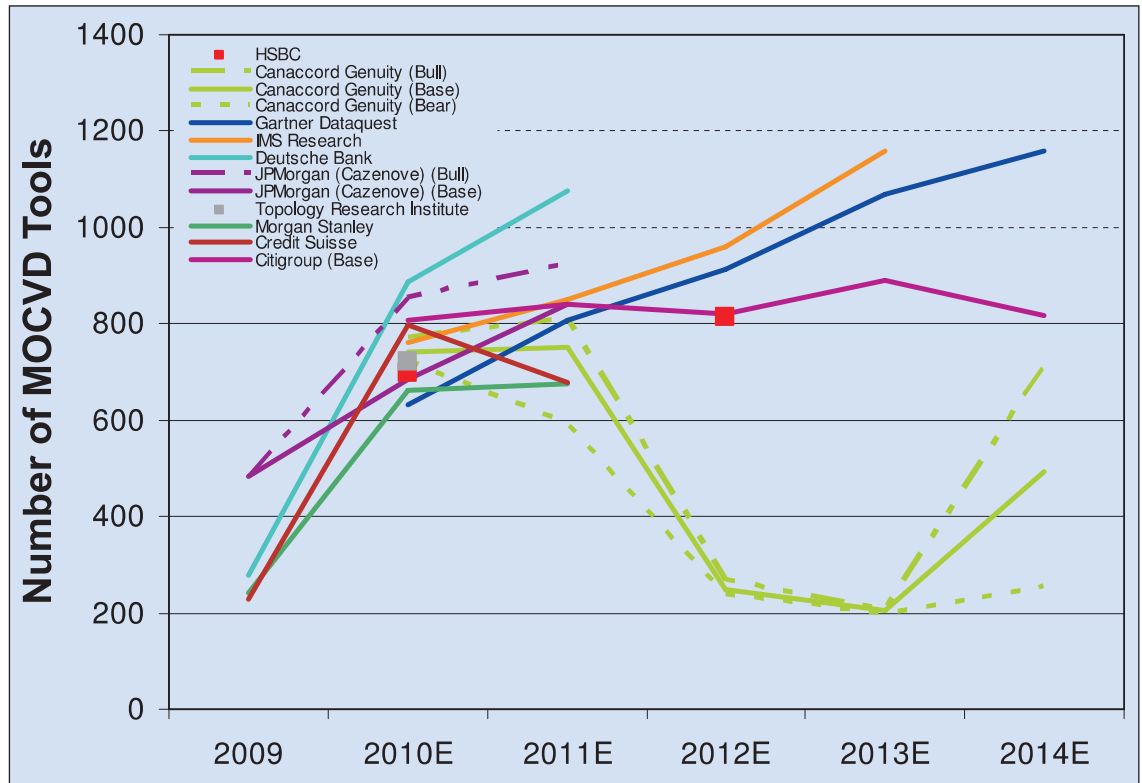


Figure 5. MOCVD market forecasts from HSBC, Canaccord Genuity, Gartner Dataquest, IMS Research, Deutsche Bank, JPMorgan, Topology Research Institute, Morgan Stanley, Credit Suisse, and Citigroup.

Aixtron has also made announcements about its recent sales in China, including: Long De Xin (LDX), Neo-Neon International, Epilight Technology, Yangzhou Longyao, Sanan Optoelectronics, Hangzhou Silan Microelectronics, Xi An ZoomView, Yangzhou Zhongke Semiconductor Lighting Center, Jiang Su Can Yang, Changelight, and Lattice Power.

Elsewhere sales have been made to Philips Lumileds Lighting Company (USA), INCOTEX Group (Bulgaria), Visual Photonics Epitaxy (VPEC, Taiwan), Tekcore (Taiwan), and Epistar (Taiwan).

To fund its expansion, Neo-Neon has recently raised TWD2.06bn (\$64m) on the Taiwan stock market, allowing the firm in Q4/2009 to order ten Aixtron CRIUS 31x2-inch configuration deposition systems for GaN ultra-high brightness (UHB) blue/green LED production. The systems are due for delivery in Q3-Q4 this year, and will be installed in a five-story facility in Guangdong.

Neo-Neon has also ordered one Veeco TurboDisc K465i as part of a LED manufacturing capacity ramp at a factory in Jiangmen. Neo-Neon's chief technology officer Dr Jurgen Yeh reports that his company plans to expand LED wafer output seven-fold over the next three years. The company specializes in flexible LED-based 'Neon-like' light replacements and has recently begun making LED streetlights.

Epilight made a 'phase 5' purchase of four CRIUS 31x2 inch Aixtron tools. These are being commissioned at the company's Shanghai facility in Q3 2010. ▶

► Financial performance

In Q2, Veeco reported record revenues of \$253m (up 250% on the previous year and 53% better than Q1). The firm shipped 81 MOCVD systems. MOCVD equipment is sold by Veeco's LED & Solar division, which made bookings of \$260m out of \$347m across the firm, including its other divisions Data Storage and Metrology.

Veeco recently agreed to sell its Metrology (scanning probe microscopy and optical) businesses to Bruker in a \$229m deal expected to close in Q4. Veeco's aim is to focus on its LED & Solar and Data Storage businesses.

CEO John R. Peeler commented on his firm's Q2 results: "We received \$251m in MOCVD orders, with customer wins in all regions, including the USA, Europe, Taiwan, Japan and Korea, and experienced accelerating demand from LED companies expanding facilities in China."

Veeco expects strong order quoting patterns, both from China's domestic companies and from Korean and Taiwanese customers that are partnering with Chinese entities.

The company has plans to ship 100 MOCVD tools in Q3 and to increase its capacity to 120 in Q4. It has a variable-cost, outsourced manufacturing strategy that allows it to 'flex' actual MOCVD shipments up or down each quarter, depending on specific customer demand and delivery requirements. In the present case, Veeco is able to 'dramatically increase' MOCVD production.

Veeco estimates sales opportunities for several hundred MOCVD units and more than \$500m in subsidies for the 2010–2011 timeframe. Customers anticipate continued investment into 2012, Veeco reports.

For Aixtron, Q2 revenues were €191.8m (~\$260m, €1 = \$1.35), up 258% on the previous year and 24% on the previous quarter. The company sees the high system demand being fuelled mainly by high-brightness LED backlighting and lighting applications.

Equipment orders were €168.5m in Q1 and €175.4m in Q2. Some 8% of the LED system orders in first-half 2010 were for new-generation systems, launched in Q1.

Aixtron's president/CEO Paul Hyland commented on the Q2 results: "It seems clear to me that a combination of the positive volume and performance effect the backlighting applications have had on LED industry yields and efficiencies and the sustained government subsidies we are now seeing, are creating tangible momentum in the development of solid-state lighting applications." He added: "The macro perspective is that the industry is clearly moving from a technical niche market to a more sustainable and larger commodity market, and this development is already having a corresponding effect on the expectations of customers who are demanding better performing products with better cost of ownership, which in turn is driving shorter product cycles and, for us, increased R&D investments." ■

MOCVD equipment suppliers' growth strategies

Veeco has two main pieces of MOCVD equipment that it is selling into the Chinese market: K465i and E475 for nitride and arsenide/phosphide deposition, respectively.

The TurboDisc K465i GaN MOCVD system was based on Veeco's 'production-proven' high-throughput K465 platform. The K465i aims to provide wavelength uniformity, run-to-run repeatability, and high yield (90% in 5nm bin, 2mm edge exclusion).

K465i incorporates new 'Uniform FlowFlange' technology to deliver alternating flows of alkyl and hydride evenly across the wafer carrier, improving uniformity and repeatability. In-situ process monitoring combines deflectometry, reflectometry and temperature measurements during growth runs.

The system can handle wafer diameters up to 8 inches. A simplified tool design allows easier tuning for fast production qualification, and fast recovery of the system after maintenance. Higher system availability results from less need to maintain the system.

The TurboDisc E475 As/P MOCVD system is engineered for high-volume production of red, orange and yellow HB-LEDs. The system can also produce laser diodes, transistors (pHEMTs, HBTs) and III-V solar cells for concentrator systems. (There is also a new K475 As/P system aimed at high-efficiency solar cell production.)

Aixtron is selling two types of production MOCVD machine for LED production — the Planetary and Close Coupled Showerhead reactors.

The Planetary reactor was developed by Philips and is under exclusive license to Aixtron. It is able to handle substrates up to 8 inches. For the lower temperatures (~850°C) needed for arsenide/phosphide materials, the heating is via infrared. The higher temperatures for nitride deposition (1200–1300°C) are achieved using induction. The precursors are delivered in a horizontal laminar flow onto substrates on a rotating carrier, allowing the Planetary reactor to create precise heterojunctions at the monolayer level.

The Close Coupled Showerhead (CCS) system introduces the reagents into the reactor through a water-cooled showerhead surface over the entire area of deposition. The showerhead system is placed near the substrates and the reagents are injected onto the substrates from a multitude of separate small tubes.

The latest CRIUS II CCS system for nitride material growth allows 55 2-inch substrates to be processed at one time for high-volume production. The rotating susceptor that carries the substrates is resistively heated. The temperature profile can be adjusted for uniformity, since the heating is divided into zones.