Both Aixtron and Emcore considered the MOCVD markets at the Gorham Outlook conference, while around them developments from Nippon Sanso and device companies such as Bookham and Hynix focus on specialised improvements. Researchers may on the whole be content with their MOCVD production, but the requirement for mass production in niche markets is a continuous development driver.

Gail Purvis

Design for production dominates MOCVD

It was Aixtron’s Paul Hyland who gave CTO Bernd Schulte’s talk on ‘Trends in MOCVD technology’, which looked at mass production for UHB LEDs, mass production for electronics as well as HeteroWafer technology development. For Aixtron, revenues by application in Q3 last year were 52% LED, 24% consumer optoelectronics, 20% tele-datacom and 4% other. Hyland’s talk, in which he claimed Aixtron’s 2002 global market share was 65% in 2002 and only allowed for Nippon Sanso as a major competitor (market share doubled from 5% in 2000 to 10% in 2002), did suggest that Aixtron still has heavy equipment manufacturing overcapacity and that the company is working hard to reflect an international, style of management, with its board members now including both US and UK directors.

Aixtron looks at trends

Among the trends that are identified are greater variety and flexibility in the larger multiwafer configuration of small wafer size production; the use of non-mechanic satellite rotation; high speed RF heating and temperature profile control.

Among Aixtron MOCVD system sales in first quarter 2003 are a 24x2 inch wafer configuration to Uni Light Technology for mass production of InGaN based LEDs [see Equipment and Material news page 24].

The other market sector research was highlighted by the sale to Princeton University of an Organic Vapour Phase Deposition (OVPD) unit.

Development of the first commercially available OVPD R&D tool is based on years of OLED experience gained by Princeton’s Prof. Forrest and his team. The main target for the design of this system has been to offer researchers a flexible tool for smaller substrate sizes (4x4 inch) consistent with typical R&D budgets.

Figure 1: Compound Semi – moving up the lifecycle curve

Solar Cells

Roy LEDs

GaN FET

UV LED

Research

Development/ pilot production

Mass production

Cash cow/ price reduction

End of life
MOCVD developments

MARKET ANALYSIS

Figure 2: Key opportunities for capital equipment

Sales thus would seem to reflect demand in large mass production units or cost conscious R&D developments.

Emcore market perspective

Bruce Nonnemaker, GM Emcore (formerly in device manufacture with Alpha Industries) profiled Emcore, looked at the compound ‘roller-coaster’ and presented the market shifts to higher, mass production with MOCVD equipment opportunities.

Emcore splits its activities between its Turbodisc system (500 installations claimed worldwide) and the first and only QS 9000 certified tool: R&D; its epi wafer foundry and device division; telecom components and PV cell manufacture.

Having presented the parallel life cycle curve for products and equipment (Figure 1) Nonnemaker noted the key drivers for production customers were in situ metrology, repeatability with a lower cost of operation or cost per wafer achieved by larger substrates, highly efficient reactors and possible higher capacity. Despite global overcapacity in MOCVD and MBE tools, he predicts that GaN materials will lead the equipment market and tools must focus on design for production.

Among recent orders a further Emcore E300 GaNzilla goes to South Epitaxy Corporation of Taiwan [see Materials and Equipment news page 22]. Emcore claims it has 150 GaN tools installed worldwide and Nonnemaker indicated some nice markets in the foreseeable future for biosensors and sterilisation. For ASP tools, little potential lurks in the short term, though there are opportunities for decommissioning, installing and recommissioning, service and upgrades.

Almost as satisfactory as equipment sales for Emcore must be its recent agreement with Zia Laser for sublease and contract manufacturing for high volume epitaxial growth and laser diode processing. The agreement includes: Zia subleasing cleanroom and supporting infrastructure for the operation of its own high volume MBE reactor; technical support by Emcore in material characterisation, wafer processing and device packaging.

Joe Dixon, COO of Zia Laser, noted confidence in a “synergistic relationship due to Emcore’s vast experience in materials, optoelectronics and fibre optics further augmented by their latest acquisitions of Alvesta and Agere’s OE West operations.”

At the heart of niche

Another niche market slowly emerging is in the region of nano research. Here Thomas Swan Scientific scored with the installation of a 3x2 inch Closed Coupled Showerhead (CCS) GaN MOCVD system at Harvard University in the Nanoscience and Nanotechnology Research Center for Professor Charles Lieber’s group. This is to be used for the growth of a broad range of nitride based nanoscale photonic and electronic structures. Also this year, TSS has installed its 6x2 inch wafer system in the heart of the UK Cambridge Centre for Gallium Nitride.

Atmospheric pressure

For Nippon Sanso Corporation, the aim and challenge has been atmospheric pressure (AP) GaN MOCVD. UV is promising for an excitation source of WLED under high injection current, said Dr Koh Matsumoto, GM marketing for Nippon Sanso. For UV and LED applications,
MOCVD developments

Overcoming MOCVD clogging

News that Hynix (150 FeRAM patents under its belt), started sampling its first 4 and 8MB FeRAMs (the biggest new thing in memory where iron atoms move around inside ferroelectric crystals and keep the contents even when there is no power) is probably only outmatched by the fact that Korea’s M Watanabe & Co has a new, faster, more efficient way of producing FeRAM by MOCVD.

The development features a clog-free vaporiser enabling non-stop operation of FeRAM volume production lines. Hynix is predicting the market will be worth $10b by 2006, and states that the FeRAM is ideal for use in mobile phones and PDAs, as it is faster than Flash memories.

The Wacom Flash CVD System is based on a Watanabe developed core vaporiser and is the outcome of joint development work with Masayuki Toda, professor of materials science and engineering at Yamagata University. Engineers at Wacom Electric, a subsidiary of M. Watanabe, presented the work at the International Symposium on Integrated Ferroelectronics 2003, held in Colorado Springs.

The core of the machine is a solution-supply system with integrated valves and a vaporiser used for multi-layer deposition. The vaporiser uses a high-speed carrier gas system to convey several kinds of organic solvents, including chemical materials, separately to the reactor for deposition. Solvents are easier to evaporate than chemicals, which often clogs pipes requiring up to two days cleaning.

In the Wacom vaporiser, solvents are kept at relatively low temperatures to prevent evaporation. At the reactor, different chemicals combine, atomise and are quickly heated to over 200°C to evaporate solvents.

For FeRAM production, the CVD system uses three or four kinds of source inlets, but the inlets can be increased up to about 10 if necessary. "The Flash CVD system can be used not only for ferroelectric deposition but for deposition of much wider materials," said Wacom's Hisayoshi Yamoto, VP and GM of production engineering. The continuous deposition allows for the formation of thick films capable of handling new devices and materials.

Deposition speed is now 30nm/minute. Wacom aims to increase the speed to 100nm/minute. "The ferroelectric layer is about 60 nm thick for FeRAM, which does not need the 100nm/minute speed. But higher speeds will be required for new applications that may need a micron-thick film," said Yamoto.

The commercial version of the CVD system will be shipped in September 2003.

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MOCVD at atmospheric pressure achieves low defect density material, but it also requires three temperature growths.

The Nippon Sanso SR6000 earlier reactor design for 6inch horizontal growth, only achieved slow AlGaN production. An improved, SR6000 design now optimises the configuration, using a horizontal reactor and it has succeeded in raising the AlGaN growth rate to close on 400nm/hr.

"Proper design of the reactor is critical for OP MOCVD" concluded Dr Matsumoto.

A browse around new MOCVD business finds a hard working sector where, as ever, new parameters are being added to this ubiquitous process.

Witness the Hynix development in FeRAM and more relevant to compound, Bookham Technology’s development of an in-situ MOCVD etch and regrowth process for uncooled InP buried-heterostructure lasers.

This is said to result in 5% lower rates of burn-in degradation than can be obtained by current standard processes. The times-2 burn-in improvement is a promising solution for increasing the long-term reliability of the devices, which also exhibit 20% lower threshold currents. And the new process is also compatible with the newer AlGaNAs materials systems.

Unfortunately AlGaNAs oxidises rapidly after etching, making the etched surface highly vulnerable to damage and contamination.

Etch in the reactor

The in-situ etching process reportedly eliminates the problem of post-etching surface damage or contamination by performing the etching step within the MOCVD reactor itself. Overgrowth is performed immediately on the clean freshly etched surface, preventing surface contamination and oxidation that can occur in the standard process of using an external etcher, to which the material has to be transferred at the risk of damage and contamination.

Buried heterostructures are essential for power-efficient, uncooled, directly modulated lasers with extended reach. However, the etching and regrowth required to make these can leave defects or introduce surface contamination on the mesa sidewalls. When the heterostructure is subsequently regrown on the material surface, any etch damage or impurities that remain at the surface can introduce a leakage current that increases the laser threshold current during device operation and degrades the laser’s long-term reliability.

This effect is particularly severe for AlGaNAs, a new laser material system of growing industry interest because of its performance...
characteristics and potential to operate at higher temperatures than standard InP. In principle, this would allow more compact devices to be fabricated as less passive cooling is needed.

Bookham has detailed how InP 2.5G/bits directly modulated lasers have been grown and fabricated and how two formulations of AlGaInAs buried heterostructure have been grown. The InP buried-heterostructure lasers consisted of an active layer with six compressively strained 6nm quantum wells in a separate confinement heterostructure, with a gain-coupled grating (154nm target wavelength) etched about the quantum well stack. The final structures for both InP and AlGaInAs showed smooth planes and excellent surface morphology.

No ideal epitaxy exists

One of the more intriguing comparative studies that exist in respect to Metalorganic Molecular Beam Epitaxy (MOMBE), Chemical Beam Epitaxy (CBE), Metalorganic Beam Epitaxy (MBE) and Metalorganic Vapour Phase Epitaxy (MOVPE) in respect to III-Vs was done in 2000 by Dr M R Leys, Eindhoven Technical University, on the growth kinetics of III-V epi layers.

"It has been said," notes Leys, "that the various epitaxial growth techniques have stimulated each other's developments. The goal of all techniques is to provide multiple layer structures of high complexity and perfection."

Considering mainly GaAs and InP gas phase and surface chemistry, Leys concludes, "no ideal epitaxial growth technology exists. For research the equipment should be as simple as possible but also flexible. ... But there is a limit to precursor molecules, which have both a convenient vapour pressure and suitable decomposition route.

"MOMBE/CBE has the freedom of choice," he felt. "Additionally it has the advantage of a low consumption of starting materials, very good thickness and compositional uniformity."

In an attempt to distinguish benefit among the many MOCVD variants, Dr Greg Parker, professor of Photonics at the University of Southampton; technical director Mesophotonics Ltd, and MD of Parker Technology was lured into making comment on some of the technology variations that exist. Among his achievements has been the design and production of the Low Pressure CVD (LPCVD) Mobius system.

"The Mobius system's key differentiator was that it was built to UHV standards (although growth took place at much higher pressures, around 1 Torr). The point of using UHV quality was that leak-up rates are extremely low and therefore the incorporation of any background gases (oxygen, nitrogen, carbon from CO or CO\textsubscript{2}) is also low.

"The prime variant for MOCVD equipment," says Dr Parker, "is temperature mostly. All the variants are just different ways of breaking up the source molecules to make the deposition temperature (substrate temperature) as low as possible, commensurate with good film growth."

He also notes that one good reason why variants arose was because different manufacturers might need a different story to overcome patenting difficulties.

"With PLD the difficulty is to get the stoichiometry of the target sorted. The main point is that the laser will ablate anything, so in principle anything could be laser deposited," he says.

"Obviously the commercial establishments want throughput and uptime. Research can do with much lower throughput, though uptime is still a serious issue.

"The point I really want to make about MBE/MOMBE is that they may appear almost perfect epitaxial growth techniques in many ways - but flounder when it comes to the practicality of running a growth system. Then they are a pain for the growth engineer.

"The other thing is that MBE/MOMBE are great for thin layers, but totally impractical for thick (several micron) layers where the long growth times make throughput an issue. This is where the main differentiator comes in between MBE and CVD. MBE is great for precision growth of thin layers, CVD gives you thicker layers in a shorter timescale. When you're making real devices for sale commercially it's all down to throughput, which quite often knocks MBE out of the equation. However, if there is a thin precise layer within your device, it may be worthwhile using a mix-and-match approach where the precision layer is grown by MBE and the rest of the device is grown by CVD. I believe this is done in practice with some optoelectronic devices."

"I would entirely agree with Leys in that no ideal epitaxial growth technology exists!" concludes Dr Parker. "But I don't agree about MOMBE/CBE, as these are full-time UHV systems, and it's a big job to keep a system running UHV full-time."