IGBT producers adapt to vibrant market

ABB, Alpha and Omega Semiconductor, BYD, Dynex Semiconductor and ON Semiconductor reveal a fertile sector to Andy Extance and Power Dev'.

Looking across the IGBT manufacturing landscape, perhaps the most notable thing about the companies inhabiting it is that they are very different beasts. True, they share a common trait, elegantly combining characteristics of both MOSFETs and bipolar transistors in IGBTs that surpass both these device types across many switching applications. But different products inhabit very specific market areas, ranging from cookers and microwaves to giant municipal power transmission systems. The specific pressures and needs of their ecological niche drive these companies to continue evolving device properties and performance. And that diversity of IGBT applications is today luring new companies, and bringing others together to boost their fortunes.

For example, Phoenix, Arizona, based ON Semiconductor had focused on IGBTs for automotive ignition, after ceasing to make motor control IGBTs in the late 1990s. But, the potential across the high performance segment of the market triggered it to release several 600V and 1,200V NGTBxx trench field stop IGBTs during 2012. Asif Jakwani, director of ON Semiconductor’s power discrete business unit, noted that different end uses require specific balances between three properties: collector-emitter saturation voltage, $V_{CE(sat)}$; turnoff energy, $E_{off}$, and the ability to withstand short circuits.

“UPS and solar applications tend to operate at high switching frequency, 40–60 kHz, so our IGBTs are optimised for lower $E_{off}$ while short circuit is also critical,” Jakwani told Power Dev’. "Induction heating, in electric hobs and home appliances, operates with 30 kHz medium frequency resonant topology, where $E_{off}$ and $V_{CE(sat)}$ are equally important. For motor control inverters we optimise $V_{CE(sat)}$ and short circuit, because switching frequency tends to be from 8-12 kHz.” ON Semiconductor tailors these properties in its trench-based field stop IGBTs using float zone (FZ) silicon substrates with state of the art backside processing and thin wafer technologies. Fine tuning backside processing dose, annealing temperatures and other processing parameters can deliver optimized $V_{CE(sat)}$, $E_{off}$ and short circuit capabilities for the target applications, Jakwani noted.

Similarly, Sunnyvale, California’s Alpha and Omega Semiconductor (AOS) entered the IGBT market with 600V devices in 2012. That was enabled by
the Portland, Oregon, fab AOS bought from San Jose, California’s Integrated Device Technology in January 2012. Yalcin Bulut, AOS’ vice president of discrete product lines, noted the company’s AlphaIGBT platform was developed at the Oregon fab. “Given the highly unique nature of discrete power technology, the acquisition of the Oregon fab from IDT was critical for AOS to accelerate proprietary technology development and speed up new product introduction,” he said.

AlphaIGBT continues field-stop IGBTs’ replacement of punch-through (PT) and non-punch-through (NPT) designs in many applications, thanks to their superior switching and conduction performance, Bulut explained. And thanks to its expertise in discrete technology, AOS was able to develop a novel field-stop design. “The AlphaIGBT technology combines a unique cell and vertical structure, which offers an excellent $V_{CEsat}$ versus $E_{off}$ trade-off, without compromising on short-circuit capability,” he said.

High power promise

Soft punch through planar and enhanced planar (SPT and SPT+) IGBTs from Zurich, Switzerland headquartered power technology group ABB meet the particular challenges of their 1,200-6,500V range. “The SPT IGBT and diode range are known for their benchmark operating temperature capabilities and the big operating temperature capabilities and the BIGT concept have been two important steps in the evolution of the IGBT,” Rahimo underlined.

Dynex Semiconductor in Lincoln, UK, produces its own die for 1,200-6,500V IGBT modules, and Paul Taylor, president and chief executive officer feels $V_{CEsat}$ dominates in this range. Field stop devices are also essentially standard architectures, he added, with system producers wanting multiple suppliers to provide interchangeable components.

In the SPT and SPT+ designs, an n-doped buffer layer adjacent to the collector electrode acts as a field stopper for higher voltages. However, ABB is circumspect in choosing whether to use FZ or more conventional silicon substrates made through the Czochralski process in such products, explained Rahimo. “We utilize different starting materials in our product range based on availability and matching our specifications for providing high performance power semiconductors,” he said.

ABB has also integrated a diode function on its IGBT chips to create compact and higher power products it calls a Bimode Insulated Gate Transistor (BIGT). “Our products’ high operating temperature capabilities and the BIGT concept have been two important steps in the evolution of the IGBT,” Rahimo underlined.

The solution to stay ahead is to innovate in the service, by proposing more than the IGBT: Drivers, Cooling, or full stacks

Striking a balance: In ON Semiconductor’s AlphaIGBT devices, processing parameters determine how performance balances between ruggedness, $V_{CEsat}$ and $E_{off}$ (Courtesy of ON Semiconductor)

Currently a comparatively small IGBT producer, that’s the role Dynex is targeting. “They’re looking for similar performance, so we focus on industrial standards,” Taylor said. “We can compete on a technological level, but raising production volume is our biggest challenge.”

Yet Dynex stands out among IGBT producers thanks to its Chinese majority shareholder and main customer, CSR Times Electric, which bought a 75 percent stake in Dynex in 2008. CSR produces electric drive converter and control systems for trains, and its partnership with Dynex emerges from a maturing power electronics industry in its native country. “The Chinese market is quite open to us,” Taylor explained. “That gives us a strong pull, particularly in rail transportation, which is developing rapidly in China at the moment. But the electric grid and renewable energy sectors are also pulling strongly.”

Shenzhen-based carmaker BYD is another Chinese manufacturer that has gained wafer-level power semiconductor technology, according to the company’s Yong Yang. “BYD Microelectronics has established an R&D institute to support analysis and research on IGBT chips and modules, to ensure reliability and performance,” Yang said. “Since 2007, we have developed five package series, including IC ranging from 25-600A, and $V_{CE}$ from 600-1700V. Our own IGBT chips are currently used in BYD auto-class power modules, but we’re not supplying them outside the company.”

Recent advances that the institute has made include improving thermal management and reliability in packaging by integrating AlSiC base plate technology into IGBT power modules, Yang said. But the automobile class IGBT modules it has developed have been successfully used in hybrid and electric vehicles. The institute has also produced industry-class modules for electric

IGBT Players landscape analysis

(Source: Yole Développement – December 2012 - Data to be released Q2 2013 in the IGBT report)
welding machines, inverters, UPS, and solar/wind energy power plants. But there remains room for improvement in these products, and Yang believes BYD Microelectronics has the capabilities to deliver them.

“We have an independent technical team to support failure analysis, the analysis and qualification of module components and materials, and improvement of module designs and assembly processes,” Yang said. “From IC design, module packages, we provide our customers full service, high performance and cost-effective products. We believe that we can do it better in the near future with other different industry customers’ requirements and support.” And the greatest needs they are working to meet for such customers are increased module integration, as well as higher voltages, current, and frequency capabilities, he added.

Dynex and CSR are also hoping to eventually supply IGBT modules for electric vehicles, but for their current applications further lowering costs is the main priority. “We have to get our production up to a level where we can further exploit economies of scale,” Taylor said. “Getting to that volume and production level is our biggest challenge.” To help achieve that, the company opened a £1.8 million ($2.9 million) R&D centre in August 2012, part of a slated £11.25 million overall investment in new product design and R&D.

“We have completed an expansion of our 6-inch IGBT wafer fabrication and assembly and test line in Lincoln,” Taylor said. “That allows us to take one step forward, but we continue to invest in R&D and production. Today we have a larger assembly and test line in China, but at the moment there’s a new 8-inch facility going up there. That will obviously be much, much larger capacity than we have in Lincoln and will come on-stream probably in 2014. It will provide the high volume, low cost capability which will allow us to participate in renewable power, electrical vehicles, and industrial power conversion.”

“AOS’ 8-inch Oregon fab already allows it to target motor control and power conversion applications, meaning that it is well placed to serve key trends in the sector, according to Bulut. “Inverter-based systems in industrial motor drives and white goods are replacing the existing topologies for higher energy savings,” he said. The AlphaIGBT properties enabling such a shift include low collector:emitter gate charge ratio (Q_{gc}/Q_{ge}), which induce lower gate voltages under rapid voltage changes (high dV/dt). Together with their 5.6V gate threshold voltage, this advantage can be used to extend the use of unipolar gate drives saving the expense and complexity of bipolar gate drives, Bulut said. “The design’s low transconductance (GM) and low gate to collector capacitance (CGC), allows ease of parallel operation with no oscillatory behaviour,” he added.

AOS’s IGBT resurgence also looks set to benefit its Tokyo, Japan, based subsidiary Sanyo Semiconductor, which it acquired in January 2011. “Sanyo Semiconductors has a group footprint in the intelligent power module (IPM) market,” Jakwani said. “They are very strong in the Asia-Pacific market in home appliances like washing machines and room air conditioners. We are working very closely with our colleagues to make sure that we can strengthen their supply chain for IGBTs and rectifiers.”

Meanwhile, ON Semiconductor will announce ten more 600V field stop IGBTs for motor control, induction heating, UPS, and solar inverters early in 2013. There Jakwani also sees reliability as an important concern, one that his company is adapting
to meet. “Customers expect higher breakdown voltage, so we plan to do 650V in next generation devices,” he said. “Besides that, every platform development moves Vcesat and Eoff curves lower for the same die size, to get better performance or price, based on the system requirements.”

ABB’s Rahimo agrees that system efficiency and reliability requirements are becoming more important, which is driving development at both chip and package levels, especially in renewable energy related applications. But overall the needs that IGBTs must meet depend greatly on the specific application, he underlined. “Device optimization to match the different application requirements is an important trend,” he said. “Lower frequency applications such as those in multi-level topologies are targeting lower conduction losses,” he said. “Emerging DC/DC conversion applications are targeting faster switching.”

Beyond already serving this wide range of uses, IGBTs are also creating new ones. In that circumstance Rahimo indicated that far from being a threat to well-established players like ABB, companies entering and maneuvering in the sector indicate its health. “IGBT products are enabling current and future applications in emerging markets especially in the automotive and renewable energy sectors,” he said. “We welcome new players providing a fair competitive landscape in our field of specialty.”