IGBT developments face off against weak economy

Yole Développement’s Alexandre Avron and Brice Le Gouic explain how the industry has been hit by a slowdown even as it’s pushing towards lower voltages, float zone and larger diameter Czochralski wafers, a foundry model and packaging innovation.

IGBT device and module producers look set for a rough ride as governments pull back on spending in areas like renewable energy and transportation. “We have recently heard feedback from IGBT manufacturers, packaging companies and passive component manufacturers, claiming that there has been a critical downturn in 2011 or maybe 2012 for IGBTs,” Yole Développement market analyst Brice Le Gouic told Power Dev’. That means these transistors’ ongoing evolution will become even more important in determining their success in power electronics applications. Developments in IGBT packaging, wafers used in device manufacturing, and other production strategy changes continue – but can they put the industry back on its former rapid growth trajectory?

Virtually all IGBT producers compete across the entire range of relevant power electronics applications above 600V, from photovoltaic inverters to motor drives. The best established players, like Neubiberg, Germany’s Infineon and Tokyo, Japan’s Mitsubishi Electric and Fuji Electric, alone have the advantage of offering devices that can block voltages as high as 3,300V. But they also serve mid-voltage applications also, and that’s where most competition is in the industry, explained Le Gouic’s colleague Alexandre Avron. “The battle is below 1,700V, where all players can manufacture IGBTs,” he said. “The biggest part of the market, in terms of revenues, is the 600-900V range.”

Now, some companies are looking to enter new territory beyond the low end of their traditional range. “We’ve seen a move towards the lower voltage 200-600V range in order to reach larger volume applications such as white goods and camera flashes,” explained Le Gouic. As well as competition from superjunction MOSFETs already used in this voltage range, this will mean producers will face stronger calls for regular price reductions. “There will be cost pressure because if you target commodity applications, necessarily cost becomes a critical driver,” Le Gouic added. “But the overall market will increase, so that means smaller margins, but much higher volumes.” Part of the ability to compete in this voltage range arises from the improvements that come as IGBT manufacturers progress through device generations. “With each new generation they’ve improved their designs, shrinking die size, which saves on costs,” Avron said. “Infineon has cut die size by 60-70 per cent between the first and fifth...
generation of IGBTs. And with today’s trench field stop devices they are also thinning the wafer. Infineon has the lead here, going down to 50-70 μm thick and looking at 40 μm. Mitsubishi is also reducing their trench sizes so they can put more cells on the same die and therefore shrink the die.”

The analysts expect manufacturers to enhance IGBTs’ competitiveness in commodity applications by making manufacturing shifts already seen in other power electronic transistors. “Along with this voltage lowering, manufacturers are moving to larger wafer diameter platforms,” Le Gouic said. “Typically today most power IGBTs are manufactured on 6-inch and 8-inch wafers, but we’ve seen companies like Infineon moving to 12-inch. We are not sure if companies are manufacturing IGBTs on 12-inch wafers yet, but they are manufacturing power MOSFETs, and really want to reach low voltage applications.”

Cost control

Improvements outside such cost-focussed measures are less important to the IGBT market, underlined Le Gouic. “Each new generation of devices aims at reducing losses and improving general performance, of course,” he said. “But IGBTs are key devices, secure on the power electronics market – proven technology with improving performance. Engineers don’t choose the IGBTs for performance necessarily, but because they fit very well with their expectations. IGBT innovation will be accepted on applications where overall cost is justified because you can reduce the size or the weight, or improve the efficiency or reliability of your system. In hybrid vehicles, innovation will be accepted for higher end vehicles, while modules from Chinese manufacturers with average quality product would be able to go in basic electric vehicles. In very high voltage applications such as grid electricity supply or low voltage consumer applications, the final user is able to pay the price for innovation.”

Therefore it might be hard to envision devices being made from anything other than conventional epitaxial silicon deposited on silicon wafers sliced from crystals made using the Czochralski method. Yet float zone neutron transmutation doped (NTD) wafers, doped by converting silicon into phosphorus in nuclear reactors, are becoming more widely used for IGBT production. “The NTD ingots come back with homogeneous resistivity all over the wafer so you can access higher performance IGBTs at higher voltage,” Le Gouic explained. “Also, once you slice them you don’t need epitaxy, which reduces the thickness of the wafer dramatically. By reducing the wafer thickness, you also can make more wafers per ingot and so you can reduce costs.”

Yet these advantages don’t currently deliver the low costs possible with Czochralski method silicon plus epitaxy needed for low voltages. That means float zone NTD wafers are only used in applications that will pay for the performance benefit they bring. “There is no trend to 12-inch wafer diameters for float zone wafers, because no reactor accepts over 8-inch ingots,” Le Gouic said. “Czochralski makes sense for lower voltage, higher volume applications simply because you can use a 12-inch platform. Most players would like to go to low voltage with Czochralski plus epitaxy and float zone wafers for high voltage applications. But nothing says that tomorrow you won’t be able to target the low voltage applications with float zone’s very thin wafer capabilities.”

China to deepen crisis?

With cost being so important, it will only be a matter of time before China’s emerging semiconductor industry makes a significant impact on the IGBT sector. Beijing, China, train manufacturer CSR has gained IGBT know-how by acquiring Lincoln, UK’s Dynex Semiconductor, though manufacturing is still done in the UK. The Yole Développement analysts expect that CSR will be joined by Shenzhen carmaker BYD, which they say can already make diodes and will be manufacturing an in-house developed IGBT by Q3 2013. But elsewhere in China, IGBTs are set to be produced according to a previously unseen manufacturing model.

“Infineon, Mitsubishi Electric, Fuji Electric and other historical manufacturers have everything in-house, IGBT technology, manufacturing and R&D, and they survive by innovating,” Avron said. “But the Chinese players trying to enter the market are not trying to get the best devices. They are trying

“The will be cost pressure because if you target commodity applications, necessarily cost becomes a critical driver,” explains Brice Le Gouic.

With cost being so important, it will only be a matter of time before China’s emerging semiconductor industry makes a significant impact on the IGBT sector. Beijing, China, train manufacturer CSR has gained IGBT know-how by acquiring Lincoln, UK’s Dynex Semiconductor, though manufacturing is still done in the UK. The Yole Développement analysts expect that CSR will be joined by Shenzhen carmaker BYD, which they say can already make diodes and will be manufacturing an in-house developed IGBT by Q3 2013. But elsewhere in China, IGBTs are set to be produced according to a previously unseen manufacturing model.

“Infineon, Mitsubishi Electric, Fuji Electric and other historical manufacturers have everything in-house, IGBT technology, manufacturing and R&D, and they survive by innovating,” Avron said. “But the Chinese players trying to enter the market are not trying to get the best devices. They are trying

China to deepen crisis?

With cost being so important, it will only be a matter of time before China’s emerging semiconductor industry makes a significant impact on the IGBT sector. Beijing, China, train manufacturer CSR has gained IGBT know-how by acquiring Lincoln, UK’s Dynex Semiconductor, though manufacturing is still done in the UK. The Yole Développement analysts expect that CSR will be joined by Shenzhen carmaker BYD, which they say can already make diodes and will be manufacturing an in-house developed IGBT by Q3 2013. But elsewhere in China, IGBTs are set to be produced according to a previously unseen manufacturing model.

“Infineon, Mitsubishi Electric, Fuji Electric and other historical manufacturers have everything in-house, IGBT technology, manufacturing and R&D, and they survive by innovating,” Avron said. “But the Chinese players trying to enter the market are not trying to get the best devices. They are trying

China to deepen crisis?

With cost being so important, it will only be a matter of time before China’s emerging semiconductor industry makes a significant impact on the IGBT sector. Beijing, China, train manufacturer CSR has gained IGBT know-how by acquiring Lincoln, UK’s Dynex Semiconductor, though manufacturing is still done in the UK. The Yole Développement analysts expect that CSR will be joined by Shenzhen carmaker BYD, which they say can already make diodes and will be manufacturing an in-house developed IGBT by Q3 2013. But elsewhere in China, IGBTs are set to be produced according to a previously unseen manufacturing model.

“Infineon, Mitsubishi Electric, Fuji Electric and other historical manufacturers have everything in-house, IGBT technology, manufacturing and R&D, and they survive by innovating,” Avron said. “But the Chinese players trying to enter the market are not trying to get the best devices. They are trying

With cost being so important, it will only be a matter of time before China’s emerging semiconductor industry makes a significant impact on the IGBT sector. Beijing, China, train manufacturer CSR has gained IGBT know-how by acquiring Lincoln, UK’s Dynex Semiconductor, though manufacturing is still done in the UK. The Yole Développement analysts expect that CSR will be joined by Shenzhen carmaker BYD, which they say can already make diodes and will be manufacturing an in-house developed IGBT by Q3 2013. But elsewhere in China, IGBTs are set to be produced according to a previously unseen manufacturing model.

“Infineon, Mitsubishi Electric, Fuji Electric and other historical manufacturers have everything in-house, IGBT technology, manufacturing and R&D, and they survive by innovating,” Avron said. “But the Chinese players trying to enter the market are not trying to get the best devices. They are trying
to manufacture basic devices well, and they also rely on foundries, which the historic players don’t. So you’ve got fabless or fab-lite companies and foundries in China that will be able to manufacture IGBTs in the near future, we believe. You don’t have this in the rest of the world.” Chinese foundries with IGBT processes on their roadmap include Jiangsu’s CSMC, plus SMIC, Grace Semiconductors and Hua Hong NEC in Shanghai.

When devices made using these processes become commercial, that will load even more pressure on manufacturers with in-house production. “It will be tough for European, US and Japanese players to follow this trend,” Le Gouic said. “Their survival will be mostly due to innovation at the die level, and we also know that those companies are working on packaging technology at the module level.”

In fact, packaging technologies’ importance has increased surprisingly rapidly, according to Avron. “People realise now that there are some issues at the module, or even at the system level, they really want to improve the packaging technologies,” he said. “You’ll see packaging innovation even for discretes, moving them from TO-220 and TO-247 to smaller surface-mount packages, like DPAK and D2PAK. They’ve already got the smaller packaging and reduced labour benefits this brings in MOSFETs, and we expect that IGBTs will also move to this kind of package.”

Le Gouic agrees that along with Chinese manufacturing companies’ entry into IGBT production, the surge in packaging innovation has been one of the most surprising recent developments. He added that it’s partly down to rapid module evolution. “You can use several types of devices in the same module, for example, IGBTs and super junction MOSFETs or IGBTs and SiC diodes. These have different temperatures to withstand, and have different frequency to support,” he noted. “This means innovation at the die-bonded copper substrate level, at the cooling level, at the die attach. It also means innovation at the wiring level. Will they keep on using wire bonding? If so, will they remain with aluminium or move to copper? Or will they use ribbon bonding or copper pillars? These are the questions that we are facing now.”

Progress in these areas, as well as external economic factors, will mean IGBT growth will recover the analysts predict. “At worst there was some kind of slowdown in 2012 for the IGBT market, caused by a slowdown in the applications in 2011, in wind turbines, renewable energies and traction,” said Avron. “The impact is one year later as there were stocks and quite long lead times for these devices and modules.” While they are still studying the downturn’s full impact, the analysts don’t believe it has reduced the size of the IGBT market. In total, Yole Développement has estimated that $3.5 billion worth of IGBT discretes and modules were sold in 2011, but future growth will likely fluctuate. “It will be a sawtooth,” Avron explained. “Some recovery in 2013, a smaller slowdown in 2014 and more steady growth in 2015 if the general economy recovers and stabilises.”

Yole Développement will release in 2013 Q2 its first IGBT market & technology trends report. www.yole.fr

Flexible design: The silicon layers in Infineon’s Trenchstop 5 IGBTs are so thin that the wafers they’re made on are flexible. (Courtesy of Infineon Technologies)