The Next Generation…in a Distant Future

Ken Gilleo - Ken@ET-Trends.com
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Most who read about the old "copper and insulator" PCBs are amazed at how far we have come. In fact, some are surprised that useful products were even possible with such simple "printed wiring" technology. Today, nearly all conductors are made with organic materials, as are many of the devices, especially the nano-deposited structures. While electrons are still used, photons are more dominant although the full-photonic computer is still years away. Many had predicted that the light-powered computer would replace the old electronic version by 2050, but this didn't happen simply because electrons are very good at so many functions, especially storage.

Another surprise was that Nanotechnology, hyped as a panacea in the early part of the 21st century, is rarely talked about today. Over the years, "nano" was assimilated by the fundamental sciences, especially chemistry and physics that had been operating at nano-scale and even sub-nano, long before the term was coined. In fact, the semiconductor industry had broken the nano barrier in the 20th century when device feature sizes fell below 100-nm.

Just about all of today's packaging is done at wafer level and this is almost a requirement because devices typically require stacking, not just for density, but also for functionality. In the first half of the 21st century, and even earlier, MEMS technology used wafer stacking to build devices with chambers for pumps and such. The memory industry had adopted some of these wafer interconnect and bonding techniques to boost density many years earlier. But today, many types of devices, even those made with different materials, are combined at wafer level. In a way, the old "horizontal" concept of multi-chip modules of the 1990's, has simply been converted to "vertical". But modern stack-ups are much more than a pile of bonded chips like those from the 2010 – 2030 era. An entire 3D pharmaceutical factory is now possible; *pharma-in-cube.*

Many stacks incorporate mixed technology where incompatible layers are interconnected. But discreet devices can also be nano-deposited onto, or into wafer layers, especially for sensors. Organic semiconductors are the most common of the "deposited devices". Fluid jetting and mechanical pens, using MEMS array technology can simultaneously deposit nearly a million nano-dots of compound in milliseconds making the technique very competitive with electromagnetic lithography. Interconnect structures for stacking also utilize deposited technology since low temperature wafer bonding is possible. Some even use remakable connections reminiscent of the old Lego product. Also, the use of deposited materials enables electrical and photonic interconnects on the same wafers. This is especially important since most stacks combine electronics and photonics, and even fluidics. Complex biomedical stacks require fluidic channels and connections easily made with deposited polymers.

The substrate business, once called printed circuit boards, is now very sophisticated compared to the old "copper and insulator" days. The copper-epoxy PCBs served the industry for over 150 years, but a new strategy was necessary as photonics, fluidics and organic systems became prevalent. Modern substrate can handle electrons, photons, fluids, and even nano-particle solids. The hundreds of substrate fabs have adopted materials and processes from the device industry, especially 3D structural methods from MEMS. Today, there is much less disparity

between device makers, packagers, and substrate fabricators. Today's vast substrate industry is highly customized since the finished module is really the finished product without the "wrapping". While there had been predictions of mass consolidation among PCB makers, the ever-evolving substrate industry experienced just the opposite as they adopted highly programmable processes where a run of a single part could be economical. Of course, customization is mostly automatic where computers simply plan the run using a vast library and "invent on the fly" as needed.

Unlike the old days, when the semiconductor industry was king, The Substrate Fab is now dominant. In fact, leading-edge substrate companies typically design, build and market their own product lines. While it's taken a few centuries, the Substrate community is in command and devices, once called semiconductors, are essentially a commodity.

Footnote: assembly was not covered but and is non-existent for some areas like deposited devices. But solder assembly would be unlikely for photonic and fluidic coupling, and maybe not even for conductors that may not be made of metal.