Circuits Unusual: THE NEXT GENERATION
by Ken Gilleo

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 nanodeposited structures. While electrons are still used, photons are more dominant, although the full-photonic computer is still years away. Many predicted that the light-powered computer would replace the old electronic version by 2050, but this won'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, which had been operating at nanoscale, and even subnano, 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 multichip modules of the 1990s has simply been converted to vertical. But modern stackups are much more than a pile of bonded chips like those will be from the 2010 to 2030 era. An entire 3D pharmaceutical factory is now possible.

Many stacks incorporate mixed technology where incompatible layers are interconnected. But discreet devices can also be nanodeposited 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 nanodots of compound in milliseconds, making the technique very competitive with electromagnetic lithography. Interconnect structures for stacking also utilize deposited technology because low-temperature wafer bonding is possible. Some even use remarkable 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 because 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 nanoparticle 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 because 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 it 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 has taken a few centuries, the substrate community is in command, and devices, once called semiconductors, are essentially a commodity.

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