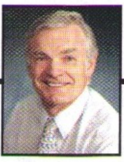
By Ken Gilleo PhD



PCBs, Semiconductors, and Nanotechnology

Nanoscale materials are more easily defined as particles, films, coatings, and fine structures that fall into the 1 to 100 nm range. Nanoparticles were used long before anyone muttered the word "nano." Tires have used nanoparticles of carbon for decades, Egyptian cosmetics utilized nano-size pigments, and red cathedral windows were colored with nanoparticles of gold millennia ago. We likely won't use the unusual optical properties or their quantum effect phenomenon very soon, but the high surface area could be useful. Surface area/mass increases with a decrease in particle size, and nanoparticles are so small they act as if they are all area with no mass. In fact, properties of pure elements can change at small sizes because a typical atom may not be surrounded by neighboring atoms that produce the bulk properties we use as the standard for elements. The increased surface area may have value for PCB materials, especially additives and catalysts. Flame retardants can be more effective as nanoparticles.

Nanosilica is commercially available and found in packaging materials, like "no flow" underfills. The small particle size reduces the CTE but doesn't interfere with solder joint formation, which has been a problem with micron-sized silica. Nonconductive nanowires, ropes, and fibers might be woven into fabric mesh to replace the relatively course glass weave. The result could be thinner, smoother, and a more dimensionally stable PCB substrate. Most of the nanotube, rope, fiber, and mesh research now involves carbon, especially carbon nanotubes (CNTs), but there are nonconductive forms. CNTs also have extraordinary thermal conductivity (up to 6,000 W/m·K; about 15 times better than copper).

Structures containing air, or even a vacuum, can produce low dielectric constant because air has a dielectric constant of 1.0006 and a vacuum, with dielectric constant of exactly 1, represents perfection. We've used air as a dielectric modifier for years, simply by creating microbubbles. Air-containing fillers, in the form of glass and ceramic bubbles, are also available, but the relatively high wall thickness limits their value. Perhaps nanotechnology will produce strong, spherical structures with walls only a molecule thick but keep the interior empty. A "bucky ball" structure (C_{60}), essentially a fully enclosed molecular geodesic dome, could be a starting point. The 60-carbon sphere is very strong and one of the earliest nanostructures; CNT can be viewed as a bucky ball that is open at one end and extended outward.

Nanotechnology might be used to reduce the dielectric constant in PCBs for better high-frequency performance. IBM recently announced an unusual breakthrough in low-dielectric constant materials that achieves the ultimate value of 1.0. Dubbed "Airgap," the technology employs clever tricks with unusual polymers and surface chemistry to produce nanocavities containing absolutely nothing—a vacuum. Airgap is based on nanotechnology and self-assembly using autonomous material segregation. IBM invented a polymer that segregates into two very different materials at a specific temperature. The thermal reaction produces very uniform nodules about 100 atoms in diameter. These nanonodules are different from the matrix polymer and repel each other to generate a symmetrical nanoarray. IBM likely uses a combination of plasma and etchant to open and selectively dissolve out the nodules, creating what looks like the world's finest Swiss cheese. The open nanocell structure can be sealed in a vacuum for lowest dielectric constant to close the cells; they can possibly be filled with other materials. The key is that chemistry has been used that can probably be readily scaled up for a low-cost process. Finally, the substrate is planarized and metal conductors are added using conventional methods.

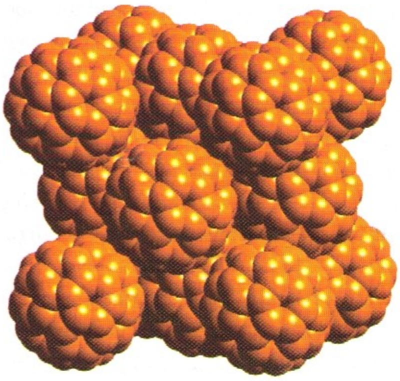


Figure 1 Bucky Ball (C_{60})

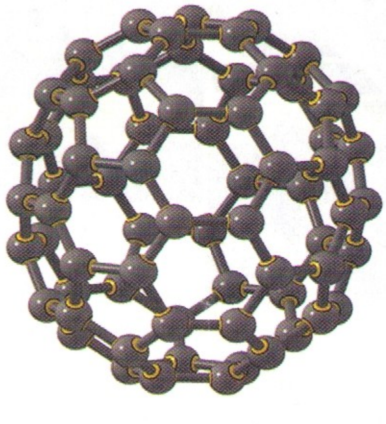


Figure 2 Bucky Ball (Fullerene): A 60-Carbon Nanomolecule

Can an Airgap-type process be used for PCBs to produce nanocell structures in a cost-effective manner, though? The real point is that we should monitor the semiconductor arena, where R&D can afford to spend billions. While semiconductors and PCBs are in totally different worlds and use substantially different materials, both are mostly about interconnects—"wires and insulators." The fields seem to be drawing closer together, or perhaps semiconductors are becoming more like PCBs. Recall that only about a decade ago, semiconductors transitioned to copper conductors, the century-old standard for PCBs. And today, through silicon via 3D stacking is making stacked chips look like a multilayer PCB. So maybe it's time that we started adapting ideas from semiconductors.

References at www.circuitree.com.

Ken Gilleo is technical packaging editor for *CircuiTree*. Email: ken@et-trends.com