CONDUCTORS

Ken Gilleo PhD
Ken@ET-Trends.com

Circuit definitions typically include, “a patterned array of electrical conductors”. But we rarely stop to think about what a conductor might be made from even though it’s the most important part of the circuit. This is because the conductor is assumed to be a non-variable with copper as the *de facto* standard. Some will want to include Polymer Thick Film circuit conductors, but these are metal-filled polymer composites that should also be counted as metals. The last time we changed conductors was about 100 years ago when easily fabricated copper replaced metal strips of brass and such. Since the circuit conductor is assumed to be a constant, we spend our time with dielectrics as the main variable in circuit board materials development although finishes have become important again because of lead-free initiatives. But there is another good conductor and it’s not even a metal.

Only one chemical element stands out as the most unusual and important. It’s one of the best electrical insulators, the winner of thermal conductivity, but it’s also a good electrical conductor. Sounds like a paradox, right? If elements had personalities, this one would win on congeniality and sociability. No other element is so mutually compatible and companionable in the world of atoms where opposites have the strongest attraction. OK, its carbon, the element of life that appears in at least seven allotropic forms (different molecular configurations of the same pure element). Carbon is also the foundation for tens of millions of compounds including polymers often made of long repeating chains of carbon atoms. Other elements, with a few exceptions like silicon, don’t like to mate and form repeating chains. Carbon, when structures as a diamond, is a phenomenal dielectric, the hardest substance known, and has very high thermal conductivity; more than 5 times higher than copper. But in two of its other allotropic forms, graphite and amorphous carbon black, it’s conductive enough to print the world’s lowest cost circuits like those used for calculators and other low current products. But these carbon allotropes are not conductive enough for most circuits.

Today, the most publicized carbon molecule is the Carbon Nano Tube (CNT) that might become the future building block that replaces silicon-based transistors and copper-based circuits. But organic carbon compounds can also be made conductive. Intrinsically Conductive Polymers (ICP) have been known for a few decades. Compounds with alternating double bonds (**–C=C–C=C–C=**) become conductive when doped; poly-acetylene doped with iodine is one of the earliest and newer ICPs have twice the conductivity of copper (on a weight basis). The human body also uses carbon-based electrical circuitry, but ions and fluids are required so this model may not fit our circuit board needs.

So are we really going to replace metal conductors with non-metallic carbon? The likely answer is “yes”, sometime in the next 30 years, but probably sooner. But what form and how will we pattern non-metals? CNTs are getting all the limelight right now because they’re new and nano-sexy. They can be orders of magnitude more electrically conductive than copper and there is no corrosion issue. They’re also stronger and better thermal conductors than metals. So while the ICP family is still a contender, the nano-carbon clan gets the smart money and some big government bucks. But coming up with the material is the easy part. Ask circuit builders and all will tell you that patterning is the real challenge. So how will we make *a patterned array of non-metallic conductors* in the future?

Maybe we can “grow” nano-carbon structures on a patterned array of catalyst somewhat analogous to additive copper processing. Perhaps we can form and fill channels, or grooves, a very old circuit process that has been reborn as micro- or nano-imprinting. We could still use photolithography to form the grooves or catalyst patterns. But don’t rule out printing, especially ink jet. Sooner or later, nonmetallic printed circuits will begin showing up and they could be much more conductive and have a few orders of magnitude higher density. And that could bring on the next big challenge – assembly. But before worrying about “solder” for non-metallic circuits, we need to know what to assemble. The device may not be silicon and that package may not have any metal. Maybe the components will be formed during circuit fabrication since that’s how integrated circuits (IC) are made. In just a few decades, we may be in a new world where carbon is king of electronics and “King Coal” is back on the throne as the only energy source that we haven’t used up.