The Bleeding Edge: Printed Electronics and the Military

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In my job as a technology consultant, I get to play with some advanced military applications. Being paid to play with carbon tubes and new nano ceramic materials is the best job in the world. However, military work is often a dichotomy: They'll research the very best advanced materials, yet they'll send you board quotes still listing G10 material from 40 years ago.

But the military likes to spend money trying to predict the future. I have worked on quite a few projects focused on looking into the glass ball and predicting the future of PCBs.

One military project I was involved with was not successful using even the most advanced PCB technologies. My job was to create a new methodology to address the problem.

The design called for 3 mil vias in a 4 mil pad, with 1.5 mil lines on 12 layers only 20 mils thick. The standard laser drill subtractive technology was tapped out in almost every area. The laser could not accurately hit a 4 mil pad - it blasted through beside the pad, creating carbon shorts to the traces or pads below. The LDI imaging was beyond its reliability point trying to process 1.5 mil lines, and the lamination process with the combination of ABF dielectric film and FR-4 laminations created scaling problems which further caused the laser drill to miss the pads in the center.

I tried to totally rethink the process: We can't laminate because the heat and pressure cause the panel to expand and move. We can't use subtractive dry film imaging because it can't create an accurate enough line at 1.5 mils and we can't use a laser drill because the smallest via is too big. OK, we just eliminated most of the shop.

This was one of those "brick wall" moments for me.

After researching on Google, I found a few companies that use silver ink as conductive vias. They utilize CO2 lasers to drill the vias which are then filled with silver ink. Research backed up with real production life cycles has shown silver conductive ink is an acceptable, reliable interconnect. Further research shows that it's not easy to produce 2 or 3 mil vias with a CO2 laser, forcing me to look to photoimageable via formation as the only method to create very small vias required by this advanced military application.

The photoimageable dielectric method also opened up a positive twist. Since most photoimageable ink was silk-screened or vacuum laminated on, it was thinner than a layer of FR-4. The thinner via is easier to fill with silver ink and more reliable.

One problem was the photodielectric ink or dry film. One company sells a silicon process photoimageable film dielectric, but at $80 per square foot was too expensive. Solder mask is not suitable as it does not stick well in subsequent applications, and it also has to low a voltage breakdown.

Working with an ink manufacturer, we developed a nano ceramic photoimageable dielectric material with very fine resolution, good adhesion and high voltage breakdown ratings.

The printed electronics revolution is about to take place for this simple reason: We can add chemicals and nano partials to ink, thus radically changing the ink's properties and leading to unbelievable new products.

When I first investigated the possibility of printing PCBs using additive ink technology, my mind was overflowing with ideas. We can't easily add nano particles to plated copper. But we can add ferro nano to the dielectric conductive ink to absorb electrical/radiation pulse, and therefore harden the circuit against nuclear destruction.

We can use clear, invisible conductive ink with invisible dielectrics and print invisible electronic circuits on clear plastic or glass. This is perfect for tactical safety glasses for military applications. Wow, a whole market exists for clear invisible circuitry! Imagine a depth gauge on your dive mask lens. Is this just a dream? No, it is possible today to manufacture clear circuits on glass. Clear circuits and many more new printed electronic products are just waiting for some adventurous person to build a business around them.

With inks we can add photoluminescent powders, allowing the circuit board to glow for a few hours after exposure to UV light. One chemical I've researched will change color based on voltages; you could print a circuit on the plastic case of your cell phone and have it change color when it rings. We can add chemicals to the ink to change color when a physical shock level is exceeded, or a humidity level is passed.

Additive printing allows a quantum leap - from static to active boards. We can add magnetic material to the ink, and little motors and relays can be manufactured right in the PCB. Imagine a relay only 12 mils by 20 mils built inside a 6-layer board. We can make comb devices with small, built-in electrical generators that charge batteries as the circuit board is moved and vibrated. This is called energy harvesting. A solar cell can now be printed as part of the circuitry directly onto a PCB.

The future will bring stretchable PCBs, wearable cloth circuits, and micro microcircuits - circuits so small that you can't see them. New inks will allow you to print a very good battery as a layer inside a printed electronics board.

This new technology is possible now, primarily because printed electronics uses none of the destructive processes used in traditional fabrication. Chemical baths are not conducive to printing batteries inside a board. The high temperature and pressure of the lamination press destroys active components - and some passive components - inside a board, eliminating this equipment from possible future advancements.

It's easy to understand how printed electronics, with its green additive advantage, opens up a big future for the military - and for any entrepreneurial PCB technologist willing to harness the power of his imagination.

*Robert Tarzwell is president of the technology provider DMR Ltd. He can be reached at **Bob@dmrpcb.com**.*