Vertical Thinking

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Creativity experts caution against too much *vertical thinking*, suggesting that *lateral thinking* will get us *out of the box* to find ideas that are more novel. But those who have been in the circuit business for a while, have done plenty of "vertical thinking". Circuit crafters are very good at laying down fine conductor patterns in a plane, but making finer and finer inter-planar vertical connections is more challenging. Connecting vertically generally requires forming precise, well-aligned tiny holes and then adding a conductor that makes a stable junction between the tracks being connected. Economics also demands that the method be highly cost-effective.

Even the earliest circuit pioneers, like Albert Hanson, understood that top and bottom tracks needed connecting, and so he used crimped metal in his 1903 circuit invention [1]. Those who followed, likewise recognized the need to go vertical and clever, but mostly mechanical connections, were devised. Parolini [2] increased density while avoiding through-board connectors by adding a metal "staple", a jumper secured with electroplated copper, but most early inventors placed solid conductors right through the dielectric. Screws, rivets and wires were the most popular vertical connectors, but the mechanical methods were tedious and labor-intensive.

Finally, chemistry was skillfully brought in to solve the interconnect problem when Clyde Coombs helped perfect the plated-through hole process that allowed all of the vertical conductors to form simultaneously. The plated through-hole process is still in wide use today although the industry has sought to replace hollow plated "barrels" with solid conductors to reduce hole size while boosting current capacity. Advancements include forming smaller holes using micro-drills, piano wire punches, lasers, plasmas and even chemical milling. Small vias can be plated shut to eliminate the hollow conductor. The electroless plating "seed copper" step has also been eliminated in several process, but the basic "drill & plate" concept is used in nearly all of them.

Thick film circuit practitioners applied different strategies. The ceramic and polymer thick film circuit makers develop <u>printed</u> through-hole processes. In one version, the circuit conductors are screen printed on pre-drilled dielectric sheet while applying controlled vacuum to pull ink through holes to efficiently produce a "barrel" shaped vertical conductor [3]. Other thick film processes eliminate drilling or punching by simply printing "holes" and leaving openings in the dielectric. Alternatively, photoimageable dielectric can be used to form small and precise holes. Holes can be filled with conductive ink or paste to complete the connection. The steps can also be reversed where the vertical conductive post is formed first and the dielectric applied last. These build-up processes have been adopted for PCBs.

But are there any fundamentally new *vertical pipes* on the horizon? Table 1 list methods that have been used or proposed and there are other concepts that could be added.

Table 1 - Vertical Connections

#	PROCESS	Status
1	Piercing connectors	Early, mostly obsolete
2	Drill & Plate	Many mature commercialized methods
3	Drill & Fill	Newer but mature
4	Sea of vias; lase and sputter Cu	Limited, commercial for flex circuitry (Sheldahl-Multek)
5	Programmable laminate/interposer	Proposed, some R&D (Tessera)
6	Programmable interposer	Proposed, some R&D (Sheldahl-Multek), Cookson

The last two ideas in Table 1 are worthy of a second look. The vertical connections are programmed in # 5 and #6. The idea of programmable connections has long been used in the semiconductor industry, but not widely applied to PCBs. Tessera, while evaluating Multi-Chip Modules (MCM), tested laser-drilling vias formed only where needed followed by filling with conductors. A laser was used to form the via pattern in a thin polyimide sheet followed by filling with elastomeric conductive adhesive.

Sheldahl, while developing the Z-Link® multilayer circuit process, looked at creating interposer adhesive sheets that contained a standard grid of vertical connects - a form of anisotropic conductive adhesive (ACA) [4]. The via grid could either be programmed to selectively form and fill vias, or the circuit pairs being mated could be programmed with connector pads only were desired. The latter approach worked with conventional random-particle ACA. Cookson Electronics also developed via grid adhesive interposers potentially useful for circuits, BGAs, and flip chips (see Fig.1).

The concept of a programmable vertical connector grid still makes sense today, perhaps more so. But could emerging materials help? Perhaps nanomaterials could be used to produce vias that opened or closed by application of energy; electrical, mechanical, thermal or photonic. We might even consider a non-volatile memory material that would be configured "on" or "off" during fabrication, or even altered later to customize products. A material might be composed of vertical nanotubes or fibers rendered conductive on command, or perhaps use nano-composites that achieved conductivity when nanoparticle filler was made to connect. Some phase-change compounds being evaluated for nano-memory cells might be useful. While Nanoelectronics appears to be moving forward, not much is happening in the PCB area, but this could, and should, change.

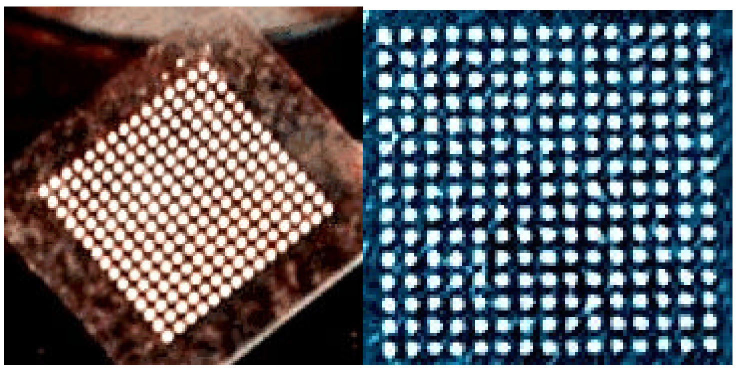

FIG.1 - Grid Array Z-Axis Adhesive (Cookson Electronics)

References

[1] Hanson, A., British Patent 4,681, 1903.

[2] Parolini, C., British Patent 269,729, 1926.

[3] Gilleo, K., "Method and Apparatus for Preparing Conductive Screened Through Holes …", US Patent 4,747,211, May 31, 1988.

[4] Gilleo, K., "A New Multilayer Circuit Based on Anisotropicity", draft, published in Nepcon West proceeds, (Feb. 1991).