The Other Circuit Process

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CircuitsUNUSUAL 2006

Today, subtractive etching remains the popular process for making circuits although additive methods (mostly semiadditive) are increasing, especially in the flex circuit area where the required thin copper substrates are available. The subtractive process has dominated for so many decades because of simplicity and low cost. In the most basic form, we print resist, etch away metal, and strip off the resist to make a circuit. But the subtractive process leaves much to be desired and the semiadditive method is gaining share where high density is essential. Semiadditive is more complex since a plating mask must be applied, metal carefully plated up, the mask striped and the thin "seed", or the copper buss, etched away. After a century of circuitry, are there no other processes? Yes, there is at least one more approach, and it is very different. Let's call it "conversion" for lack of a better term. The goal of the conversion circuit process is to selectively convert dielectric to conductor by means of an energy beam such as a laser. What a great idea! Shine light through a mask, or guide a laser beam over the surface, and instantly generate a circuit. This sounds to good to be true, and it is - well, maybe.

Let's step back nearly a century to find the first glimmer of the conversion circuit principle. Thomas Edison was kicking around some ideas for getting rid of wires with Frank Sprague, founder of Sprague Electric Co. One of Edison's concepts, in his 1904 letter to Sprague, suggested using silver salts on dielectric. The salt could be reduced to metallic silver to produce the conductors. Edison had been describing other methods for circuits that involved painting on materials, but it is not clear just what he had in mind for the silver reduction. Photography, based on the conversion of silver salts to metallic silver (fine particles appear black), was well established at this time. Could Edison have been thinking of selective light exposure? Many of the early photographic processes used only light and no developer. So why not invent a direct conversion circuit process? But apparently Edison didn't give further thought to printed circuits, so the "would be" conversion process did not "develop".

Over the years, circuit innovators have played around with conversion ideas with some degree of success, but no home runs. The ideal conversion process would only use light beamed through a mask or applied by a maskless method such as a guided laser. Conductors would form where the special dielectric was activated by the photons causing the conversion to electrical conductors. A laser beam with dynamic focusing capability might produce conductors at any depth to give us multilevel, 3D circuits. If you think that the multi-level idea is far fetched, check out the Corning Glass Museum (Corning, NY) where there is a collection of laser-patterned glass artwork, with the pattern inside. One simply configures the beam to reach a critical energy density at the desired depth allowing the reaction to occur inside. OK, this is not a simple concept but the principle is consistent with the laws of optics.

Several decades ago, AT&T, then very active in circuit R&D and production, developed one of the more successful conversion processes. Their Western Electric (AT&T's mfg. group) process involved impregnating Kapton® (the only polyimide film back in the late 60's) with photosensitive salts (De Angelo, USP 3,562,005, 1971). When the material was exposed to strong light (UV), the oxidation state of the salt (tin preferred) changed. The inventor sought a “photographic-like method”. Salts could be used that were activated or deactivated by light so that both positive- and negative-acting systems were possible. But alas, we are not done yet. The next step was to dip the material in a palladium activation bath causing this catalytic to deposit when it reacted with the active salt. Then, the material was placed in an electroless copper bath and the pattern plated in the Pd-activated areas. In order to build up copper thickness, the sheet, or roll, next went into electrolytic copper. All right, this is not the ideal conversion process we had hoped for, but at least it was “resistless”. And that caused the problem. With no resist, copper plated upward and outward. The conductor width increased. The process, according to the inventor, was used for a few years, but it was limited to large feature size and loose tolerances. Some Sheldahl alumnae think that the process would have faired better if improved copper-Kapton laminates had not come along so quickly.

Inventors along the way have tried other ideas aimed at conversion. One Japanese researcher carbonized laminate with a laser. This idea seems to pop up every few years. The carbon wasn’t very conductive, but it did serve as a base for electrolytic plating. The resistless plating ran into the same outward plating problem as it did for AT&T. Perhaps one could form a containment groove while carbonizing, but the idea still lacks cleverness.

Still others have worked with organo-copper complexes and various photo-reactive metal compounds that can be reduced to metal using light. So far, all of these processes have used additional steps. But yet, the idea of making conductors by just shinning light is an intriguing one, and should be possible.

Have you heard of other conversion processes, or perhaps you have one. We’d like to hear from you.