Making a Small Impression

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PCB and IC Density Dilemmas

We've known how to make printed circuits for over a century - right from the start of the endearing and enduring ***telecom revolution***. But conductor dimensions keep getting smaller in the relentless drive for density, especially in advanced packaging. Integrated circuits are facing an ever-greater density dilemma, as the Moore's Law (transistor doubling every 18-months) quest pushes that industry closer to "can't do" barriers erected by the laws of science. But how close are we in our PCB universe to running processes ragged to achieve finer lines? Electronic packaging that utilizes organic high-density interconnect (HDI) printed circuitry, has been able to delivery 1-mil (.001"; 25-micron) trace widths during the last decade. But will PCBs require new processes in the future, perhaps even Nanotechnology?

One of the highly touted newer nanotechnologies proffered to the semiconductor industry is nanoimprinting with a promise to deliver much finer conductors in far fewer steps. MIT even placed nanoimprinting on its top ten technologies list and it's on industry roadmaps. This sounds like something that the PCB industry may want to consider right now. But what is nanoimprinting?

Nanoimprinting is just what the term suggests, making nanoscale imprints - or very small impressions. The material to be imprinted is typically a polymer, or polymer precursor, that can accept an impression from a 3-dimensional mechanical tool, thus avoiding resist-coating, imaging and developing. While photolithography uses photoimaging to form patterns, nano-imprinted relies on direct mechanical shaping processes - a form of embossing or debossing. Two basic approaches are widely described although there can be many variants. Common plastic thermoforming can be used where the polymer is first heated to softening and then hardened by cooling while the embossing tool is kept pressed against the plastic surface during the cycle. Alternatively, a liquid polymer precursor, such as a monomer, can be applied to a substrate surface. Next, a nanoimprinting patterning tool is pressed against the surface so that the dispensed liquid fills cavities of the imprinting tool. Radiation, usually UV, is then directed through the transparent tool; this is actually a polymer casting process even though the "mold" may be inverted. The resulting pattern in the polymer film, consisting of grooves or channels, can now be filled with conductors such as metal composite pastes. Metal can also be applied by vacuum deposition or chemical plated. Can these processes work for PCBs? The answer is"yes". Not only can imprinted (thermal debossing or UV casting) be easily applied to printed circuits, it's was used by the PCB industry long before anyone ever heard of nanoimprinting. It sure seems like our industry continues to show the way for semiconductors. Recall that after a century of using copper for PCBs, the semiconductor folks finally adopted copper after struggling with higher resistance aluminum for many decades. And now, the IC folks are learning how to build "multilayer circuits", apparently adopting another century-old PCB invention.

Early Micro/Nano Imprinting

The plastics industry has long used imprinting processes to make an endless variety of patterns on surfaces, especially on films. The patterning tool is typically made from metal by photoengraving or electroforming (electroplating technique). Plastic film is usually patterned using a cylinder-shaped tool to enable highly efficient roll-to-roll (R2R) processing. The patterns often have very fine features, even submicron, for optical effects such as holographic and "psychedelic" finishes; e.g.; credit card and software security decals. In fact, much of the technology for producing extremely fine-featured holographic plastic films was developed and patented in the 1970's using methods similar to those now being described as "new" nanoimprint technology. Nanoimprinting seems to have been invented around 1994, but similar concepts, filed decades earlier, can be found in patent art. Many of these old processes are capable of producing nanoscale features. [See US patent 3,944,420; filed 1974].

Our printed circuit industry began experimenting with imprint patterning for conductors, or groove circuits, over 80-years ago [Ref. 1]. Figure 1 shows figures from the old Charles Ducas patent. Grooves could be filled with solder or electroplated. The earliest processes used mechanical methods to form grooves, but photo-pattern was later adopted [Ref. 2]. Poly-Flex Circuits (now part of Parlex) used groove circuit processing for their “Channel Circuit” system that was rather innovative. The debossed conductor pattern, formed with a laser, or using photoimaging, was filled with conductive adhesive with a custom multi-blade squeegee [did the shaver people borrow this idea?]. The next step was to place components onto bond pads that also contained uncured conductive paste. The conductive ink/adhesive was thermally cured so that the assembly step was “free”; no extra energy input. The Channel Circuits, while never fully commercialized, provided a novel “imprint circuit” process that eliminated the need to add joining material for assembly, saved considerable energy, and it was lead-free.

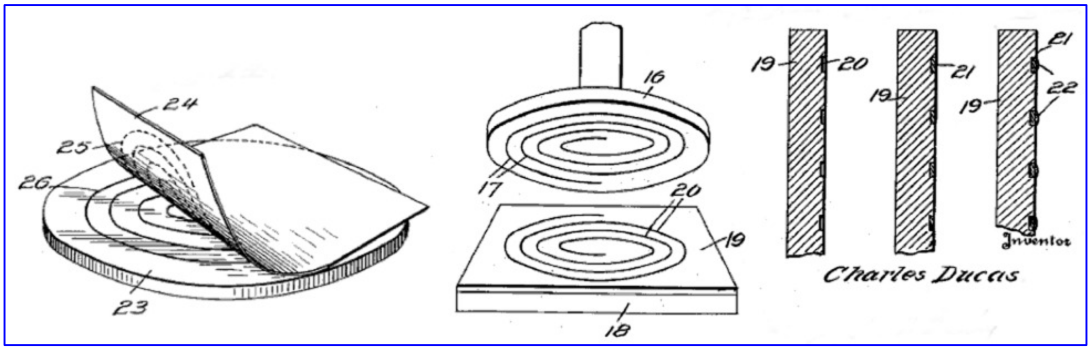

Figure 1 - 1925 Groove & Fill Circuits; Reference 1

Here's one older “nanoish” idea that has potential for making circuits, but it comes from the “metal deco” industry. Northern Engraving, based in Sparta, WI, came up with a slick way of making continuous roll plastic films with extremely fine features. First, they formed an imprinting cylinder by photoengraving, laser-etching, or mechanical machining. Liquid photopolymer was coated onto the rotating cylinder using a doctor blade process that allowed the film thickness to be adjusted. A powerful UV lamp quickly cured the urethane monomer and the newly formed film was peeled off the cylinder and wound on a take-up roll. The company used this efficient process to produce many types of decorative films, but the method could readily be used to make flexible circuits with grooves. This sounds like a modern “Nano” process, maybe even more advanced than the step and repeat methods that seem to be the rave of the modern nano-impressionists. Well, this high-volume continuous imprinting process was developed during the 1970’s by a metal/plastic decorating firm in a small Midwestern town. High tech is where you find it. Figure 2 shows the continuous imprinting process.

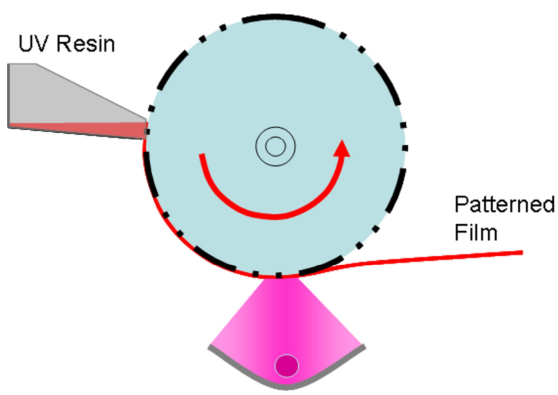

Figure 2 - Continuous Roll Imprinting

References

1. Ducas, C., “Electrical Apparatus and Method of Manufacturing the Same”, US Patent 1,563,731, Dec. 1925. [Earliest Groove & Fill; use Google/patents and search this patent number.]

2. Stepan, W. E., “Method of producing fine line conductive/resistive patterns on an insulating coating”, US Patent 4,508,753 April 2, 1985.