Ultrafine str ucturing of flexible circuits

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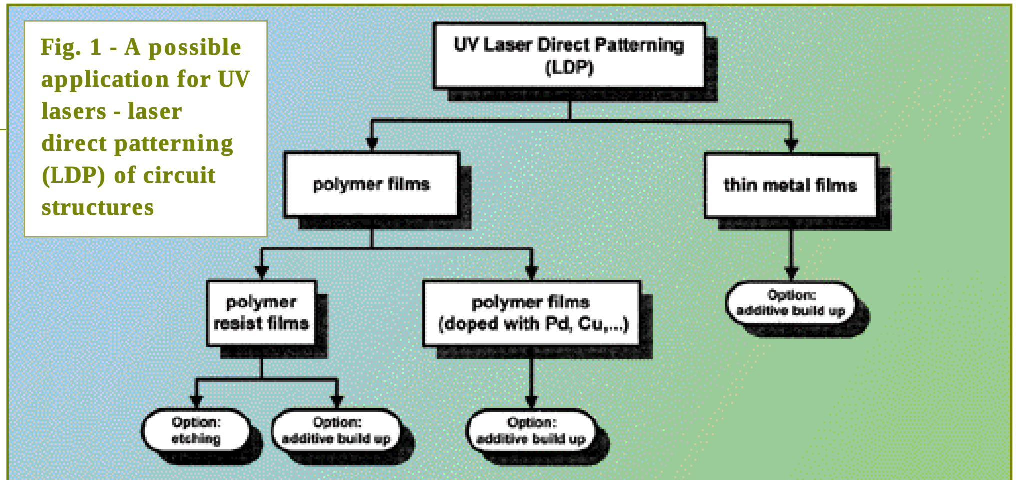

Fig. 1 - A possible application for UV lasers - laser direct patterning (LDP) of circuit structures

The continuing trend towards miniaturisation requires the development of new cost-effective and environmentally friendly materials and processes for the electronics industry. The gap between chip production, now producing sub-0.2 µm lines and spaces, and PCB and packaging, must inevitably shrink.

High density interconnects (HDI) will be used wherever weight must be kept down while packaging densities, signal propagation speeds and clock frequencies increase. This, as has been widely documented, is mainly driven by the portable electronics marketplace.
Laser technology has come into its own in recent years in the drilling[1] and laser direct imaging[2], [3] processes involved in PCB manufacture. It is also a route to finer features[4], and even though it is still rarely used for the production of ultra fine structures, laser technology will become established where it can be integrated into existing production processes, and where high resolution (< 5 µm) is essential.
This article describes the use of UV laser technology for the production of ultra fine line circuits on flexible (polyimide) circuit carriers and presents an alternative electroless build-up process.

UV - Laser

As early as 1982, it was known that UV lasers could be used to ablate polymer films[6]. This is because organic materials have high absorption coefficients at the lasers' operative wavelengths that allow the UV radiation to penetrate to a depth of some 10nm according to Lambert-Beer's law. Combine this minimal penetration with the typical excimer laser pulse duration of about 25ns and the result is a so-called "cold ablation". "Cold" here refers to the structuring result - the remaining material is only slightly heated and shows no signs of thermal damage (melting, pyrolysis), even though the plasma plume resulting from the sudden evaporation of the material reaches temperatures of several thousand degrees C!
The UV ablation of polymer resist films (excimer ablation lithography or EAL) represents another patterning application. Polyurethanes have proved to be particularly suitable for this[7], with

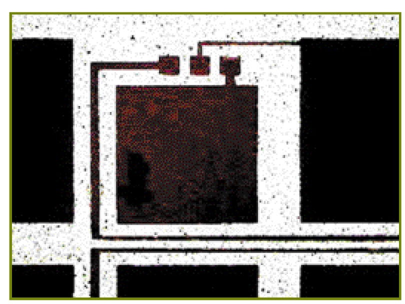

Fig. 2 - LPD polymer film on Si-wafer. A UV laser was used to produce ≥30 µm features

ablation possible at a rate of 0.13µm /shot using a wavelength of 248nm (KrF laser). The resultant structured films can be used as alkaline as well as acid resists and can be etched (subtractive) or additively built-up (semi-additive).

Another way to laser structure thin polymer films for lithographic applications in electronics manufacture[8] uses an electrochemically synthesised 100nm thick polythiophene film that can be ablated by a He-Cd laser at 325nm. Polythiophene has proved to be chemically stable against all acids and dilute alkalis, and it seems that it may be used as a self-developed UV resist. Using the process, it is possible to produce 1.9-2.7µm grooves at a pitch of 20µm.

Pd-doped polymer films laid onto polyimide substrate may also be laser patterned[9] and circuit tracks built up by using an electroless metallising process with copper as shown in fig. 3.

This produces ≥20µm lines, and the electroless metallisation process with Cu, Ni and Au allows further processing for the electronics industry.

Thin metal films laid down on a polymer may also be patterned by a UV laser. Here, the UV radiation penetrates the metal film and cracks the chemical bonds at the metal-polymer interface. The resulting plasma plume lifts off the metal layer in a mini explosion. Due to

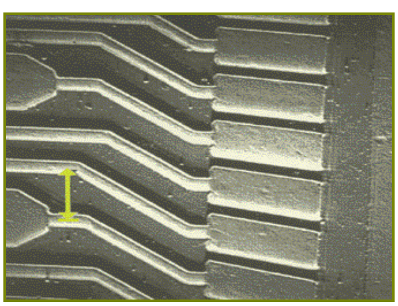

Fig. 3 - UV-patterned Pd-doped polymer film

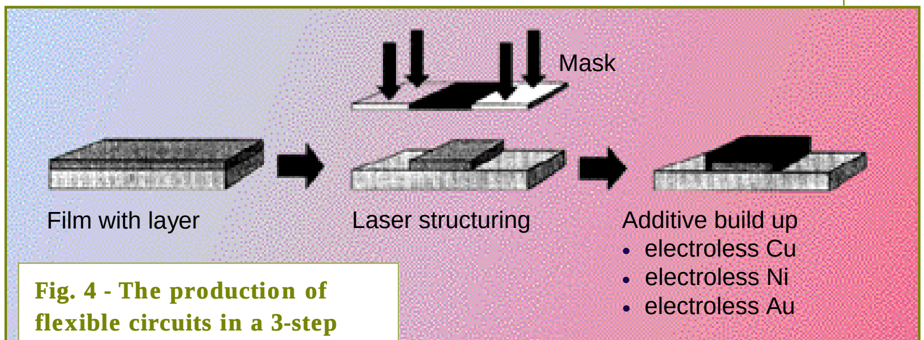

Fig. 4 - The production of flexible circuits in a 3-step LDP process

the high photonic energy of the UV laser it is assumed that this process also includes thermal ablation[12] .

A UV laser was used to structure thin Al/Zn-layers on polypropylene foils with an XeCl-laser (wavelength 308nm)[5], making it possible to produce 150µm structures using a fluence of 200mJ/cm^2 and ≥20 µm lines and spaces.

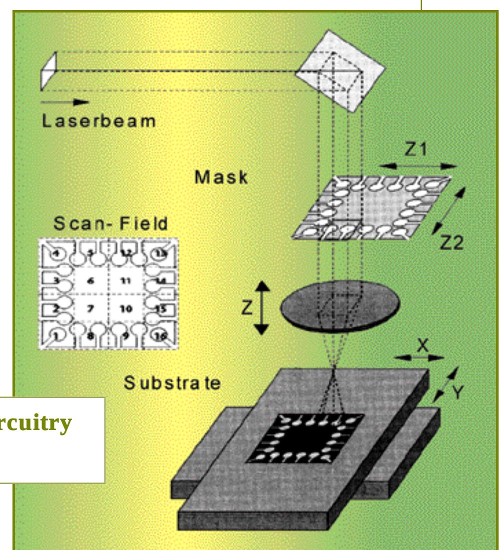

Fig. 5 - Laser ablation of flexible circuitry through a chromium mask

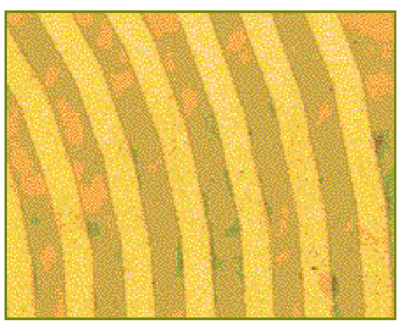

Fig. 6 - Detail of a microcoil patterned with optimised power density

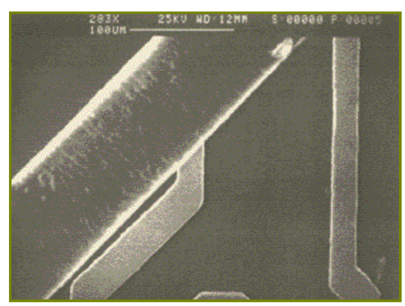

Fig. 7 - 15 µm (0.6 mil) ablated tracks compared with human hair

Laser direct patterning (LDP)

Fig. 4 shows the general idea for producing flexible circuits in just three steps. Given the foregoing results, it should be possible to produce flexible circuitry using LDP, and this article looks at the results of research into this potential use of laser technology[11] using a KrF UV laser source that "images” the film through a chromium mask (see fig. 5). This process uses an adhesiveless flex polyimide substrate on which is a 15nm Cr tiecoat and a 50nm Cu seed layer that has been processed in a proprietary vacuum metallisation process by an experienced base materials manufacturer[10].

Results and discussion

Optical evaluation of the first laser ablated Cr/Cu metallisation indicated the need for extensive tests to determine an optimum imaging power density, that varies between 150-350mJ/cm².

Figs. 6 and 7 show the results of using the optimised technology to produce circuits with 15 micron lines and spaces, and table 1 shows some process parameters.

After ablation

Although commercial quality baths are used for the electroless metallisation of the laser-structured substrates, special care is necessary for the activation of the first ultra-thin layers. Following the careful ultrasonic removal of the laser debris, cleaning agents should be used at low-concentrations to avoid damaging the layers. Electroless copper metallisation using an appropriate bath then selectively builds up at approx. 2µm/hour.

TABLE 1 - PROCESS PARAMETERS FOR LDP PROCESS

TOTAL PROCESSING RANGE (INCHES)	8 X 8
MAX. LAYOUT DIMENSIONS (INCHES)	5,5 X 5,5
MIN. LINE AND SPACE WIDTH	15µm (0.6MIL)
SYSTEM RESOLUTION	2µm (0.08MIL)
MAX. THROUGHPUT	1.55 SQ. INCH/ SEC
MAX. LASER POWER (W)	50
WAVELENGTH (nm)	248

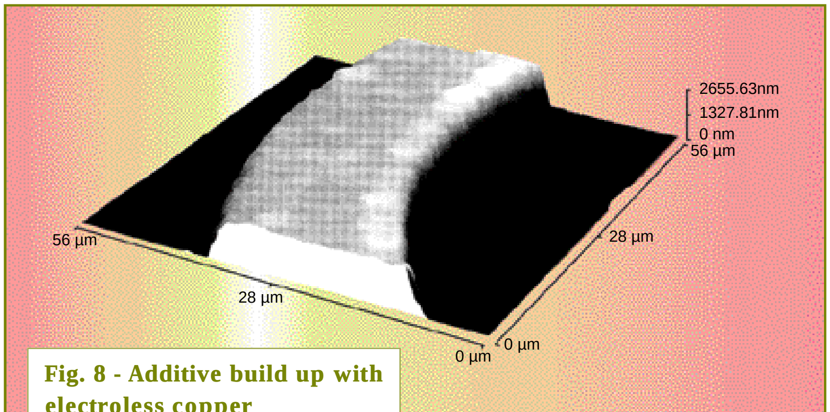

Fig. 8 - Additive build up with electroless copper (19 µm line width)

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Applications for the LDP process

Figs. 9 to 12 illustrate some applications for the LDP process.
Fig. 9 shows a detail of a microcoil with 15 micron lines and spaces, produced using LDP.

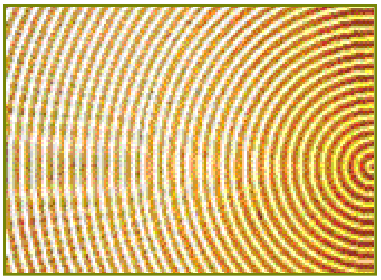

Fig. 9 - Microcoil (15 µm lines and spaces)

Fig. 10 shows a printer head application with 12 micron lines and spaces.

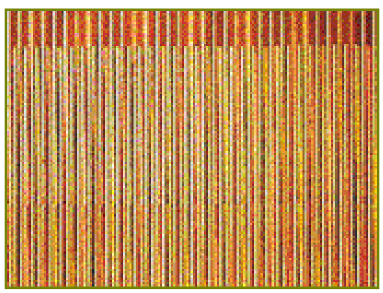

Fig. 10 - Applications for the LDP process. High density interconnect (12 µm lines and spaces)

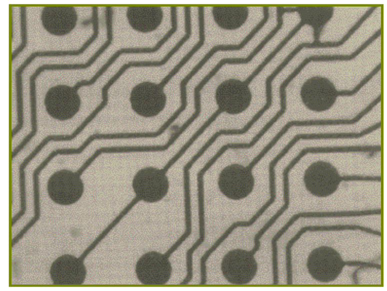

Fig. 11 - Applications for the LDP process. Flex interposer for CSPs (15 µm lines and spaces)

Fig. 11 shows a flexible interposer. This micropackaging (Chip Size packaging) application has 15 micron lines and spaces.

Fig. 12 shows an LDP interposer. This was completed as a CSP demonstrator and has been tested successfully according to the general reliability test for electronic components.

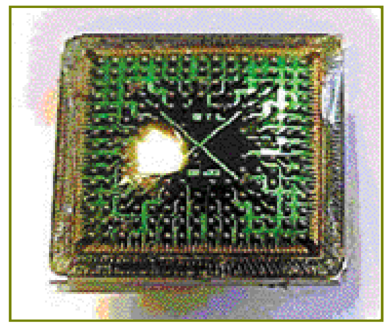

Fig. 12 - Laser-structured CSP flexible interposer application. This has been tested successfully

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Summary

Copper layers applied to polyimide films by PVD processes to a maximum thickness of 50nm can be ablated and patterned with a UV laser machine. A system has been developed that is suitable for industrial use that allows the production of ≥15µm (0.6mil) lines and spaces. Structures for flexible circuit applications can be produced by the additive build-up of functional layers.
The advantages that this new technology brings to the production of fine line structures for HDI applications are as follows:

- precision lines and spaces without etching
- ≥15µm geometries
- no photo imaging
- fewer process steps => cost reduction
- reduced chemicals and waste
- tracks can be built up to 6µm as desired

Now, as well as being used for microvia drilling and laser direct imaging, the UV laser can be used for laser patterning. The author believes that this will reduce the gap between thin film techniques and PCB production. ✓

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