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Selective Copper Plating on Polymers Induced by Laser Activated Fillers

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Abstract

Selective plating of metals on polymers has many applications from decorations of artworks to building's engineering. However, the best prospects of this technology are for electronics application: making conductive tracks for integrated circuits. There are two basic techniques of laser writing for selective plating on plastics: the laser-induced selective activation (LISA) and laser direct structuring (LDS). In the LISA method, pure plastics without any filler can be used. In the LDS method, special fillers are mixed into the polymer matrix. Laser writing for selective plating is fast and cheap for prototyping. Moreover, there is material saving because it works selectively. However, the biggest merit of this technology is the potential to produce moulded interconnect devices, enabling to create electronics in the 3D structure, thus saving space, materials and cost of production. There are some commercial materials available on the market, but mostly they are based on expensive fillers, usually palladium.
In this work, both methods of the laser writing for the selective plating of polymers were investigated and compared. We present the LDS results on polymeric materials with new carbon-based additives, and the laser processing has been studied using picosecond and nanosecond laser pulses.

Keywords: Laser-induced, selective plating, 3D electronics, polymers, molded interconnect devices.

1. Introduction

The technology of selective plating of polymers has a high prospect for nowadays and future electronics. Particularly in the fields where usage of electronics increases sharply, like in automotive industry, the problem is that amount of electronics components must fit into the certain volume of a device. In this case, a printed circuit board in 2D shape is inconvenient to use, and thus the technology of moulded interconnect devices becomes more of importance (Amend et al., 2010). The laser writing for selective plating of polymers could be also used in 3D structures because localized and selective activation of the polymer is achieved with a laser beam. The scanning of the laser beam on 3D surfaces can be simply obtained technologically (Tsoukantas et al., 2003).

In our work, we have investigated two technologies LISA and LDS. LISA contains three steps: 1) Laser surface structuring. This step is used to make porous, the sponge-like surface structure of a polymer. The structure is needed to keep the activation particles inside cavities. 2) The second step is activation. The activation is made by colloidal solution, usually palladium tin chloride. This step consists not only of immersion of a workpiece in the activation solution but also of its rinsing after the activation. Rinsing is critical and not an easy task. All the colloidal particles must be washed away from untreated areas but must be left inside the porous. 3) The last, third step is plating in a chemical solution, usually copper chloride (Zang et al., 2011).

Plastics with special additivities are used for LDS. These additivities are activated during the laser treatment. Additivities are based on organometallic compounds usually with palladium (Huske et al., 2001).

2. Experimental setup

The experimental section is divided into two parts, physical – laser structuring of polymer surface and chemical – surface activation and plating.

2.1. Laser machining

Two types of lasers, with different pulse duration, were used in experiments. A Q-switched Nd:YAG laser with a pulse duration of 10 ns and a mode-locked Nd:YVO_4 laser with a pulse duration of 10 ps were utilized. Two different wavelengths of both lasers were used: the fundamental harmonics at 1064 nm and the second harmonics at 532nm. The laser beam was scanned with a galvanometric scanner. The experiments were performed by changing the scanning speed (pulse overlapping) and average power of the laser. Laser parameters used in the experiments are presented in Table 1.

Table 1. Laser systems parameters used in the experiments.

Laser parameters:	PL10100 (Ekspla)	Baltic HP (Ekspla)
Wavelength	1064, 532 nm	1064, 532 nm
Pulse length	10 ps	10 ns
Rep. rate	50 kHz	50 kHz
Average power	0.1 - 1 (step 0.1) W	0.1 - 1 (step 0.1) W
Beam control	Pockels cell with polarizer	Attenuator
Beam positioning	SCANgine (1064 nm), hurrySCAN (532 nm)	SCANgine (1064 nm), hurrySCAN (532 nm)
F-theta lens	+80 mm	+80 mm

2.2. Activation and plating

For the LISA experiments, PP and PC/ABS polymers were used. Activation of the laser structured surface was performed by using $PdCl_2$ mixed with $SeCl_2$ solution and $AgNO_3$ solution. Wayne – Mayer's (Table 2) solution was used for plating. Two different types of the LISA experiments were made: laser structuring of clean polymer surface and laser structuring of the polymer pre-treated before with $AgNO_3$.

Table 2. Wayne- Mayers solution for plating

Material	Concentration
$CuSO_4$	0,22 M
NaK tartrate	0,25 M
NaOH	0,95 M
Na_2CO_3	0,3 M
Formalin	1,5 M
pH = 12,7	

3. Results

3.1. LISA

For this experiment, we used PC/ABS polymer. Laser parameters employed in the experiments are presented in Table 1. The initial result has shown that the plating results were better when the second harmonics was applied for the first (laser structuring of the polymer surface) step of the process (see Fig. 1).

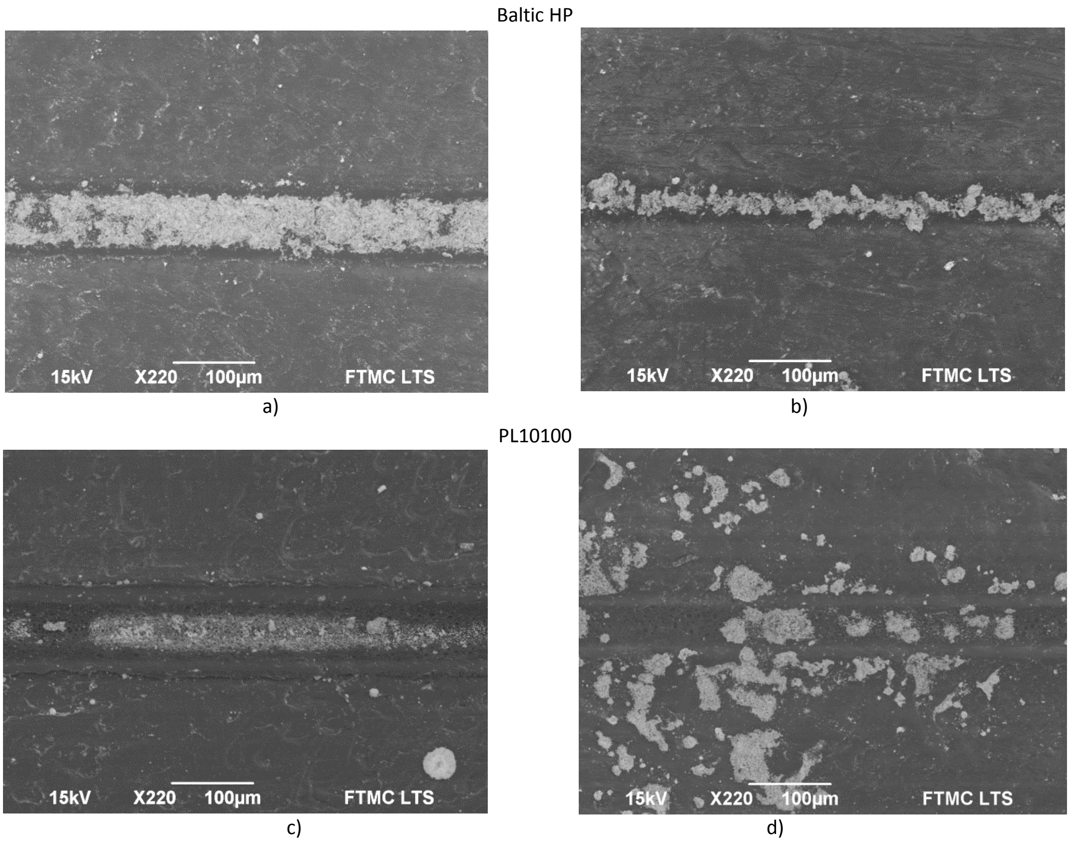
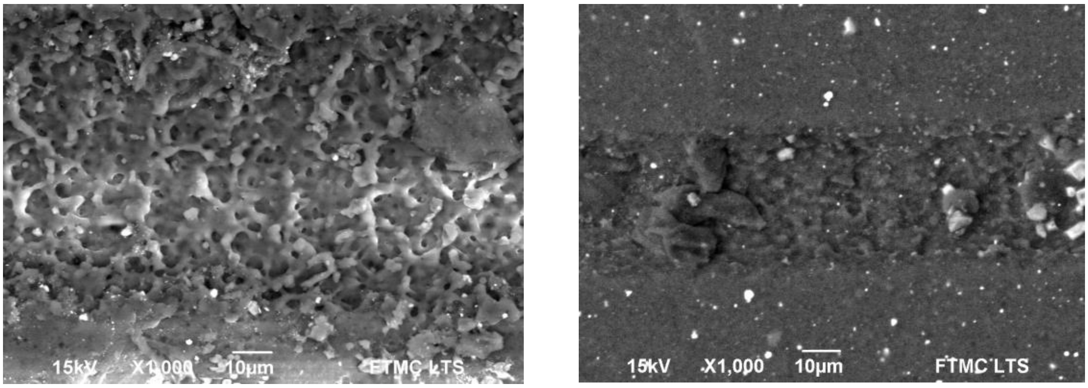


Fig. 1. SEM images of plated surface structured by different lasers: a) and b) the nanosecond Baltic HP laser; c) and d) the picosecond PL10100 laser. Different harmonics has been used: a) and c) 532 nm, b) and d) 1064 nm. Polymer PC/ABS.

The reason of the better plating for the structuring with the 532 harmonics could be explained by the higher porosity of the surface (see Fig 2.)



a) b)

Fig. 2. SEM images of the machined surface with a) 532 nm and b) 1064 nm of the wavelength. Laser: Baltic HP, the polymer: ABS.

The better porosity for the laser treatment with 532 nm than 1064 nm wavelength can be influenced by the higher absorption coefficient of PC/ABS plastics for the 532 nm wavelength (Larosa et al., 2009). Thus, a local increase of the temperature was necessary for melting of polymer surface that led to the porous formation.

The LISA method results did not show the high selectiveness of plating. Metal layer after coating was observed not just on the areas treated with the laser, but also next to them. That could be a consequence of insufficient procedure of rinsing. Therefore, the plating coating quality was different for plastics treated with the picosecond and nanosecond pulses. On the polymer treated with the nanosecond pulses, the copper coating was more homogeneous and continues, contrary to the coatings on plastics treated with the picosecond pulses. This difference, probably, refers to the higher porosity too, as thermal diffusion time is longer for the nanosecond pulses, and they initiate melting in the larger area than picosecond pulses.

Another test was made on the samples initially covering with the activator $AgNO_3$ (1M) and later treated with a laser. For this experiment, the rinsing procedure was not applied after the activation. After the plating step, the areas treated with the picosecond laser were less covered by copper than the untreated areas. In case of the plating areas structured by the ns-laser, the influence of this phenomenon was smaller. The reason could be that the activator was evaporated from the surface by the laser.

3.2. LDS

For the LDS experiments, PP polymer doped with carbon-based additivities with different concentration was used as a sample. The laser system setup was the same applied in the LISA experiments. We have tested the copper plating for various laser regimes indicated in the experimental setup section. Wayne – Mayer's solution with different temperatures and pre-treatments were used for the plating.

The results of the LDS experiments have shown excellent selectiveness of the plating when the nanosecond laser was used for structuring of the samples. Several lines with a different spot size of laser beam were scanned on the samples (see Fig. 3). The narrowest width of continuous plated line was less than 30 µm. No cleaning procedures were needed. Samples structured with the picosecond laser did not show any plating results – samples were uncovered by a metal.

PP doped with carbon particles of different concentration was also investigated. The best plating results were achieved with the higher carbon concentration in PP. The best structuring regime for the scanning speed and average laser power were selected to be: 0.2 m/s, 0.2 W.

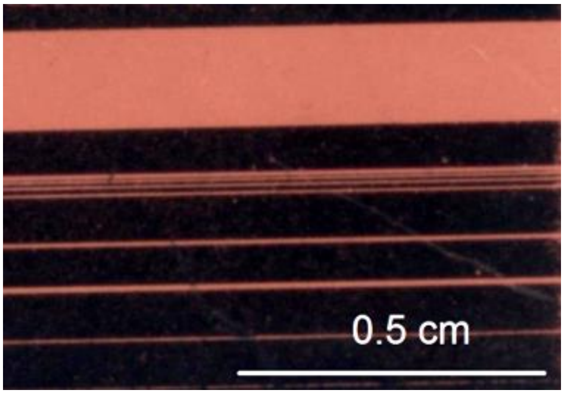


Fig. 3. Selectively metalized sample of PP with carbon- based additivities using LDS.

4. Conclusions

LISA and LDS plating method were investigated. LISA method showed low selectiveness of plating of the laser structured areas, but still appropriate results were achieved after cleaning.

LDS method showed the high selectiveness for plating of the surfaces structured with the nanosecond laser, but no plating was observed after the structuring with the picosecond laser. The best results of the plating were achieved with the higher concentration of carbon-based additivities in PP used in the experiment.

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