ABSTRACT

We report a facile and low-cost laser-assisted method for selective deposition of copper traces on polymer surfaces. The technique uses a laser for selective polymer surface modification. The electrical conductivity of some polymers could be increased due to laser irradiation. Kapton PI film was used in our experiments. Samples were patterned using nanosecond and picosecond lasers working at the 1064 nm wavelength. The experiments were performed using average powers ranging from 4 to 8.5 W in 0.5 W increments, pulse repetition rates from 10 to 100 kHz and a constant scanning speed of 100 mm/s. The sheet resistance was measured using the four-probe method, and it was reduced to < 50 Ω per square after laser patterning. Afterwards, the modified surface was metal deposited by electroplating.

The main advantage of the method is that direct electroplating on polymers allows very fast, selective and low-cost metal deposition process to compare with other deposition methods, like PVD coating, painting with conductive ink, etc. Selective deposition of copper on polymers could be used in flexible electronic devices. This technology shows a huge potential in many fields: consumable electronics, automotive, medicine, etc. The aim of this research is to find the optimal laser patterning and copper plating parameters for high quality, recurrent fabrication of copper traces on polymer.

EXPERIMENTAL SETUP

![Fig. 1. Principal experimental setup for laser patterning process. Laser – picosecond and nanosecond pulsed lasers were used in our experiment. WP – half wavelength wave plate, P – polarizer, D – dump, BE – beam expander, GS – galvanometer scanner, TFTO – telecentric f-theta objective, S – sample.](image)

![Fig. 2. A sheet resistance was measured using the four-probe method.](image)

![Fig. 3. Electroplating scheme. Kapton PI film and pure copper rod (Cu) were immersed in to the electrolytic solution for the electroplating experiment. Kapton PI film was connected to cathode terminal and a copper rod (Cu) was connected to anode terminal. The plating bath solution consisted of sulphuric acid and copper sulphate. The current density of 1 A/dm² was used and the plating process time was 45 min in our experiments.](image)

Kapton PI film from DuPont with the thickness of 127 μm was used in our experiments.

RESULTS

![Fig. 4. Polymer Kapton PI film before laser patterning (A), after laser patterning (B) and after electroplating process (C).](image)

![Fig. 5. Dependence of polymer Kapton PI sheet resistance on the irradiation dose after patterning with nanosecond (A), and picosecond laser pulses (B). Sheet resistances as low as 30 Ω/square were achieved during ps-laser irradiation, and one order bigger values were got after ns-laser irradiation (lowest sheet resistance was achieved 354 Ω/square in ns-regime). Patterning repeatability was better on ps-regime. Selective copper deposition on patterned surface occurred when the sheet resistance was 10000 Ω/square or lower on both, ns and ps-regimes patterned samples. (C) show the (B) graph section at which, patterned PI film could be electroplated. Electroplating occurred when polyimide sample was patterned with irradiation dose of at least 180 J/cm².](image)

CONCLUSIONS

- The sheet resistance of patterned surface as low as 30 Ω/square was achieved after irradiation of the picosecond laser.
- Selective copper deposition was obtained in the patterned areas, where sheet resistance was 10 kΩ/square or less. To achieve this resistance, laser irradiation dose of 180 J/cm² or higher is required.
- Kapton PI films, patterned in nanosecond and picosecond regimes, were compared. Pattern repeatability was better in ps-regime. Using ns-regime, thin PI samples were deformed due to excessive heating at irradiation doses larger than 200 J/cm². Sheet resistance smaller by one order of magnitude was achieved in ns-regime.