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<th>Recycle of Metal-Plating on Plastics by Pulse Arc Discharge</th>
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<tr>
<td>Citation</td>
<td>Digest of Technical Papers-IEEE International Pulsed Power Conference, 2007: 1437-1440</td>
</tr>
<tr>
<td>Issue date</td>
<td>2007-06</td>
</tr>
<tr>
<td>Type</td>
<td>Conference Paper</td>
</tr>
<tr>
<td>URL</td>
<td><a href="http://hdl.handle.net/2298/10322">http://hdl.handle.net/2298/10322</a></td>
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Abstract

Metal-plating on plastics has been used in household appliances, cars and others. Metal-plating and plastics have to be separated for recycling. The crush separation system is a high running cost. A melting separation system using an acid or an alkali causes deterioration of the performance of plastics. Therefore, a new method of separating metal-plating and plastics is expected.

A method to separate metal-plating on plastics has been developed using pulse arc discharges by pulsed power [1]. A large current flow into a metal thin film, and then a part of the metal film is vaporized by heating. At the same time, a shock wave occurs and removes the metal thin film from the plastics. The plastics and the metal removed are recyclable. In this paper, the effects of ceramic tubes covered on electrodes, the kind of electrode material, the distance between electrodes and the diameter of electrodes on the removal efficiency are studied.

EXPERIMENTAL APPARATUS

Figure 1 shows a sample of the metal-plated plastic used in the experiments. Thicknesses of Cr, Ni and Cu, which are measured by EDX (Energy dispersive X-ray spectrometry), are 0.14, 7.0, 21 µm, respectively.

Figure 1. Sample used for metal separation

Figure 2 shows the photograph of experimental apparatus, which is composed of a direct-current power supply, a pulse power circuit, 3 axis robot and the electrodes attached at the tip of a robot arm.

Figure 2. Photograph of apparatus

Figure 3 shows the composition of the electrode part. Two electrodes are covered with the ceramic tube (alumina pipe). The distance between the electrode tip and sample is defined as gap separation.

Figure 3. Schematic configuration of rod electrodes

Figure 4 shows the pulse electric discharge circuit used in order to verify the effect of a ceramic tube. The capacitor of 1.2µF is charged by the high voltage DC power source. The charging voltage is 3kV. A thyristor is triggered by the pulse generator. The output energy is transmitted to electrodes through a transformer, and pulse arc discharges are generated between two electrodes.

Figure 5 shows the pulse electric discharge circuit used in order to investigate the dependence of removal efficiency on gap separation, electrode material and the diameter of an electrode, respectively. The applied voltage between electrodes is measured by the high-pressure probe, EP-100K, and the current through the electrodes is measured by the Pearson current monitor. Output energy is computed by the current and the voltage waveform which are measured.
II. RESULTS AND DISCUSSIONS

Figure 6 is a photograph of the metal-plated plastics after a shot. The electrode is tungsten with 0.5mm in diameter. The outer diameter of the ceramic tube is 2mm and the inside diameter is 1mm. A gap separation is 0mm and an electrode distance is 3mm. The circuit of Figure 4 is used. The removal of metal plated on plastics occurs only near the electrode tips in the case without ceramic tubes. On the other hand, the metal of a large area including near the electrode tips is removed in the case with ceramic tubes. Metal-plating is turned from ABS resin.

Figure 7 shows the comparison of current waveforms with and without ceramic tubes. With the ceramic tube, the maximum current is 2.7kA and input energy is 29J. Without ceramic tube, the maximum current is 2.7kA and input energy is 30J. Though the difference of current and input energy is negligibly small, the removal efficiency improves from 0.10mm²/J to 0.73mm²/J by covering of the ceramic tube.

Figure 8 shows a schematic diagram for investigating the effect of a ceramic and a polyimide sheets on the removal efficiency of the metal. The ceramic sheet is 2mm thickness and there is a hole of 20mm in diameter. The polyimide sheet covers the hole. For the comparison, the polyimide sheet is placed at the same place without the ceramic sheet. The gap separation and electrode distance are 0mm and 3mm, respectively. The circuit of Figure 4 is used.

Figure 9 shows the photographs without and with the ceramic sheet. Without the ceramic sheet, the removal area is reduced like the case where ceramic tubes do not cover the electrodes. However, with the ceramic sheet, the removal area is expanded like the case where ceramic tubes cover.
Figure 9. Photographs of the metal-plated plastics after one shot

Figure 10 shows the dependences of the removal area and input energy on the gap separation. The pulse electric discharge circuit of Figure 5 is used. The tungsten electrodes with a diameter of 1.0 mm are covered by the ceramic tubes with outer diameter of 2.0 mm and inner diameter of 1.0 mm. The electrode distance is 3 mm. The gap separation is changed from 0.5 mm to 3.0 mm. The maximum removal area of 99 mm$^2$ is obtained at 2 mm gap separation. At the gap separation of 0.5 mm, the removal area is 89 mm$^2$. The differences of the removal area and the input energy are small on the gap separations between 0.5 and 2 mm. At the gap separation of 3.0 mm, the removal efficiency decreases 1.0 mm$^2$/J.

Figure 11. Dependence of removed area and input energy on the materials of rod electrodes.

Figure 12. Current waveforms.
such as 3, 4, 4 and 6 mm, respectively. In the case of the electrode diameter of 1.0 mm, the ceramic tube with 2.5 mm in outer diameter and 1.5 mm in inner diameter is used. In the cases of 1.6 mm and 2.0 mm in electrode diameters, the ceramic tube with 3.0 mm in outer diameter and 2.0 mm in inner diameter is used. In the case of 3.0 mm, the ceramic tube with 5.0 mm in outer diameter and 3.0 mm in inner diameter is used. The maximum removal area is 92 mm$^2$ at 1.0 mm in electrode diameter. If the diameter of an electrode becomes thick, the removal area decreases with the increase of electrode diameter. The input energy decreases with the increase of electrode diameter, and becomes almost constant over 1.6 mm in electrode diameter. The concentration of the electric field and the strength of shock waves produced by discharges might be influenced by the electrode diameter.

![Figure 13. Dependence of removed area and input energy on electrode diameter.](image)

**III. Summary**

The separation of metal-plating on plastics occurs using pulse arc discharges by pulsed power. The plastics and the metal removed are recyclable. The effects of ceramic tubes covered on electrodes, the kind of electrode material, the electrode separation and the diameter of electrodes on the removal efficiency are studied. The obtained results are summarized as follows.

1. The removal efficiency of metal increases using the electrodes covered by ceramic tubes.
2. There is the optimum value of a gap separation in the removal efficiency. The optimum gap separation is 2 mm at ceramic tubes with 2.0 mm in outer diameter.
3. The removal area increases with the electric conductivity of the electrode.
4. As for the diameter of an electrode, the removal efficiency becomes higher at 1.0 mm.

**IV. REFERENCES**