Fundamental study on metal plating removal using pulsed power technology

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ABSTRACT

A novel method for the metal removal from metal-plated substrate using pulsed power technology is proposed. A metal-plated substrate with three metal-layers structure (Cu, Ni and Au) is used as the sample substrate. Repetitive pulsed arc discharge plasma is generated between a rod electrode and the surface of substrate. Effect of the type of electrode system on metal plating removal was investigated. The removal region is produced by the moving phenomena of the pulsed arc discharge. A part of Au layer, which is the topmost metal surface of the substrate is vaporized and removed by the repetitive pulsed arc discharges. The proposed method can be used for recycle of metal-plated substrate.

Keywords

Key Words : metal plating removal, pulsed arc discharge, recycle

1. Introduction

Environmental destruction and depletion of resources has become a problem due to the economic growth of recent years on a global scale. Therefore, there is a need for conversion to a sustainable, recycling-oriented society from traditional mass disposal type society by 3R (Reduce, Reuse, Recycle). There is a recycle of printed circuit board for mounting electronic circuit parts with respect to recycle in the 3R. In order to recycle the printed circuit board, it is necessary to recover the metal plating material from the insulator substrate such as metal-plated plastics.

The purpose of this study is to develop recycle technology to separate and recover the metal plating material from the insulator substrate used as printed circuit board.

2. Experimental Setup

Schematic diagram of printed circuit board used in this experiment was shown in Figure 1. The printed circuit board has a structure in which three metal-plated layers are formed on an insulator substrate made of FRP. Materials of the three metal-layers are composed of cupper (Cu), nickel (Ni) and gold (Au).

On the other hand, it is reported that as an electrode system for the removal of metal plating by the pulsed arc discharge, a thin wire or rod-shaped metal electrode covered with an insulator such as a ceramic tube is effective electrode system [1-3]. Therefore, the similar electrode system was also used in this

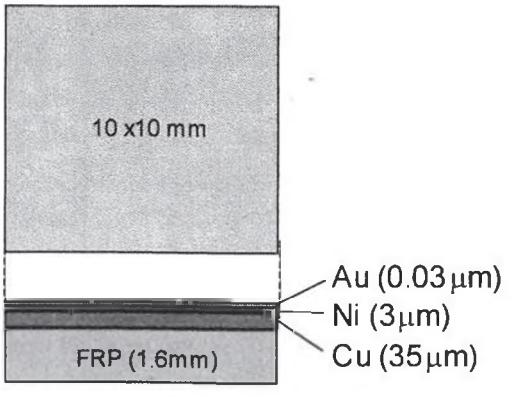


Fig. 1 Metal plating substrate

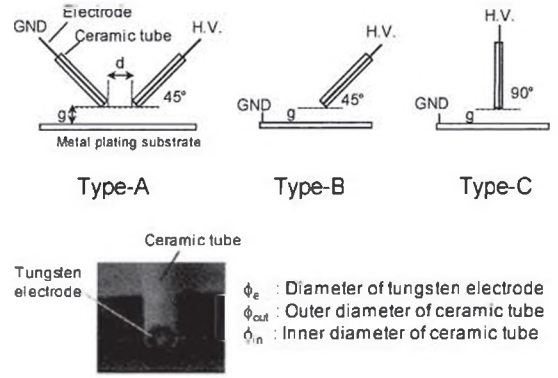


Fig. 2 Electrode system

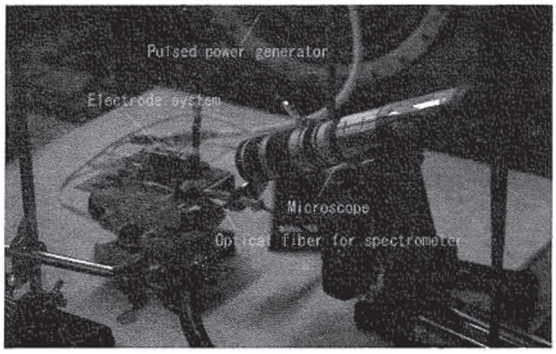


Fig. 3 Experimental setup.

study. Three types of electrode system (Type-A, Type-B and Type-C) were used to investigate the effects of the relative positional relationship between the electrode and metal-plated substrate on the removal of metal plating. The electrode systems were shown in Figure 2.

<Type-A> Rod electrodes made of tungsten inserted into the ceramic tubes were used as the high voltage and ground electrode. Both electrodes were set up above the metal plated substrate at the angle of 45 degrees. In this case, we defined the separation between two electrodes and the distance from the substrate as *d* and *g*, respectively.

<Type-B> The tungsten rod electrode inserted into the ceramic tube and the metal plated substrate were used as the high voltage and ground electrode, respectively. The rod electrode was set up at the distance of *g* from the metal plated substrate, which was used as the ground electrode. Angle of the rod and substrate was 45 degrees.

Table 1 Experimental condition.

Pulsed power generator	Output voltage(%)---Max. 120kV
	Repetition rate(pps)---Max. 40pps
	Number of shots
Electrode system	Diameter of tungsten electrode, ϕ_e (mm)
	Inner diameter of ceramic tube, ϕ_{in} (mm)
	Gap length,g(mm)

<Type-C> Type-C electrode system was similar that of Type-B, however, Angle of the rod and substrate in Type-C was 90 degrees.

Experimental apparatus was shown in Figure 3. A pulsed power generator was used to generate the pulsed arc discharge on the metal-plated substrate. The specification of the generator has the maximum output voltage of 120kV, discharge repetition rate of 40pps and the energy of 40J/shot. Output voltage and current were measured with a high voltage probe (Pulse electronics co. ltd, EP-100K) and Rogowski coil (Pearson electronics, Inc, Model101). A high-speed microscope (Keyence co., VW-6000) was used to observe the surface condition of metal-plated substrate and the behavior of repetitive pulsed arc discharges. Optical emission spectra from the discharge were measured with a spectrometer (Ocean optics co, HR4000CG-UV-NIR). An electron probe microanalyser (Shimazu co, EPMA-1720) was employed in order to investigate the metal elemental analysis on the surface of the metal-plated substrate.

Experiments were performed concerned with effects of the electrode systems on removal of metal plating from the substrate, relationship between the removal region of metal plating and the discharge phenomena, and surface analysis of the metal-plated substrate after the repetitive pulsed arc discharge.

3. Results and Discussion

3.1 Effects of electrode systems on the removal of metal plating

Figure 4 shows the surface condition of metal plating substrate after the pulsed arc discharge

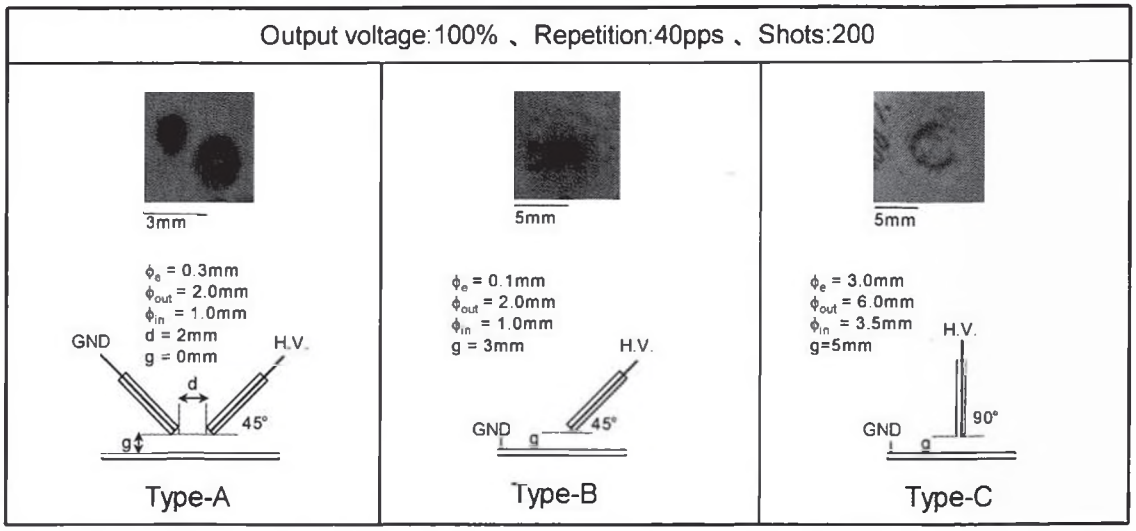


Fig. 4 Metal removal using pulsed arc discharge on different type of electrode systems.

generated in the three types of electrode system. Settings of the output voltage, repetition rate and number of shots were 100%, 40pps and 200shots, respectively. Details of the results for each electrode system are follows.

<Type-A> Pulsed arc discharge was generated between electrodes through the metal plating surface by applying the pulsed high voltage between electrodes. After the discharge of 200 shots, removal region of the metal plating were formed on the substrate just below the high voltage and ground electrode. Size of the removal region was several mm in diameter. The removal region tended to become larger as increasing the number of shots and output voltage setting value. However, the removal regions were formed at only two positions corresponding to each electrode below and it was difficult to remove the metal plating from the substrate efficiently between electrodes as a whole.

<Type-B> When the pulsed high voltage was applied between electrodes, pulsed arc discharge was generated between electrodes and the metal plating was removed. Size of the removal region of the metal plating was increased to approximately 10 mm in diameter compared to that in case of the Type-A electrode system.

<Type-C> The metal plating was removed by the pulsed arc discharge and the size of removal region

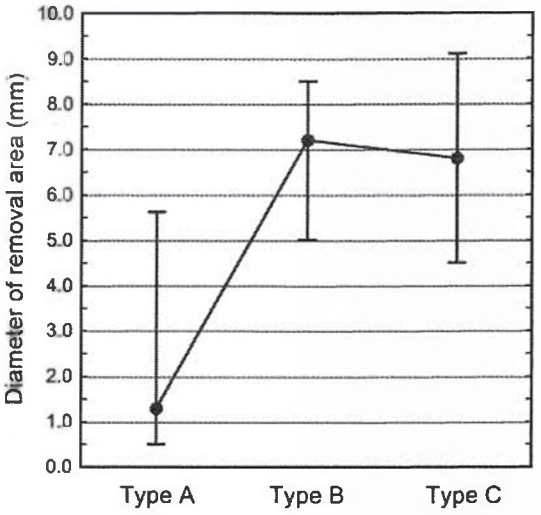


Fig. 5 Dependency of diameter of removal area on 3-type of electrode systems.

was approximately 10 mm in diameter, which was almost same size in case of the Type-B electrode system. However, ring-shaped arc discharge spots were formed in the removal region. It was different from the result of the Type-B electrode system.

Figure 5 shows relationship between the removal region and type of electrode system. The removal region was evaluated by its diameter. Diameter of the removal region formed in the Type-A electrode system was about 5 mm and it was varied widely. Meanwhile, Diameter of the removal region formed

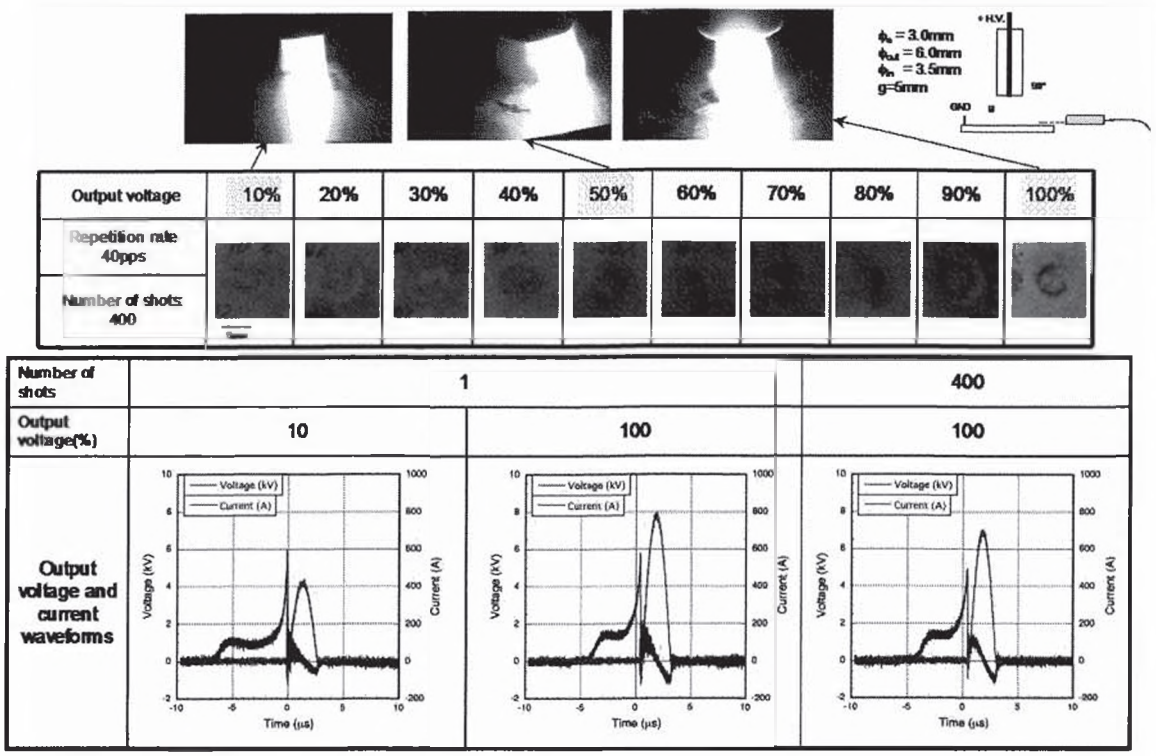


Fig. 6 Effects of pulsed arc discharge on metal removable. Top: photos of pulsed arc discharge, middle: surface condition after discharge, bottom: output voltage and current waveforms.

in the Type-B and Type-C electrode system was increased to about 2 times. From Figure 5, it was found that the Type-B or Type-C electrode system was more effective on the removal of metal plating in this experiment. In particular, the characteristic ring-shaped discharge region is formed in the Type-C electrode system as shown in Figure 4. Therefore, then we investigated relationship between the removal region and the discharge phenomena using the electrode system Type-C.

3.2 Relationship between removal area of metal plating and discharge phenomena

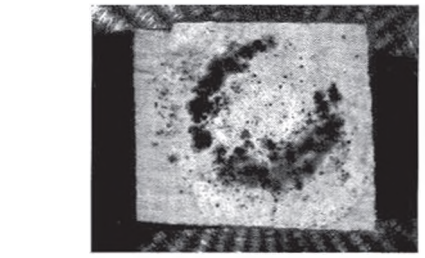
Figure 6 shows the metal removal region and the pulsed arc discharge phenomena by changing the output voltage setting value from 10% to 100% in case of the Type-C electrode system. Repetition rate of the discharge and number of shots were 40 pps and 400 shots, respectively. It was found that the ring-shaped discharge region was formed at the output voltage setting value of 50% and the removal region became larger as increasing the voltage setting value. The high-speed microscope observation revealed that the formation of ring-shaped discharge region was due to the behavior of pulsed arc discharge. The discharge plasma channels were produced between electrodes shot to shot and these plasma channels were moved in the shape of the ring between the tungsten rod and ceramic tube. This result suggested that the metal plating was gradually removed from the substrate by the repetitive pulsed arc discharge.

Output voltage and current waveforms were also shown in Figure 6. The peak output voltage and current value at the voltage setting value of 10% was 6kV and 400A, respectively for 1 shot discharge. When the voltage setting value was increased to 100%, the peak output voltage was almost same but the current was increased to 800A. As increasing number of shots up to 400 the current value was decreased to 700A. The decrease of current was thought to be due the increase of impedance between electrodes because of the removal of metal plating

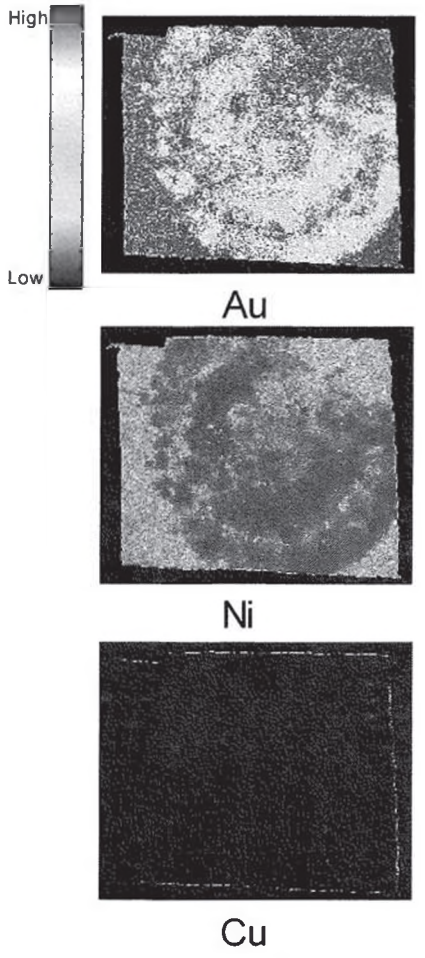
from the substrate.

3.3 Surface analysis of the metal-plated substrate after the discharge

Figure 7 shows the metal elemental analysis of metal plating substrate after pulsed arc discharge. The metal plating materials were composed of Cu, Ni and Au. The material of topmost surface of the metal plating three layers was Au and the middle layer material was Ni. It was clear from Figure 7 that the Au layer was removed by the pulsed arc discharge. However, the Ni layer could not be removed by the repetitive pulsed arc discharge.



(a) Metal plating substrate after pulsed arc discharge for surface analysis.
(Output voltage:100% Repetition :40pps 200shots)



(b) Mapping images of metal elements

Fig. 7 Metal elemental analysis of metal plating substrate after pulsed arc discharge.

4. Conclusions

The removal method of metal plating by the pulsed arc discharge was proposed. Obtained results were summarized below.

(1) The rod electrode inserted into ceramic tube to plane electrode system (Type-C) was most effective to the removal of metal plating.

(2) The metal plating was removed from the substrate by the repetitive pulsed arc discharge, which formed the ring-shaped discharge region.

(3) Au layer, which was the topmost material of the metal plating layer was removed by the pulsed arc discharge.

These results suggest that the metal plating layers can be removed selectively by controlling the parameters of the electrode system and the pulsed power generator.

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