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Adhesion Property between Resin and Aluminum Surface-treated by Atmospheric Pressure Plasma Jet

大気圧プラズマジェット表面処理したアルミ材の樹脂密着特性

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In recent years, the aluminum and resin are widely used for various industrial applications. Accordingly, the bonding technique between aluminum and resin has been developed. In this study, we focused on the treatment of aluminum substrate by an atmospheric pressure plasma jet. We compared the shear fracture strength between untreated sample and plasma treated one. The present experimental results show that the shear fracture strength was clearly increased by atmospheric pressure plasma jet. We are planning to check the surface roughness by AFM and constituent element of plasma treated sample by XPS.

1. Introduction

Aluminum has been widely used as various parts of transportation equipments to reduce the weight. In addition, it has been used for architectural materials because of improvement of air tightness. Similarly, the resin material is lightweight and intensity is high. In addition, it is good moldability and low cost. So, the resin material and aluminum have been widely used for many applications in recent years. In the practical application, however, it is often required to develop the bonding technique between aluminum and resin. So far, the treatment with chemicals was mainly used for surface treatment to enhance the adhesion of aluminum and resin. But there are some problems, such as the cost performance and environmental issue of the effluent. Hence, the surface treatment with the plasma processing recently attracts attention in various industrial fields. In the present research, we used atmospheric pressure plasma jet. It has a great advantage to produce the plasma without vacuum equipment. Furthermore, atmospheric pressure plasma jet can treat the substrate cleanly, since there is no effluent. Moreover, the surface treatment can be made without damage of sample. In the present study, we tested the effect of hydrochloric acid vapor addition to the plasma to produce highly reactive chlorine radicals for aluminum etching.

2. Experimental setup

The schematic diagram of the experimental setup is shown in Fig. 1, where the atmospheric pressure plasma jet was produce by applying 100W RF waves between ring-shaped copper electrodes wrapped over the quartz tube. The outer diameter of the quartz tube is 6 mm, and inner diameter is 4 mm. We compared with two experimental conditions, where we used only He gas (2000sccm) in case1, and we used He gas with hydrochloric acid vapor mixture gas (total gas flow is 2200 sccm with 200 sccm by bubbling of HCl solution) in case 2.

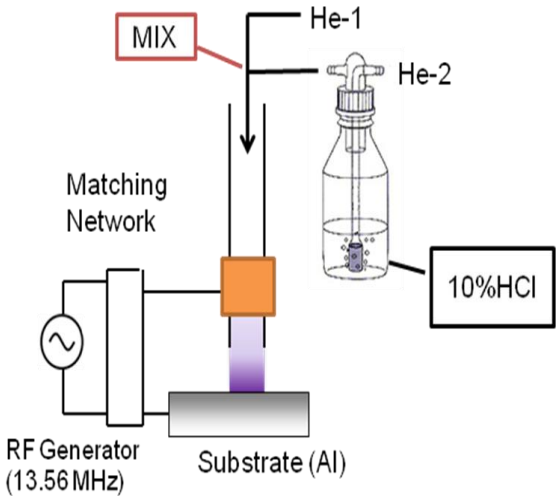

Fig.1. Experimental setup.

3. Results and discussions

The condition of plasma jet discharge is shown in Fig. 2. We generated the plasma in the quartz tube, and plasma jet was irradiated to aluminum substrate. We used “autograph” (Shimazu factory AG-100KND) for measuring shear fracture strength. We treated the aluminum substrate at 3 different points by atmospheric pressure plasma jet. And we bonded it to the same treated aluminum by epoxy bonding agent. We compared 7 samples (He plasma jet treated for 1min, 2min, 3min per 1 point,

He/HCl mixture plasma jet treated sample and untreated sample). The result of shear fracture strength measurement is shown in Fig. 3. It is found that adhesion strength is significantly increased by treating plasma jet. The shear fracture strength of untreated sample is about 6 MPa. By contrast, the sample treated by He and HCl mixture plasma jet for 2 min exceeded 30 MPa in shear fracture strength. Generally, shear fracture strength of 30 MPa is required for practical application. So the present results indicated enough strength. When we increased the treatment time to 3 min. the result showed that the strength was almost same as the value of 2 min.

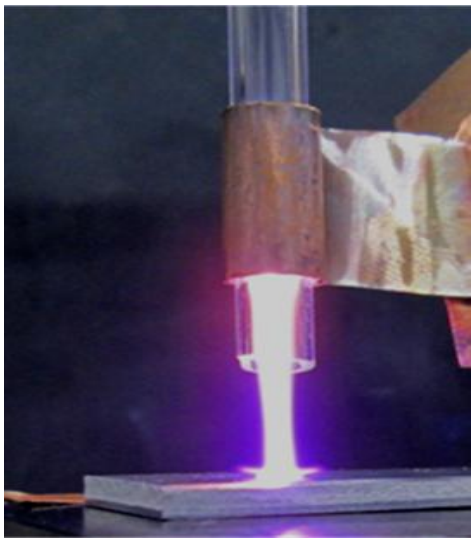

Fig.2. Picture of atmospheric pressure plasma jet

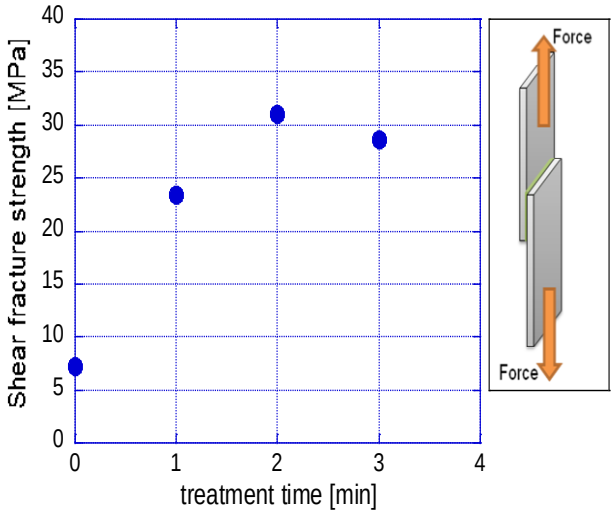

Fig.3. Results of shear fracture strength vs treatment times.

Next, we compared breaking cross-section of untreated sample and plasma treated sample. In this measurement, we used 2 min plasma treatment with He and HCl mixture gas because this sample showed the maximum intensity. Fig. 4 and Fig. 5 show one example of pictures of each breaking cross-section. In the case of untreated sample, we observed the adhesion breaking. By contrast, the sample treated by 2 min He and HCl mixture plasma has cohesion breaking. From these results, it is considered that the adhesion intensity was improved by treating atmospheric pressure plasma jet.

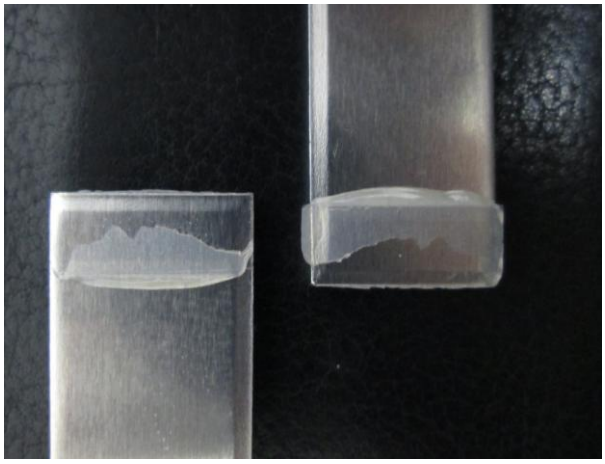

Fig.4. Breaking cross-section of untreated sample.

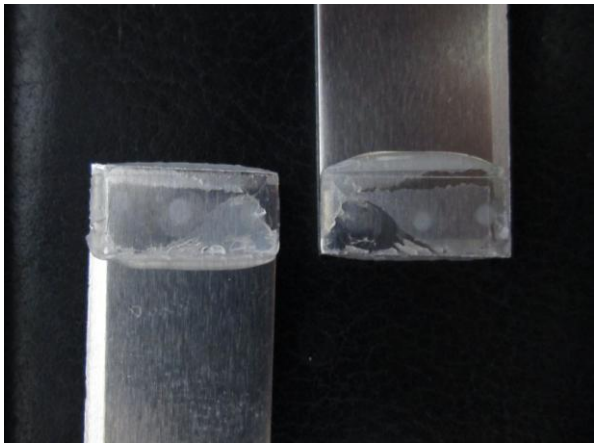

Fig.5. Breaking cross-section of treated sample.

4. Conclusion

In the present study, we studied the adhesion property of aluminum plate treated by atmospheric pressure plasma jet. The results showed a significant improvement of adhesion between aluminum and resin by treating the aluminum surface by the atmospheric pressure plasma jet. We are now trying to measure the surface roughness of aluminum by using AFM (Atomic Force Microscope) and also analyze the constituent element of sample and electronic state by using XPS (X-ray Photoelectron Spectroscopy). More details of result will be presented at the conference.