Surface Modification of Titanium by Means of High Temperature Plasma Jet†

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Abstract

The nitrization of titanium by means of a high energy type plasma jet has been investigated. According to the experimental results of the formation of titanium nitride (TiN) film on the surface of Ti substrate, the advantage of this surface modification method has been described, and the mechanism of this nitrization of titanium has been discussed.

KEY WORDS: (Titanium) (Surface Modification) (High Temperature Plasma Jet) (Titanium Nitride) (Vickers Hardness)

1. Introduction

It is well-known that the materials play very important role for the rapid development of the recent high technology. However, it is pointed out that Japan is presently far behind Europe and America in the field of the research and development on the new functionality materials, especially epoch-making and creative development. Therefore the fundamental study for the formation of new functionality materials by means of new idea is strongly hoped.

In this study, considering above circumstances, the surface modification of the materials which is currently very important field is picked up. And is carried out the fundamental study of the formation of the new functionality materials by the heat source of an ultra-high temperature arc which has been developed by the original idea[1].

For the substrates, titanium is adopted, which has high specific strength, high creep strength and high corrosion resistance. By the surface modification of titanium, the nitride of this material is formed by means of ultra-high temperature arc such as high energy type plasma jet and a gas tunnel type plasma jet[2].

The important problem in such surface modification of titanium is that many cracks appear in the film when the formation speed is very high in the case of the surface modification by means of a high energy density heat source such as laser. This study was carried out in order to suppress those cracks. In this paper, the result is described about thin film of titanium nitride which was formed by means of a high temperature plasma jet.

2. Results and Discussion

Figure 1 shows a nitrogen plasma jet generator used in this study. This plasma jet is constricted by the working gas (nitrogen) and is stable. The energy density and temperature can be controlled by changing the arc current and nitrogen gas flow rate.

Table 1 shows the contents of impurities in titanium substrate used in this study. This materialis commercially available pure titanium of 99.5% in weight, but contains small amount of oxygen.

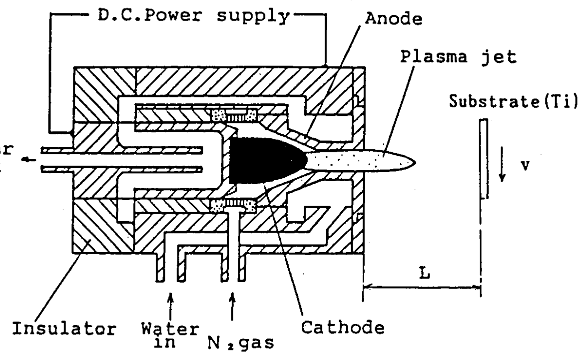

Fig. 1 Schematic diagram of nitrogen plasma jet generator.

Table 1 Impurities in Ti(99.5%) substrate

Fe	H	N	O
640 ppm	29 ppm	100 ppm	1070 ppm

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In this experiment, the scanning speed of the substrate (v) is changeable as shown in Fig. 1. The heat load against the substrate can be controlled by this scanning speed and the distance from the plasma jet torch (L). In this case, the optimum parameters were searched and decided by controlling the interface of Ti substrate in various experimental conditions.

When the substrate was traversed, the edge of the substrate was melted by the heat of plasma jet. **Figure 2** shows the dependence of this melting area (S) of titanium after plasma processing on the distance from the torch (L). The plasma jet power was P=13 kW, and the scanning speed of the substrate was v=8 mm/s. The thickness of the substrate was 3 mm. This melting area corresponds to the heat load to the substrate from the plasma. Therefore the surface temperature of the substrate of non-melting zone seems to have similar dependence on the distance from the torch.

Now, the cross sections of the substrate processed by the above method was observed by using the optical microscope and the change of the microstructure was discussed. **Figure 3** shows a typical photograph of the cross section of the nitride film on the surface of the titanium substrate. The forming conditions of this

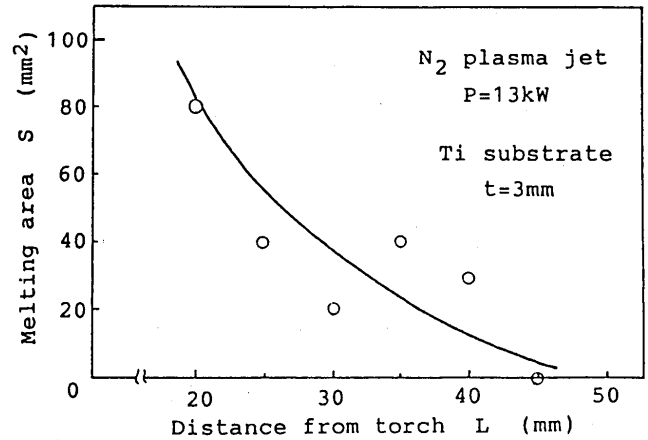

Fig. 2 Dependence of melting area of titanium substrate on distance from torch at P=13 kW.

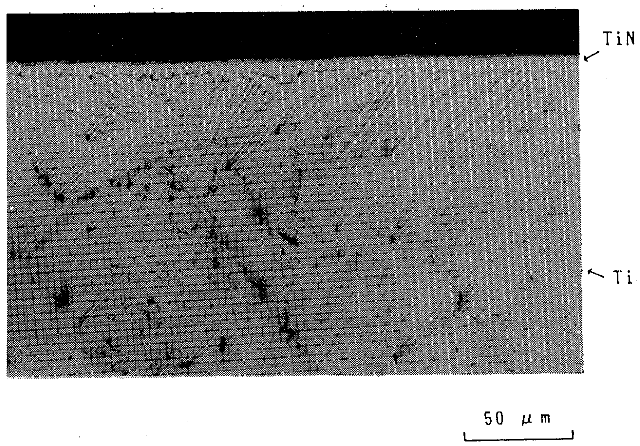

Fig. 3 Typical photograph of the cross section of the titanium nitride film.

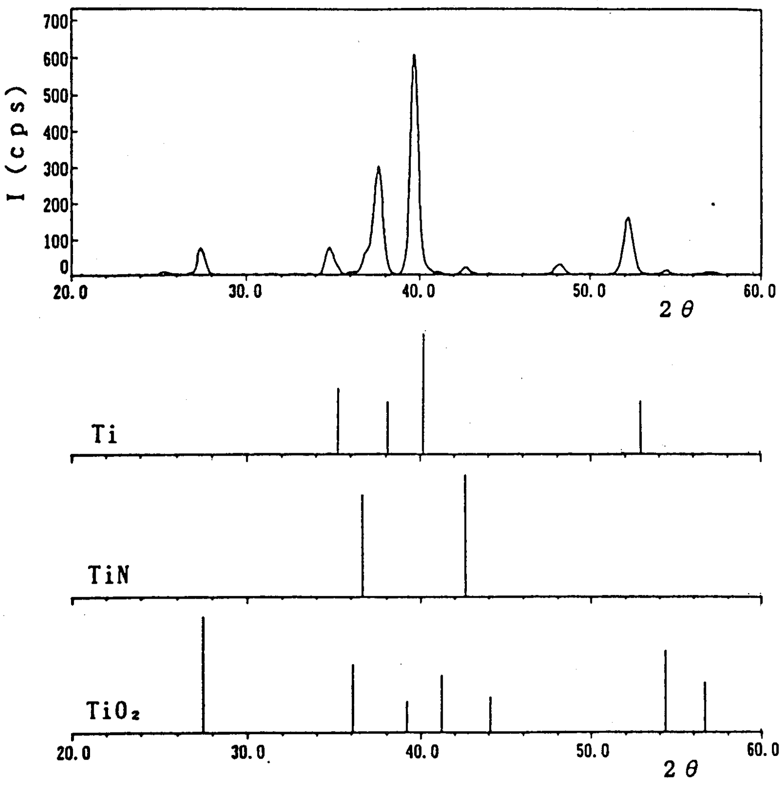

Fig. 4 X-ray diffraction pattern on the surface of titanium nitride film.

test piece were as follows. The plasma jet power was $P=13$ kW. The distance from the torch was $L=30$ mm, and the scanning speed of the substrate was $v=8$ mm/s.

As shown in this photograph, the thin film of 10 μm thickness is formed on the surface of the titanium substrate. The Vickers hardness of this film was more than $H_V=1000$. This result shows the titanium nitride exists in this part. And it is observed under this film that the needle-like structure grows downward in the substrate. The Vickers hardness of this part was about $H_V=400$. From this result, it is considered that this part was formed after the nitrogen solid-soluted into the titanium. Moreover, it seems that the titanium nitride also dispersed in this part. The depth of this structure became larger as the plasma energy became higher.

The result of the thin film X-ray diffraction method is shown in **Fig. 4**. In this case, the incident X-ray angle is 2°. In the lower part of this figure, are shown the locations of those peaks of Ti, TiN and TiO_2 of the standard materials for the comparison.

From this result, it is proved that the peaks of TiN exist on the surface of Ti substrate in addition to Ti peaks of the substrate. The peaks of TiO_2 are observed at the same time in the diffraction pattern. This result shows the importance of controlling the environment in the experiment. Considering the above results, the efficiency of the formation of TiN has been discussed on the experimental conditions.

3. Conclusion

TiN was formed by means of high energy type plasma jet on the Ti substrate. In this study, the processing time of TiN formation was very short as well as laser surface modification, and no crack was observed in the TiN film. It is considered that this was achieved by the surface temperature near the melting point of Ti substrate.

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