The rapid nitriding of Al alloys with the controlling of plasma power density and pretreatments

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Abstract

The properties of AlN make this material very attractive for optical, electronic, and tribological application. Also, if the AlN could be formed on the Al surface to enhance its surface properties, Al could be applied for the lightening of machine parts. However, a dense oxide film exists on the surface of Al, which prevents the formation of the Al nitride even during plasma nitriding and plasma coating process. In this study, plasma nitriding has been tried to form an AlN layer on Al after the surface activation processes. During the plasma nitriding, the density of the nitrogen ions was amplified by means of controlling the power of the Al substrates. The film thickness, microstructural features and the mechanical properties such as hardness and wear properties of the AlN layer were examined as a function of the process parameters of pretreatment and plasma nitriding.

Introduction

Light metals have been utilized for automotive parts to reduce the weight of automobiles, aiming at the significant reduction of CO_2 emission and environmental burdens. In fact, many vehicle classis and suspension components are manufactured with aluminum alloys to improve the strength-to weight ratio. In order to broaden the usefulness of aluminum alloys toward a full-aluminum car, various surface treatments are indispensable to improve their original low tribological properties.

Although uniform AlN layer is possible by the normal plasma nitriding, its processing time must be much shortened and its process controllability must be further improved for reliable surface treatment of aluminum alloy, automotive parts.

In this study, plasma nitriding has been tried to form an AlN layer on Al based on the changes of some parameters such as plasma power, gas compositions, temperatures, etc.

Experimental detalis

The Plasma nitriding of Al alloys were carried out in a plasma-assisted nitriding facility. Aluminium alloys 2024, 6061, 7075 were used as the samples. These samples were mechanically polished with abrasive papers and finally diamond powders with the size of 3 ㎛. They were cleaned for 15 minutes in the alcohol with ultrasonic machine.

After evacuating the vacuum chamber to a pressure of 10^{-3} Pa, the discharge space was heated by substrate heating for several hours at a substrate temperature of 400~600 ℃.

Pre-sputtering experiments were performed in high pure argon and hydrogen-argon mixtures gases at pressures in 7~13Pa and substrate temperatures from 400 to 600 ℃ for 30 minutes. Nitriding treatments were carried out in nitrogen-hydrogen, nitrogen-hydrogen-argon mixtures at pressures about 13 Pa and temperatures from 400 to 600 ℃ for 2~8 hours. The plasma was applied by a DC pulse power with the voltage of 400~650 V. The microstructure of the nitrided samples were examined by SEM with EDS, XRD, optical micrographs and their mechanical properties were examined by micro-hardness tester, nano-indentor, & tribometer.

Results

After plasma nitriding, a black and rough surface were formed on the specimens as shown the Fig 1. SEM micrographs showed that the surface were consisted of very rough and densely arranged micro-particles with size of a few ㎛. Their thickness were almost 50～100 ㎛ after 8h treatment. The growth rate of nitride layer was 20 ㎛/hrs.

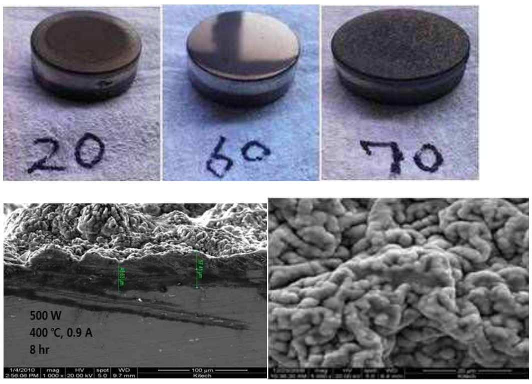

Fig 1. Optical and SEM micrographs showing the plasma nitride sampes and its surface characteristics.

About 500W:

Element	Wt%	At%
NK	05.94	11.54
OK	05.45	09.27
MgK	06.72	07.52
AlK	60.96	61.49
CrK	07.69	04.03
FeK	08.21	04.00
CuK	05.03	02.15
Matrix	Correction	ZAF

About 350W:

Element	Wt%	At%
NK	03.10	06.21
OK	03.41	05.97
MgK	05.25	06.06
AlK	70.25	73.00
CrK	05.51	02.97
FeK	04.79	02.41
CuK	07.69	03.39
Matrix	Correction	ZAF

About 230W:

Element	Wt%	At%
OK	02.32	04.57
MgK	04.02	05.21
AlK	64.61	75.45
CrK	02.11	01.28
FeK	01.90	01.07
CuK	25.04	12.42
Matrix	Correction	ZAF

Fig 2. SEM with EDS analyses on the the plasma nitride samples with changes of the plasma power.

According to the EDS analyses as shown in Fig. 2, the plasma nitriding of Al alloys were much successful with the increase of the power density. SEM analyses showed that the surface of the plasma nitrided sample was consisted of Al nitrides & Al oxides.

At the same power density, the lower temperature was more effective for the Al nitriding. Addition of hydrogen gas was positively affected during both the sputtering and the nitriding process of Al alloys.

Although the thickness of Al nitrided layer, the hardness was only 600～800 HV because the structure was very brittle because of the mixture of two phases (nitride and oxides) and pores. The wear properties of the samples will be presented.

Conclusion

The rapid nitirding of Al alloys were successfully processed by controlling the plasma power density and the addition of hydrogen gas.