Comparative study on atmospheric-pressure plasma nitriding processes with pulsed-arc jet and barrier discharge

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We have demonstrated nitrogen atom diffusion into steel surface using the atmospheric-pressure the atmospheric-pressure pulsed-arc (PA) jet and the dielectric barrier discharge (DBD). The elementary processes occurring in the two kinds of atmospheric-pressure plasmas proved to differ considerably; that is, the PA jet nitriding involves NH radicals as key radicals, while NH is not essential in the DBD nitriding.

1. Introduction

Plasma nitriding is one of the case hardening technologies for upgrading the mechanical properties of steel surface by nitrogen atom (N) diffusion. In industry, low-pressure plasmas are utilized for plasma nitriding. On the other hand, our group has developed atmospheric pressure plasma methods for nitriding to offer novel material processing to industry. For the present, we achieved nitriding with the pulsed-arc (PA) plasma jet [1] and the dielectric barrier discharge (DBD) [2]. In this paper, we discuss the chemical and physical differences of the two nitriding methods to understand the elementary process and technological potential of them.

2. Experimental

2.1. PA jet nitriding

The pulsed-arc is ignited inside the cylindrical electrode, where the pulsed voltage of 5 kV and several μs is applied to the inner electrode at 21 kpps. The operating gas is N_2/H_2 mixture at the flow ratio of 99:1. The afterglow (jet plume) is sprayed onto the steel sample at 530°C.

2.2. DBD nitriding

One of the planer electrodes is the sample electrode to be treated. The opposite electrode is fitted with an alumina barrier of 2.5 mm in thickness. The discharge gap is 1 mm. The ac voltage of 5.7 kV and 12.8 kHz is applied to the sample electrode to ignite DBD. The operating gas is N_2/H_2 mixture at the flow ratio of 9:1. The treatment temperature is 530°C.

3. Results and discussions

We have achieved to diffuse N atoms into steel surfaces by the both experimental procedures. Here, the thickness of the hardened layer, several 10 μm, is similar to the conventional nitriding of industrial use.

Fig. 1 shows the comparison of optical emission spectra from the two plasmas during the treatment. In the PA jet, the emission of NH is dominant, implying that NH radicals are actively produced. Besides, the NH emission is found to decrease with increasing H_2 addition to the operating gas. Moreover, we demonstrated that the diffusion amount of N into the steel is decreased by increasing H_2. These facts indicates that NH is the key radical in the PA jet nitriding.

On the other hand, we see that in the DBD, no NH peak appears, while N_2 2nd positive band is dominant. In addition, we have succeeded in DBD nitriding even without H_2 addition. These facts indicate that NH is not essential in the DBD nitriding. In addition, the N atom emission is not observed, implying that the active production of N is unlikely. We regard the dissociative adsorption of excited N_2 as a possible scenario of N diffusion.

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4. References

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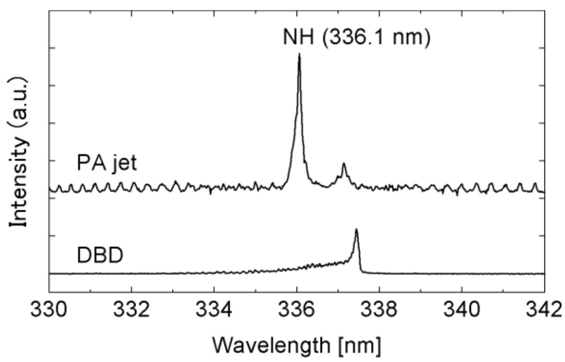

Fig. 1 Optical emission spectra of plasmas.