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Nitrogen diffusion treatment to metal surface using atmospheric-pressure plasmas

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Plasma nitriding is one of the plasma diffusion technology utilized for hardening or functionalizing metal surfaces by thermal diffusion of nitrogen atoms created in plasmas. The conventional plasma nitriding for industrial use requires low-pressure plasmas such as DC glow plasmas for mass production. On the other hand, we focus on applying the atmospheric-pressure plasmas to nitriding to offer new technological seeds to manufacturing industry. We have developed original atmospheric-pressure plasma nitriding techniques with the pulsed-arc (PA) plasma jet and the dielectric barrier discharge (DBD). Here we present the nitriding methods with the above atmospheric-pressure plasmas and special characteristics of treated steels.

First, nitriding by the PA jet is described. We have achieved surface hardening of tool steel by spraying the jet plume as shown in Fig. 1 [1-3]. The operating gas is N_2/H_2 gas mixture. For the present, we can supply nitrogen atoms to an entire circular area of 20 mm in diam almost uniformly. The depth profile of nitrogen concentration measured by EPAM is shown in Fig. 2. The maximum diffusion depth is ca. 70 μm when the treatment temperature is 530°C and the duration is 2 h. The outermost surface contains dense nitrogen corresponding to "the compound layer", which proved to be composed of iron nitride, $Fe_{2\text{-}3}N$ and Fe_4N, by XRD analysis. Just below the compound layer, we can see a zone in which the nitrogen concentration gradually decreases with depth. This zone is called "the diffusion layer" possessing high and gradually changed hardness

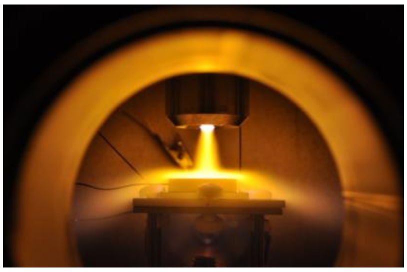

Figure 1 Spraying pulsed-arc plasma jet for nitriding.

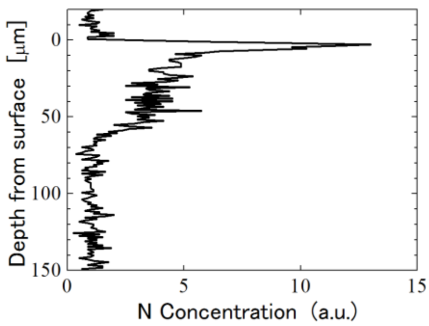

Figure 2 Depth profile of nitrogen concentration.

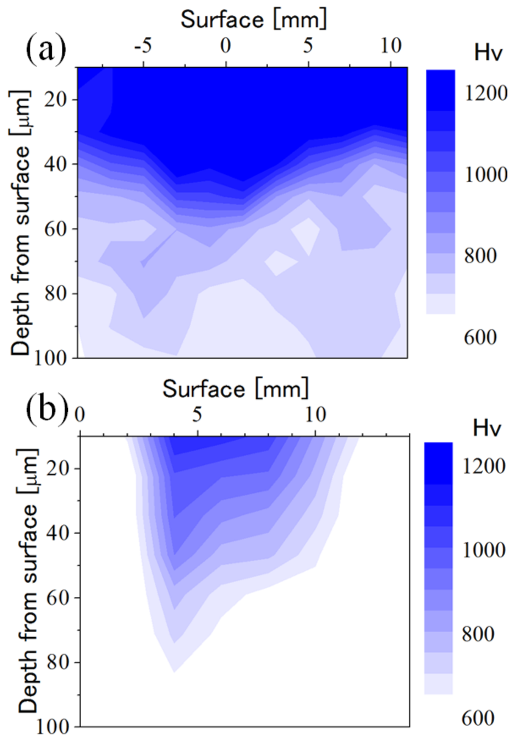

Figure 3 Hardness profile of sample cross-section treated by (a) PA jet. (b) DBD.

shown in Fig. 3(a). The nitrogen diffusion increases the steel hardness from 600 to 1200 Hv. The optical emission spectroscopy implies that the creation of NH radicals occurs in the jet plume [1].

On the other hand, Fig. 3(b) shows the hardness profile of the steel cross-section treated by N_2-based DBD [4]. Compared to Fig. 3(a), we can find several different characteristics such as the treated area. In the conference, we discuss the physics of the difference and suggest new application of DBD nitriding related to the difference.

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