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# Demonstration of Bright Nitriding for Steel with Pulsed-Arc Plasma Jet

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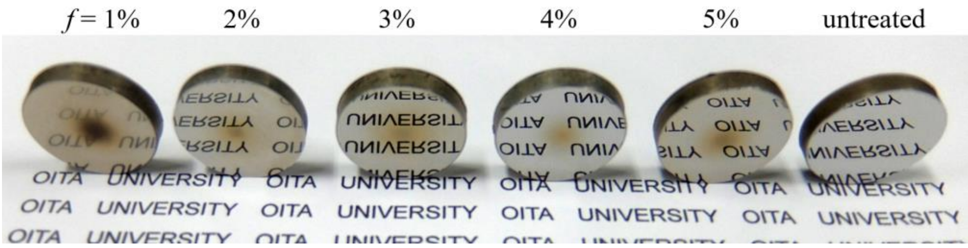


Fig. 1 Appearance of nitrided steel surfaces for several hydrogen fractions *f*.

Plasma nitriding treatment for steels is widely used in industry to increase the surface hardness. We have developed an original nitriding technique.in which the atmospheric-pressure plasma jet is utilized instead of low-pressure plasmas. However, the technique had suffered the issue that the treated surface becomes rough owing to the formation of the compound (iron nitride) layer in the outermost surface. Here we report the first achievement of the “bright nitriding,” namely the nitriding without forming the compound layer maintaining the original surface luster.

The experiment is performed using the pulsed-arc plasma jet, the operating gas of which is the mixture of nitrogen and hydrogen gas [1]. The jet plume is sprayed onto the steel sample (JIS SKD61, 20 mm in diameter) to dope nitrogen atoms for 2 h. The sample is heated up by the plume itself to ca. 800 K. The treatment is operated in a cylindrical cover to purge residual air.

Here the non-formation of the compound layer is attempted by increasing *f*, the fraction of hydrogen in the operating gas, from the original value of 1% to more values for the following reason. We have observed that the emission spectral intensity of NH radicals decreases in the plume with increasing *f* somehow [1]. This suggests the possibility that the increase in *f* tends to decrease the density of NH which is considered to govern nitriding [2]. We expected that the decrease in NH density leads to non-formation of the compound layer.

Fig. 1 shows the photograph of treated samples. Every sample surface exhibits the central dark spot and the peripheral lustrous area. As for the latter, the metallic luster seems to become clearer with *f*. Fig. 2 shows the optical reflectance of the lustrous area. The reflectance obviously increases with *f* from 1 to 4%. Fig. 3 shows the surface roughness of the sample surface. The roughness monotonically decreases with *f* from 1 to 4%, being consistent to the trend of Fig 2. Note that XRD analysis reveals that the compound layer exists for *f* = 1%, but it becomes undetectable for more *f*. From these facts, we conclude that the lustrous area has been successfully bright-nitrided [3]. This is the first achievement of the bright nitriding by the use of an atmospheric-pressure plasma.

In the conference, we also discuss the central dark spot.

References
[1] H. Nagamatsu, R. Ichiki *et al.*, Surf. Coat. Technol. **225**, 26 (2013).
[2] R. Ichiki *et al.*, Metals **9**, 714 (2019).
[3] K. Toda, R. Ichiki *et al.*, Jpn. J. Appl. Phys. **59**, SHHE01 (2020).

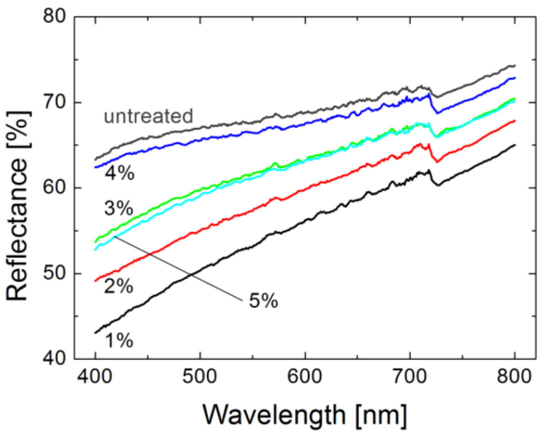


Fig. 2 Optical reflectance of the lustrous area.

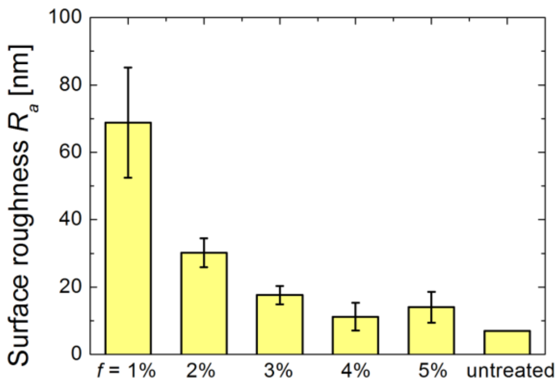


Fig. 3 Surface roughness for several *f*.