

## Accepted Manuscript

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PII: S0257-8972(17)30933-7  
DOI: doi:[10.1016/j.surfcoat.2017.09.031](https://doi.org/10.1016/j.surfcoat.2017.09.031)  
Reference: SCT 22685  
To appear in: *Surface & Coatings Technology*  
Received date: 12 May 2017  
Revised date: 12 September 2017  
Accepted date: 13 September 2017

Please cite this article as: Yinying Sheng, Zhiguo Zhang, Wei Li , Effects of pulse frequency and duty cycle on the plasma discharge characteristics and surface microstructure of carbon steel by plasma electrolytic nitrocarburizing. The address for the corresponding author was captured as affiliation for all authors. Please check if appropriate. Sct(2017), doi:[10.1016/j.surfcoat.2017.09.031](https://doi.org/10.1016/j.surfcoat.2017.09.031)

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**Effects of pulse frequency and duty cycle on the plasma discharge characteristics and surface microstructure of carbon steel by plasma electrolytic nitrocarburizing**

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**ABSTRACT**

A plasma electrolytic nitrocarburizing (PEN/C) process was used to produce a protective coating on the surface of 45# carbon steel under a pulsed direct current power mode in a urea electrolyte. The effects of pulse frequency and duty cycle on the microdischarge characteristics and coating microstructure were investigated. The results show that the pulse frequency has a small effect on the breakdown voltage. However, the micropore size in the formed worm-like feature of the sample surface increases with increasing pulse frequency. Carbide, nitride and oxide phases were identified in the PEN/C layers. The microhardness increases with increasing pulse frequency. Increasing duty cycle results in a gradual decrease of the breakdown voltage. At low duty cycles, both crater-shaped regions and worm-like features were observed. However, the microhardness of the formed PEN/C layers exhibits a minute variation, in spite of the increase of the duty cycle.

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