TiN and WC Coatings Prepared by Pulsed High Energy Density Plasma[1]

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Abstract – Titanium Nitride and Tungsten Carbon coatings are deposited on the 0.45% C carbon steel substrate by pulsed high energy density plasma (PHEDP). The microstructure and composition of the films is measured by the XPS, XRD and SEM analysis, and the microhardness and wear resistance of the films are also tested. The results show that the coatings prepared by PHEDP under certain conditions have higher hardness and lower friction coefficient.

1. Introduction

TiN and WC have been widely used to improve the performance and extend the life of materials such as cutting tools, moulds, and so on. The still existing problems in materials surface coating are low deposition rate and low adhesive strength between the substrate and coatings [1, 2].

In this paper, a new technique called pulsed high energy density plasma (PHEDP) is introduced to prepare TiN and WC coatings [3].

2. Experimental Method

The experimental equipment for the PHEDP system is schematically shown in Fig. 1. It includes three sections: the fast pulsed magnetic-valve, which is characterized by the working gas pressure (p) and the applied voltage (V_{puff}); the pulsed plasma gun, within which the most important parameter is the discharging voltage between the outer and inner electrodes (V_{gun}); the vacuum reaction chamber, within which the chamber pressure, the sample temperature, and the distance between the sample and the coaxial pulsed plasma gun (d) are the most important parameters determining the coating properties. For more details, see Refs. [4, 5]. During the coating process, when a voltage of about several kVs is applied, a discharge is initiated between the inner and outer electrodes of the pulsed plasma gun, which can produce plasma consisted of active gas particles and the electrode materials. The produced plasma can be accelerated to a high translation speed of 10–50 km/s by the Lorents-force J×B.

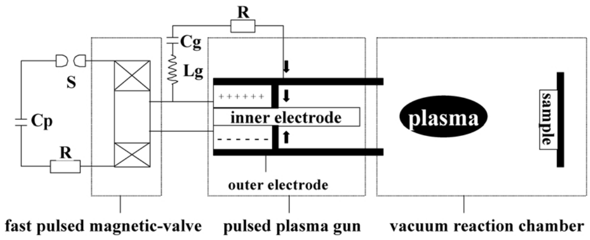

Fig. 1. A schematic diagram of the PHEDP system

The speed of the plasma depends mainly on the discharging voltages. The plasma ejected from the coaxial plasma gun will bombard the sample surface and some special reactions may occur there [4, 5].

3. Experimental Results and Analysis

The plasma parameters were detected and analyzed by a double Langmuir probe and GE-100 optical grating spectroscopy, and the plasma parameters of the coaxial plasma gun are as follows: the electron density is $10^{14} \sim 10^{16}$ cm^{-3}, the electron temperature is $10^5 \sim 10^6$ K, the power density is $10^5 \sim 10^7$ Wcm^{-2}, the pulse width is 60 μs, and the pulse frequency is 10^{-2} Hz.

Initially, TiN coating was deposited on the 0.45% C carbon steel substrate. Both the outer and inner electrodes are made of Titanium, and nitrogen with a concentration of more than 99.9 at.% was used as working gas.

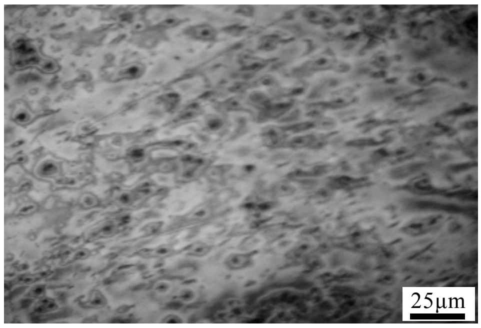

Fig. 2. The SEM images of the TiN films deposited on the 0.45% C carbon steel substrate by PHEDP. Experimental conditions: V_{gun} = 3.2 kV, N_{pulse} = 10

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Experimental conditions for the TiN coating process are as follows: the discharge voltage is 1.0 ~ 3.5 kV, the applied voltage V_{puff} is 1.5 kV, the working nitrogen gas pressure is 2.0 kg/cm^2, the gap distance between the sample and the coaxial pulsed plasma gun d is 30 mm, the gas pressure in the chamber is 10^{-3} Pa, and the sample temperature is at room temperature. The obtained results are presented in Figs. 2–8.

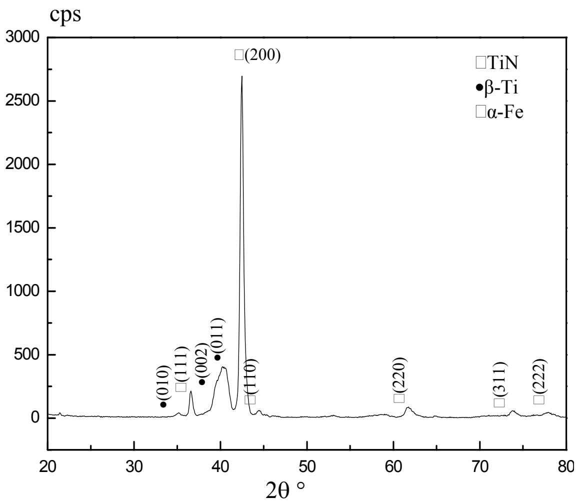

Fig. 3. The XRD spectrum of the films deposited on the 0.45% C carbon steel substrate by PHEDP. Experimental conditions: V_{gun} = 3.2kV, N_{pulse} = 10

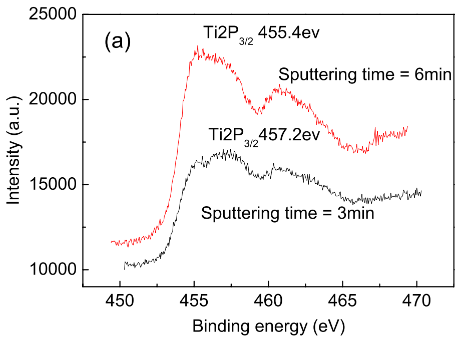

Fig. 4. The XPS spectrum of the films deposited on the 0.45% C carbon steel substrate by PHEDP. Experimental conditions: V_{gun} = 3.2 kV, N_{pulse} = 10

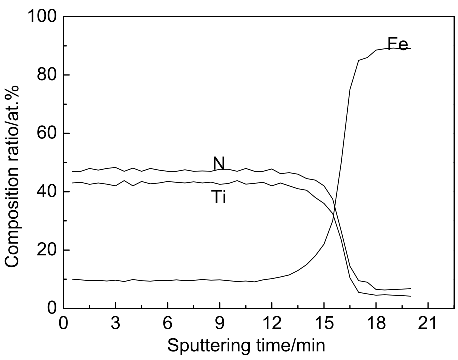

Fig. 5. Elemental AES distribution of film on the 0.45% C carbon steel substrate by PHEDP. Experimental conditions: V_{gun} = 3.2kV, N_{pulse} = 10

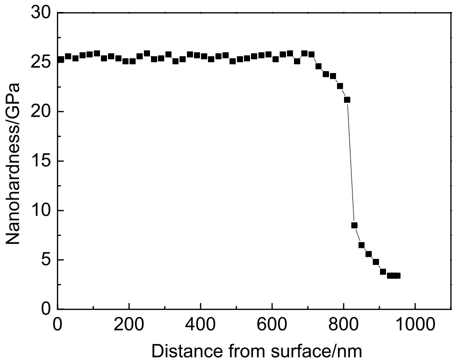

Fig. 6. The nanohardness profile of the TiN film deposited on the 0.45% C carbon steel substrate by PHEDP. Experimental conditions: V_{gun} =3.2 kV, N_{pulse} = 10

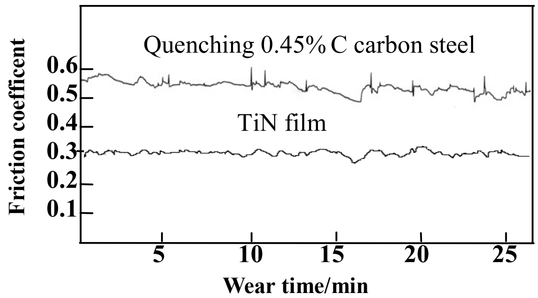

Fig. 7. The friction coefficient profile of the TiN films deposited on the 0.45% C carbon steel substrate by PHEDP. Experimental conditions: V_{gun} = 3.2kV, N_{pulse} = 10

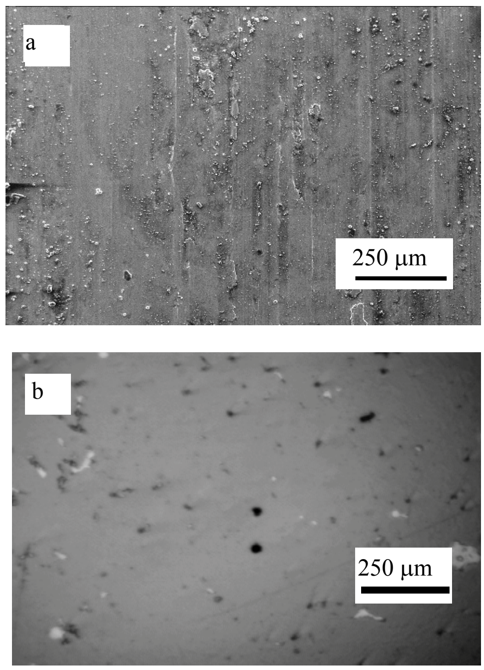

Fig. 8. The wear morphology of the TiN films deposited on the 0.45% C carbon steel substrate by PHEDP. Experimental conditions: V_{gun} = 3.2kV, N_{pulse} = 10

Next, we deposit WC on the 0.45% carbon steel substrate, the outer electrode is made of graphite and the inner electrodes are made of Tungsten, and the working gas is argon. Our obtained results are presented in Figs. 9–11.

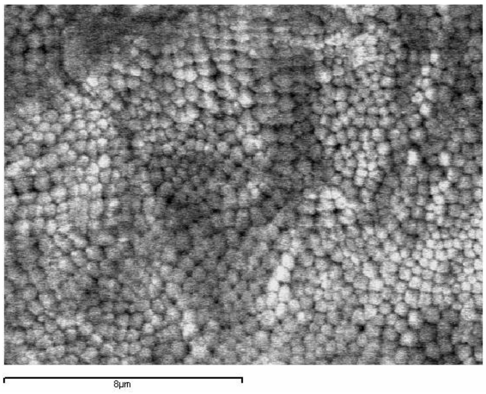

Fig. 9. The SEM images of the WC films deposited on the 0.45% C carbon steel substrate by PHEDP. Experimental conditions: V_{gun} = 3.2kV, N_{pulse} = 5

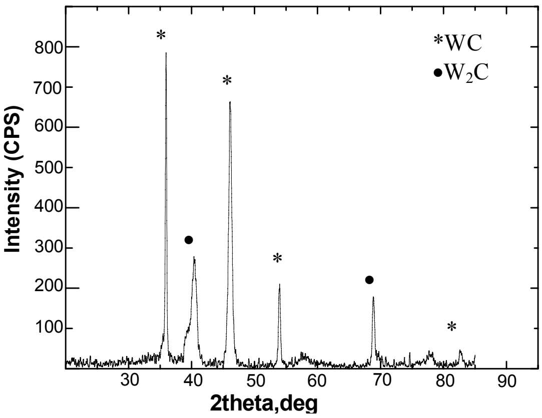

Fig. 10. The XPS spectrum of the WC films deposited on the 0.45% C carbon steel substrate by PHEDP. Experimental conditions: V_{gun} = 3.2kV, N_{pulse} = 5

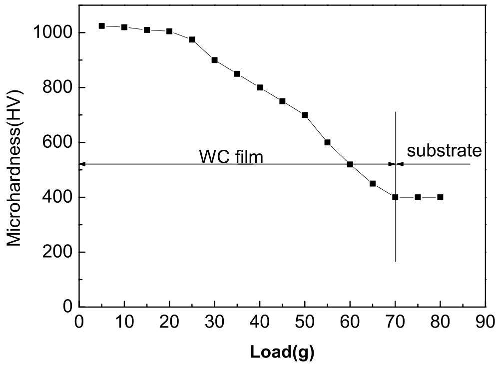

Fig. 11. The microhardness of the WC films deposited on the 0.45% C carbon steel substrate by PHEDP. Experimental conditions: V_{gun} = 3.2kV, N_{pulse} = 5

4. Conclusions

TiN and WC coatings have been successfully deposited on the 0.45% C carbon steel substrate by the PHEDP system in our laboratory. Studies show that the films have high hardness and excellent wear resistance, which can demonstrate the superiority of the PHEDP system for materials surface coating.

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