Mechanics Capability and Structure of Ion Nitrocarburized Layer of 42MnCr52 Steel

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Abstract. The ion nitrocarburized layer was prepared on the surface of 42MnCr52 steel sample by using the ion nitrocarburizing process. The nitrocarbonide grains and holes all in smaller scale distribute equably. The nitrocarbonide surface layer is about 18 μm in thickness. The ion nitrocarburized layer is composed mainly of Fe_3N that is the key composition of ε phase, which can insure the excellent hardness and toughness of the ion nitrocarburized layer. The bonding strength and stress analysis show that the nitrocarbonide surface layer and its diffusing layer of ion nitrocarburized layer all possess higher bonding strength, which may avoid the ion nitrocarburized layer to flake off during friction process.

Introduction

42MnCr52 steel is often used to produce engine cylinder. Now the intermediate frequency quenched technology is used to prove the wear resistance and scuffing resistance of the cylinder wall, but the effect is not good. Ion nitrocarburizing is the technics that carries through adding the carbonaceous medium on the base of ion nitriding technics. N atom and C atom form the nitrocarbonide layer that the key phase is ε phase and possesses high hardness and excellent wear resistance and scuffing resistance, which may prove obviously the fatigue intensity and carrying capacity of the materials.[1-3] Ion nitrocarburizing technics is the same with treat with alloy steel, stainless steel, alloy cast iron and so on.[4-10] The paper studied the mechanics capability, mophology and structure of ion nitrocarburized layer of 42MnCr52 steel, which is propitious to study ulteriorly the tribological performance of ion nitrocarburized layer of 42MnCr52 steel.

Experimental

The ion nitrocarburized layer were prepared on the surface of 42MnCr52 steel samples with ϕ 24×7.9 mm in the high frequency pulsed plasma diffusing equipment, and the key technics parameters were as follows, work frequency 20000 Hz, work voltage 700 V, work temperature 550°C, heat preservation time 5 h.

The morphology and composition of the ion nitrocarburized layer were examined by using Quanta 200 FEG field emission scanning electron microscope (SEM) and GENESIS energy dispersive X-ray spectroscopy (EDS). The phase structure of the ion nitrocarburized layer was analysed by using a D8ADVANCE type X-ray diffractometer (XRD), and the key analysing parameters were as follows, Cu target, work voltage 40 kV, work current 100 mA, diffraction angle from 20° to 90°. XPS analysis of the ion nitrocarburized layer was performed by using a Axis Ultra X-ray photoelectron spectrometer, and the key analysing parameters were as follows, Al anode target, energy resolution 0.440 eV. AES analysis of the ion nitrocarburized layer was performed by using a PHI-700 type nano scanning auger equipment, and the key analysing parameters were as follows, high voltage of the electron gun 10 kV, energy resolution 1‰, an angle of incidence 30°, vacuity of the analysis room no less than 3.9×10^{-9} Torr. The sputtering condition include sweep-type

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Ar^+ gun, thermal oxidation standard sample SiO_2/Si, sputtering speed 115 nm/min.

The bonding strength of the ion nitrocarburized layer was surveyed and evaluated by using a Nano Test 600 type nano scarificator through using critical load measured when the scratch awl cut through the ion nitrocarburized layer under continuous loading as evaluation standard. The stress analysis of he ion nitrocarburized layer was completed by using a X-350A type X-ray stress determinator.

Results and Discussion

Morphologies, Compositions and Structure. The surface morphology of the ion nitrocarburized layer is shown in Figure 1. It can be seen that the ion nitrocarburized layer has loose structure, and the nitrocarbonide grains pile layer upon layer, in which exists many fine holes with dimension in micron nano scale.

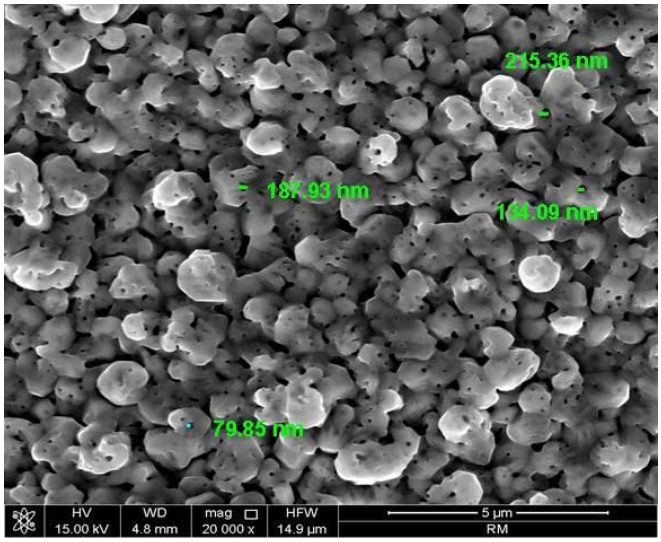
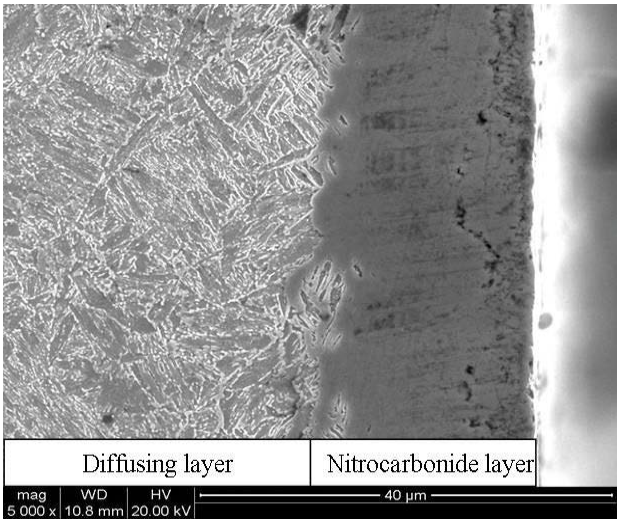
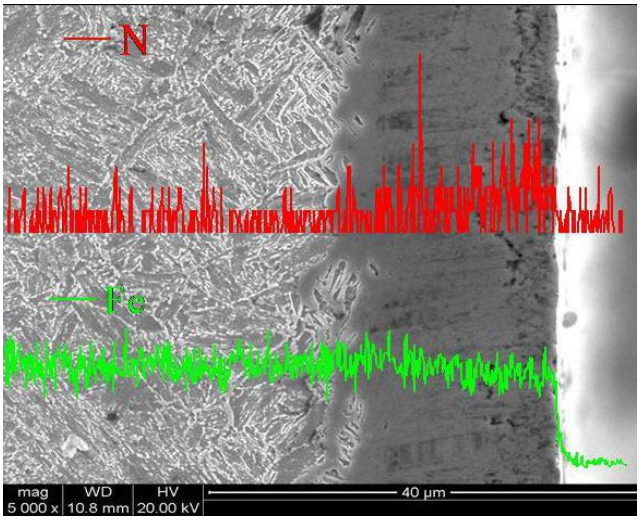


Fig.1 Surface morphology of ion nitrocarburized layer

The cross-section morphology and line scanning analysis of N element and Fe element of the ion nitrocarburized layer is shown in Figure 2. It can be seen that the nitrocarbonide surface layer is 18 μm in thickness, and the line scanning analysis shows that the nitrocarbonide surface layer comprises much N element and exists a diffusing layer that has no cracks and combines with the substrate well.



(a) cross-section morphology



(b) line scanning of Fe and N elements

Fig.2 Cross-section morphology and line scanning of the elements of ion nitrocarburized layer

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Figure 3 shows that the ion nitrocarburized layer comprises N element, C element, Fe element, and so on, thereinto, the contents of N element and C element are much more than other elements, which explains that there formed the thicker nitrocarbonide layer in the ion nitrocarbunized layer.

Figure 4 shows the XRD pattern of the ion nitrocarburized layer. We can see that the ion nitrocarburized layer is composed mostly of Fe_3N that is the key composition of ε phase, which can ensure the ion nitrocarburized layer has higher hardness and toughness.

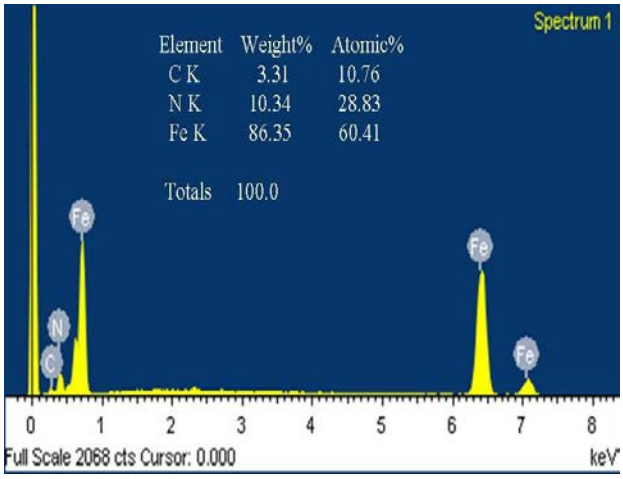

Fig.3 Composition analysis of ion nitrocarburized layer

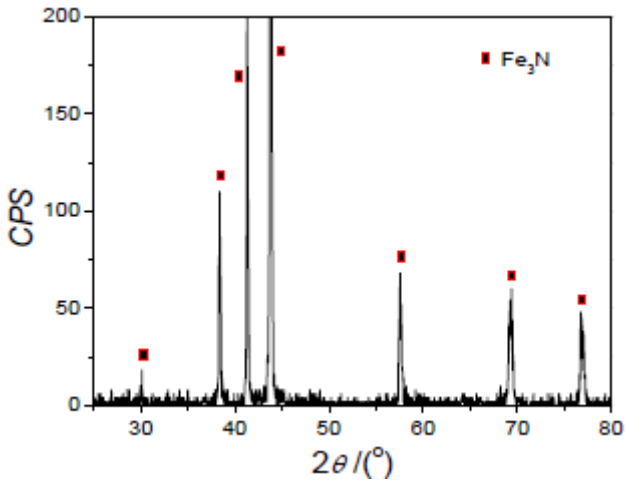

Fig.4 XRD pattern of the ion nitrocarburized layer

Figure 5 shows the XPS full spectrum of the ion nitrocarburized layer. It can be seen that the ion nitrocarburized layer contains Fe, N, O, C elements and so on. Moreover, the peaks of C element and O element weaken obviously, and the peaks of Fe element and N element rise obviously, which explains that the key compositions of the ion nitrocarburized layer are Fe element and N element.

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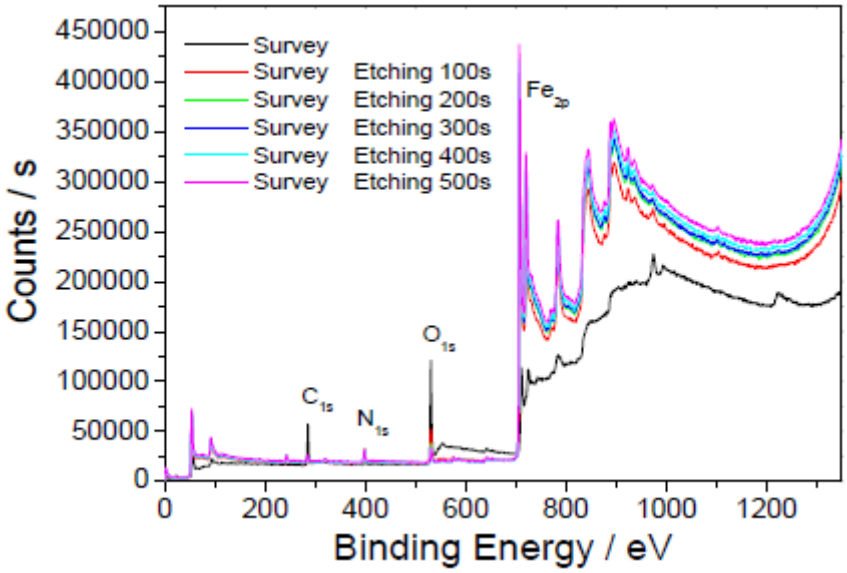

Fig.5 XPS full spectrum of ion nitrocarburized layer

Figure 6 shows the XPS patterns of $Fe_{2p,}$ N_{1s}, C_{1s} and O_{1s} of the ion nitrocarburized layer. It can be found that the binding energy of Fe_{2p} at 710.7 eV corresponds to oxide of ferrous that is Fe_2O_3, which explains that the surface of the ion nitrocarburized layer is oxidized. After sputtering from 100 s to 500 s, respectively, the peak of Fe_{2p} rise obviously, and the binding energy of Fe_{2p} at 706.8 eV corresponds to nitride of ferrous that is Fe(2/3/4)N. The binding energy of N_{1s} at 396.9 eV is close to the standard binding energy that is 397.3 eV, which corresponds to nitride of ferrous that is Fe(2/3/4)N. Moreover, after sputtering from 100 s to 500 s, respectively, the peak of N_{1s} rise obviously, which explains that there is much more nitride within the ion nitrocarburized layer. The binding energy of C_{1s} at 284.4 eV corresponds to elemental carbon, which explains that the surface of the ion nitrocarburized layer exists carbon pollution. After sputtering from 100 s to 500 s, respectively, the binding energy of C_{1s} at 282.7 eV corresponds to carbide. The binding energy of O_{1s} at 529.3 eV corresponds to Fe_2O_3, which explains that the surface of the ion nitrocarburized layer is oxidized. After sputtering from 100 s to 500 s, respectively, the peak of O_{1s} weaken gradually, which reveals that the oxide within the ion nitrocarburized layer decreased gradually.

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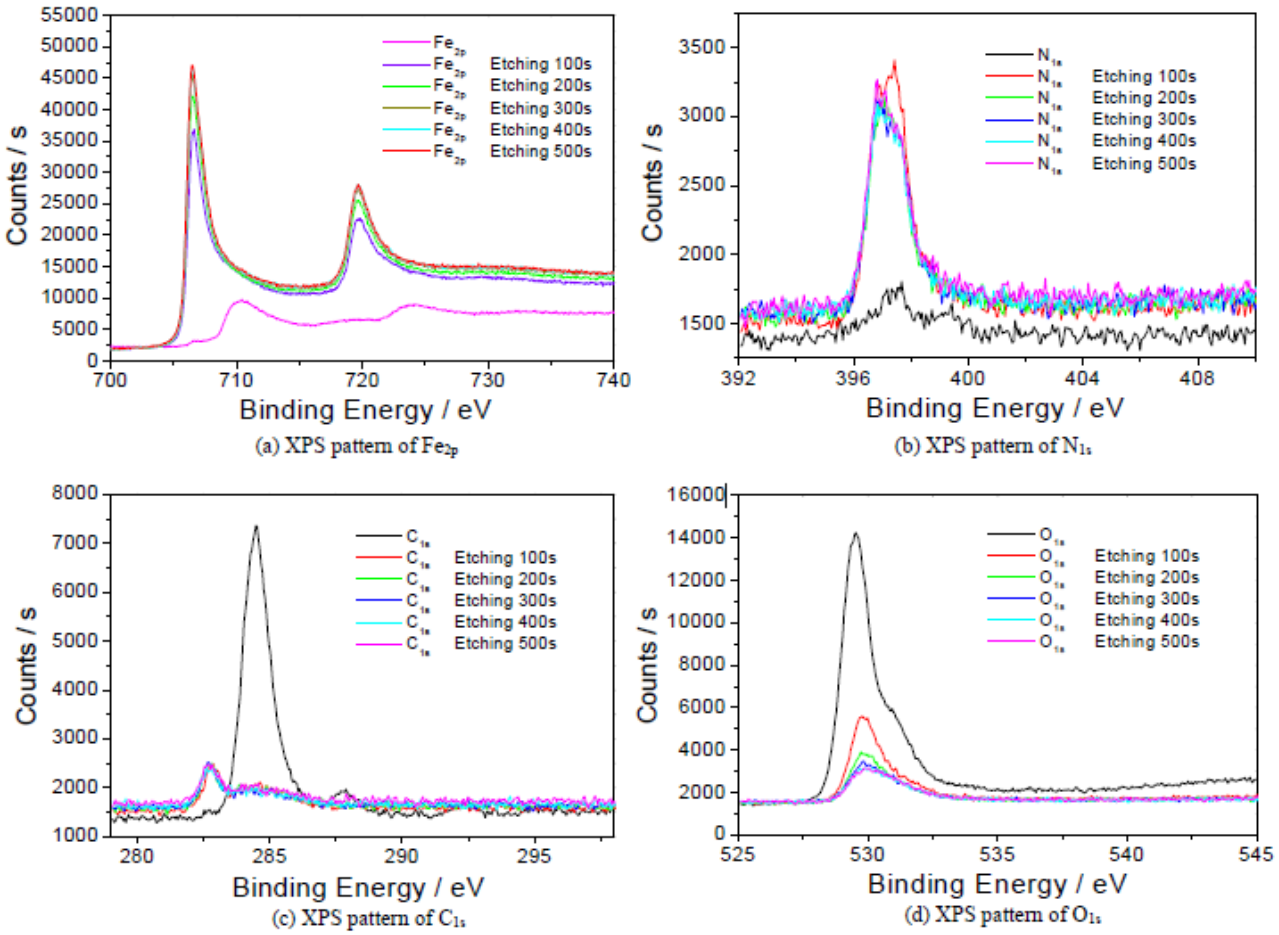

Fig.6 XPS patterns of the elements of ion nitrocarburized layer

Mechanical Property. The bonding strength of the ion nitrocarburized layer was surveyed and evaluated by using a nano scarificator. Figure 7 shows the distance-depth/distance-load testing curve. It can be seen that the scratch depth curve fluctuates obviously when the distance of the scratch awl being about 5.1 mm and the depth being about 10 μm, which illuminates that the nitrocarbonide surface layer of the ion nitrocarburized layer may be cut through, then the critical load measured to be 20.58 N is the bonding strength value between the nitrocarbonide surface layer and the ion nitrocarburized subsurface layer.

The stress of the ion nitrocarburized layer after being electrolytic polished for different depths was surveyed and evaluated by using a X-ray stress determinator. Figure 8 shows the stress grads of ion nitrocarburized layer. It can be found that the stresses of the ion nitrocarburized layer are all compressive stresses after being electrolytic polished for 0 μm, 1 μm, 11 μm, 21 μm, 71 μm, 161 μm, 211 μm , respectively, which explians that the bonding strength of the nitrocarbonide surface layer and its diffusing layer of the ion nitrocarburized layer are all higher, and tests and verifies further that the bonding strength between the nitrocarbonide surface layer and the ion nitrocarburized subsurface layer of the ion nitrocarburized layer is higher, so that to eliminate the bed separation of the ion nitrocarburized layer during friction process.

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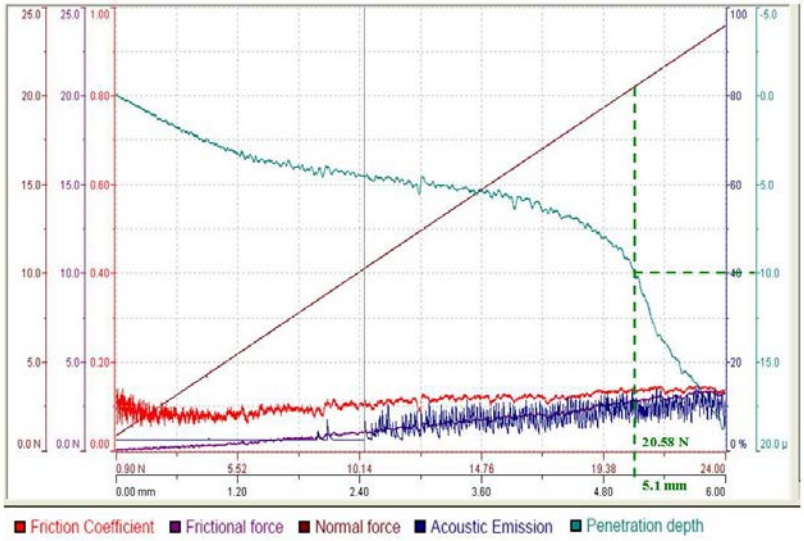

Fig.7 Distance-depth/distance-load curve

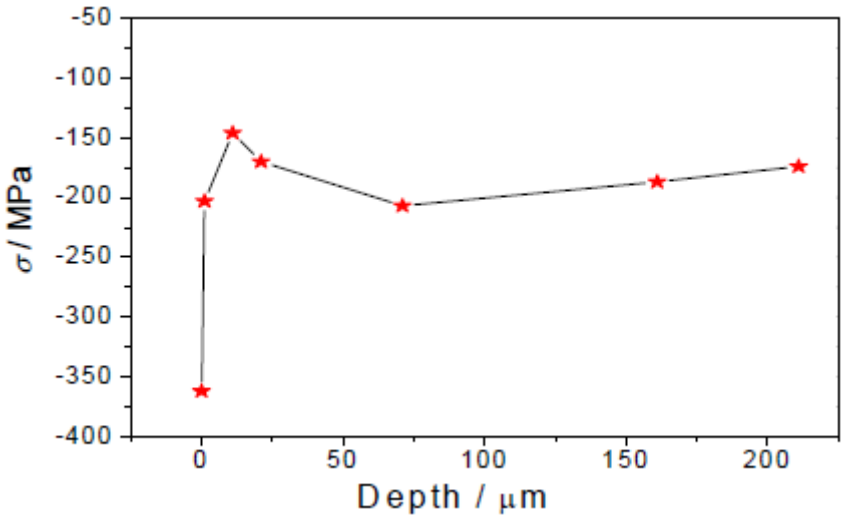

Fig.8 Stress grads of the ion nitrocarburized layer

Conclusions

a. The ion nitrocarburized layer having loose structure was prepared on the surface of 42MnCr52 steel sample by using the ion nitrocarburizing process. The nitrocarbonide grains and holes all in smaller scale distribute equably. And the nitrocarbonide surface layer is about 18 μm in thickness, and contains much more N element and Fe element. The ion nitrocarburized layer is composed mainly of Fe_3N that is the key composition of ε phase, which can insure the excellent hardness and toughness of the ion nitrocarburized layer.

b. The bonding strength and stress analysis show that the nitrocarbonide surface layer and its diffusing layer of ion nitrocarburized layer all possess higher bonding strength, which may avoid the ion nitrocarburized layer to flake off during friction process.

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