Rare Metal Materials and Engineering
Volume 46, Issue 6, June 2017
Online English edition of the Chinese language journal

Available online at www.sciencedirect.com
ScienceDirect

Cite this article as: Rare Metal Materials and Engineering, 2017, 46(6): 1503-1507.

ARTICLE

Hydrogen-Free Carburization on the Surface of Commercial Purity Titanium by Equipotential Hollow-Cathode Glow Discharge

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Abstract: The treatment of hydrogen-free carburization was applied on commercial purity titanium by the technology of equipotential hollow-cathode glow discharge at the commercial purity titanium phase transition temperature. The morphology, distribution of composition and phase composition were analyzed by the scanning electron microscope, the energy dispersive spectrometer, the X-ray diffraction, respectively; the tribology capability of the sample was studied by the friction and wear tester; the corrosion resistance of the samples in 3.5% NaCl solution was studied under the room temperature static condition by the electrochemical workstation. The results show that the high hardness alloy layer forms on the commercial purity titanium surface by the treatment of hydrogen-free carburization, and the maximum thickness of the carburized layer is 7.5 μm; and the maximum $HV_{0.2}$ hardness is 12.98 GPa, which is 5.43 times of that of the substrate. Due to the improved surface hardness, the wear resistance on the surface of the sample increases significantly, and the average friction coefficient is only 0.312, which obviously decreases compared with 0.746 of the original sample. The minimum annual corrosion rate of the samples is 1/11 of the original sample in 3.5% NaCl solution. So the wear resistance and corrosion resistance obviously improve in the premise of keeping the mechanical properties of the substrate.

Key words: commercial purity titanium; equipotential hollow-cathode glow discharge; hydrogen-free carburization; wear resistance; corrosion resistance

Commercial purity titanium possesses low hardness and poor wear resistance, which restricts its application in aerospace, petrochemical, power and other daily necessities in industry[1-4]. Improving the surface hardness of commercial purity titanium is a necessary way to enhance its wear resistance[5-7]. Surface modification technology is widely used[8-10], and the technology of hydrogen-free carburization is an effective method to enhance the titanium surface hardness[11]. Hydrogen-free carburization technology puts carbon element into the surface of the titanium, forming alloy layer to improve the surface property of the workpiece. And this method avoids hydrogen embrittlement of titanium[12,13]. The technology has achieved good results that the hydrogen-free carburization layer on the surface of Ti6Al4V alloy prepared by plasma glow discharge surface metallurgy improves its wear resistance and corrosion resistance[14]. Usually the temperature of the surface treatment by plasma glow discharge is high, and it is above the temperature of phase transition, which has a certain impact on the mechanical properties and size of the workpiece. In the present paper, the equipotential hollow cathode glow discharge technique by a special structure of the graphite source pole is used for the hydrogen-free carburization on the surface of commercial purity titanium below the phase transition temperature, which can not only

Received date: May 13, 2016
Foundation item: Beijing Institute of Petrochemical Technology Breeding Project of Outstanding Academic Leaders (BIPT-BPOAL-2013)
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improve the surface physical and chemical properties but also maintain the good comprehensive mechanical performance of the substrate.

1 Experiment

It makes the argon ionize, resulting in the production of Ar^+ and that bombard workpiece surface at low vacuum condition using the equipotential hollow cathode glow discharge technology. The acicular source and the cover bodies are made of graphite, and the multilayer covers can stabilize the carburizing atmosphere and increase the carbon concentration. Using the effect of equipotential hollow-cathode between the acicular sources, the carbon element of the source can be sputtered to the workpiece's surface. The composition and microstructure were changed when the Ar^+ bombard the workpiece's surface. Therefore the workpiece's surface can be activated, leading to the adsorption and diffusion of the carbon elements. Ultimately the workpiece's surface became the deposited layer and carburized layer. Fig.1 is the device schematic which is the schematic of equipotential hollow cathode plasma glow discharge surface alloying.

Table 1 shows the process parameters of the samples. The hydrogen-free carburization treatment was applied on commercial pure titanium TA1 by the technology of equipotential hollow cathode glow discharge. The time is from 3 to 5 h, the temperature is from 750 to 800 ºC, the working voltage is from 550 to 660 V and the current is from 3.0 to 5.0 A. The duty cycle of the power is 35% and the gas flow is 100 cm^3/min, the air pressure is 35 Pa. Fig.2 is the discharging phenomenon.

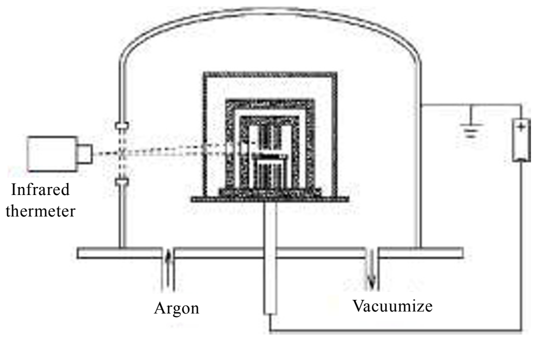

Fig.1 Schematic of equipotential hollow cathode plasma glow discharge surface alloying

Table 1 Processing parameters of each sample (No.1 is the original sample)

No.	1	2	3	4	5	6	7
Temperature/℃	-	750	750	750	800	800	800
Time/h	-	3	4	5	3	4	5

Fig.2 Phenomenon of hydrogen-free carburization by equipotential hollow-cathode glow discharge

The microstructure of the surface and the cross-section, and the composition distribution of the cross-section of the carburized layer and the wear trace on the surface were studied by SSX-550 scanning electron microscope; the phase composition of the carburized layer was studied by D8 FOCUS X-ray diffraction; the microhardness of sample was tested by HMV-1T microhardness tester; the electrochemical corrosion experiment was analyzed by CS360 electrochemical workstation; the rotating friction test was studied by the MS-T3000 friction and wear tester. The followings are the friction processing parameters: the material of the pressure head for the experiment is GCr15, the hardness is 62 HRC, the environment temperature is 25 ºC, the relative humidity is 35%, the load is 1.96 N, the experimental time is 10 min, the rotating speed of the sample stage is 500 r/min and the radius of grinding crack is 4 mm.

2 Results and Discussion

2.1 Microstructure and phase composition of carburized layer

Fig.3 shows the cross-section morphology of sample 7. The thickness of the carburized layer is about 7.5 μm. During the process of hydrogen-free carburization, the specimen's surface adsorbs carbon elements which are sputtered from the carbon source pole and the surface carbon concentration gradually increases and the elements diffuse inside gradually, and the carburized layer forms. The speed of the carbon depositing on titanium surface is larger than that of carbon from the surface of titanium penetrating the interior, eventually which forms a layer of the carbon deposition.

Fig.4 shows the results of EDS line analysis of the carburized cross-section. The carbon element content is the gradient distribution on the carburized cross-section of commercial purity titanium after hydrogen-free carburization treatment. The content of the carbon element is the highest in the surface, and the content of carbon element of