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Wettability Modification for Biosurface of Titanium Alloy by Means of Sequential Carburization

Yong Luo[1,2], Shi-rong Ge[1], Zhong-min Jin[2]

1. *Institute of Tribology and Reliability Engineering*, *School of Material Science and Engineering*, *China University of Mining and Technology*, *Xuzhou* 221008, *P. R China*
2. *Institute of Medical and Biological Engineering*, *School of Mechanical Engineering*, *University of Leeds*, *Leeds LS*2 9*JT*, *UK*

Abstract

Microporous titanium carbide coating was successfully synthesized on medical grade titanium alloy by using sequential carburization. Changes in the surface morphology of titanium alloy occasioned by sequential carburization were characterized and the wettability characteristics were quantified. Furthermore, the dispersion forces were calculated and discussed. The results indicate that sequential carburization is an effective way to modify the wettability of titanium alloy. After the carburization the surface dispersion force of titanium alloy increased from 76.5×10^{-3} J·m^{-2} to 105.5×10^{-3} J·m^{-2}, with an enhancement of 37.9 %. Meanwhile the contact angle of titanium alloy decreased from 83˚ to 71.5˚, indicating a significant improvement of wettability, which is much closer to the optimal water contact angle for cell adhesion of 70˚.

Keywords: biotribology, wettability, titanium alloy, sequential carburization, biosurface

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1 Introduction

As load-bearing joint replacements, metals are still an alternative material due to their good elasticity and wear resistance[1]. Stainless steel, cobalt-based alloys and Ti-based alloys are the most commonly used metallic materials in orthopaedic implants[2–4]. Despite the recognized success and worldwide acceptance of total joint replacement, the number of failures increases after 15 to 20 years[5]. It cannot be denied, however, that complications of total replacement surgery, particularly loosening, occur frequently and that revision cases have been increasing in number year by year[6].

Nowadays, metal release from implants is considered as the most severe factor to lead to tissue reaction, including inflammatory reaction causing pain and even leading to loosening owing to osteolysis for metal-on-metal artificial joint. Unfortunately, metal ion release is widely reported in the clinical research and has caused numerous severe problems. Dobbs *et al*.[7] proved that Co concentration was higher in the blood and urine of patients wearing artificial Co-Cr-Mo alloy joints and that Cr was detected in the synovial tissues. Ichinose[8] reported that the Co-Cr-Mo alloys were unsafe because they deteriorated markedly and released Co which was deleterious to the body. Recently, Steens *et al*.[9] reported a severe accident in endoprosthetic replacement. The chronic Co in a ceramic-metal articular pairing led to almost complete loss of sight and hearing after revision of a total hip prosthesis. It was found that the concentration of Co, in particular, was remarkably high.

Surface coating technology is considered as an effective way to solve the problems due to the modification of mechanical surface properties and wear resistance of titanium alloys. In recent years, titanium carbide coatings are considered as potential biomedical materials especially in biotribology field thanks to outstanding wear resistance, high hardness, superior chemical and thermal stability and low density. It is believed that TiC coating has an ability to form strong bonds with the titanium substrate which could provide a superior hardness and wear resistance, and carbon atoms can be induced into the metal matrix to enhance the biocompatibility[10]. Therefore, forming a TiC coating on

Corresponding author: Shi-rong Ge
E-mail: gesr@cumt.edu.cn

surface of biomaterials, especially titanium alloys, has attracted significant attention due to their potential applications in biotribological field.

Furthermore, it is generally accepted that the surface wettability has a significant role on the friction behaviour of tribological system and gives an indication of its biotolerance[11,12]. However, there is no report on the wettability of TiC coating and few reports on the wettability mechanism of the TiC coating surface. In the present study, a novel sequential carburization was used to obtain microporous titanium carbide coating on medical grade titanium substrate. Then, the changes of the surface properties of titanium alloy occasioned by sequential carburization were characterized and the wettability characteristics were quantified. Furthermore, the surface tension and dispersive characteristics were calculated and discussed.

2 Experiment

Medical grade titanium alloy (Ti6Al4V) specimens, in a square shape of 15 mm × 15 mm and 5 mm in thickness, were polished to Ra < 0.05 μm, then ultrasonically cleaned in ethanol and acetone, in turn, for 30 min and inserted into a vacuum gas carburizing furnace. Prior to heating, the reaction chamber was first evacuated by a vacuum pump. Then titanium alloy specimens were carburized in the vacuum carburizing furnace and finally titanium carbide coating was formed on the surface of titanium alloys.

X-ray Diffraction (XRD) analysis was performed on D/mrx-3B, X-ray diffractometer system with Cu-Kα radiation to evaluate the crystal structure of titanium cermet femoral head. The XRD spectra were obtained by scanning in the 2θ range of 15° to 95°. Subsequently, measurement of Contact Angle (CA) was performed on a sessile drop measurement machine by using distilled water to evaluate the wetting effects of carburization, and surface tension characteristics of titanium alloy specimens were measured. Furthermore, Scanning Electron Microscopy (SEM) was used to examine the changes of the surface morphology of titanium after the carburization.

3 Results and discussion

3.1 Changes of surface morphology

Fig. 1 shows the typical XRD pattern of the as-synthesized TiC coating. All the diffraction peaks can be indexed to the cubic structure of TiC, with lattice constant of a = 4.328 Å, which is consistent with the standard value for TiC. There is no obvious peak for the substrate Ti, which indirectly indicates that a thick TiC coating with high purity, was formed during the carburization.

Fig. 2 shows the typical SEM images of the as-synthesized TiC coatings which provide further insight into the microporous TiC structure. It is found that

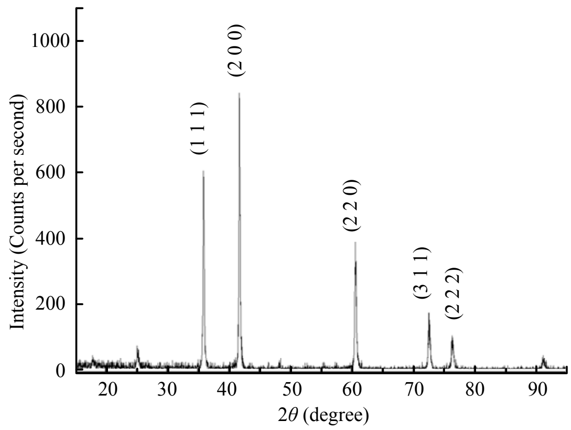

Fig. 1 The XRD pattern recorded from the TiC coating.

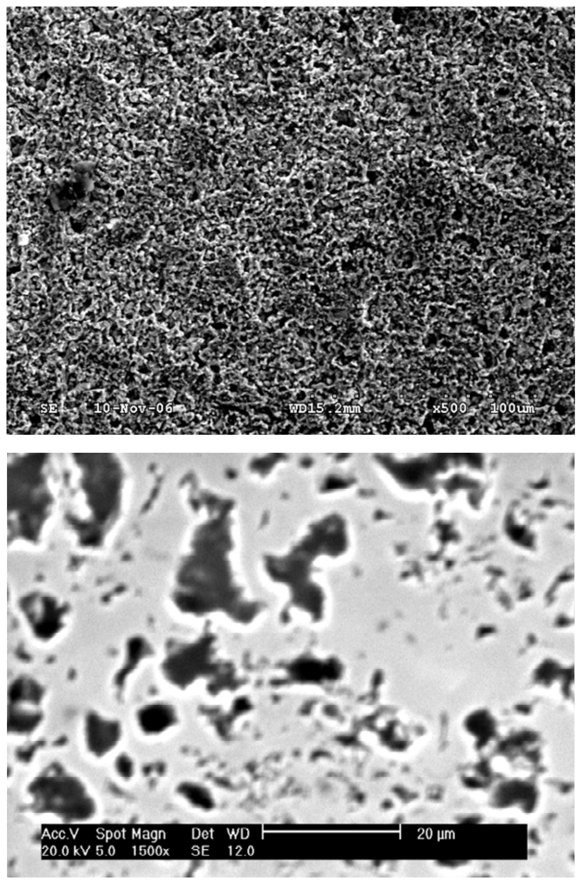

Fig. 2 Typical SEM image of the TiC coating.