Corrosion Risk Evaluation of Carbide-derived Carbon (CDC) Surface Modification for Hip Implants

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Introduction

Ti6Al4V

Good Corrosion properties

Poor tribocorrosion behavior

Early failure of total hip replacements

Surface Modification:
Carbide-derived carbon (CDC)
Excellent tribocorrosion performance[1,2]

CDC

Corrosion behavior Unknown

Objective: Investigate CDC's corrosion behaviors in comparison with the substrate alloy (Ti6Al4V).

Materials and Experiments

Two groups of experiments were designed to evaluate CDC's corrosion performances: (1) Ti6Al4V as the control group, and (2) the CDC. Each group was repeated three times (N=3). For Group (1), Ti6Al4V discs were polished until it reached a mirror finish. In Group (2), CDC was fabricated on Ti6Al4V by the electrolysis method[2]. As shown in ***Fig. 1***, a corrosion chamber with a three-electrode set up was employed.

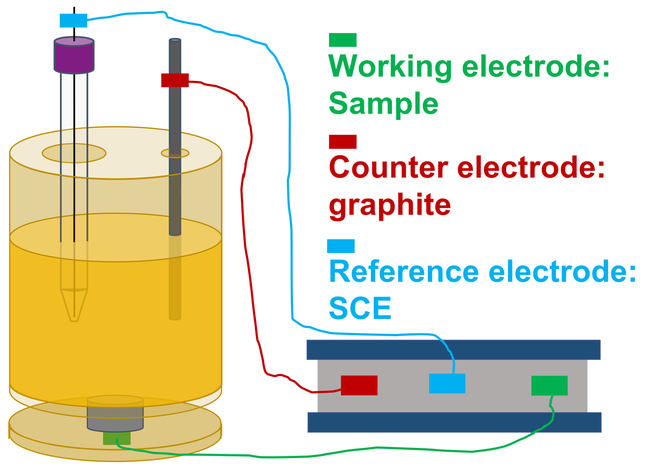

Fig.1 Schematic diagram of the corrosion system

Also, since we are aiming at the application for hip implants, bovine calf serum (BCS) was selected as the electrolyte.

OCP 1 600 s	PS	OCP 2 3600 s	EIS	CP	OCP 3 600 s

Fig.2 Electrochemical sequences for the testing.

Finally, the electrochemical protocol for the Ti6Al4V was set as open-circuit potential 1 (OCP1) for system stabilization – potentionstatic (PS) for surface cleaning) – OCP2 (stabilization) – electrochemical impedance spectroscopy (EIS) – Cyclic polarization. Same protocol without PS was followed for Group (2) to avoid damages to the CDC layer.

Results and Discussion

1. Potentiodynamic Results

- The geometric sample area exposed to the solution is 0.1256 cm^2, which was used to calculate the current density and impedance for Ti6Al4V.
- Since the prepared CDC has a rough and porous structure with a large surface area, the Brunauer-Emmett-Teller (BET) surface area of the TiC-CDC film reported by Huang et al.[3] was used to estimated our CDC area exposed to the solution, which is approximately 337.11 cm^2.
- ***Fig. 3(a)*** shows the potentialdynamic curves after adjusting the surface area. According to the Tafel equation, Ecorr and Icorr were obtained and presented in ***Fig. 3(b)*** and ***(c)***. It can be observed that the Ecorr of CDC is higher than Ti6Al4V, and the Icorr of CDC is almost four times smaller than the control group, implying that the corrosion resistance of CDC is higher than Ti6Al4V.

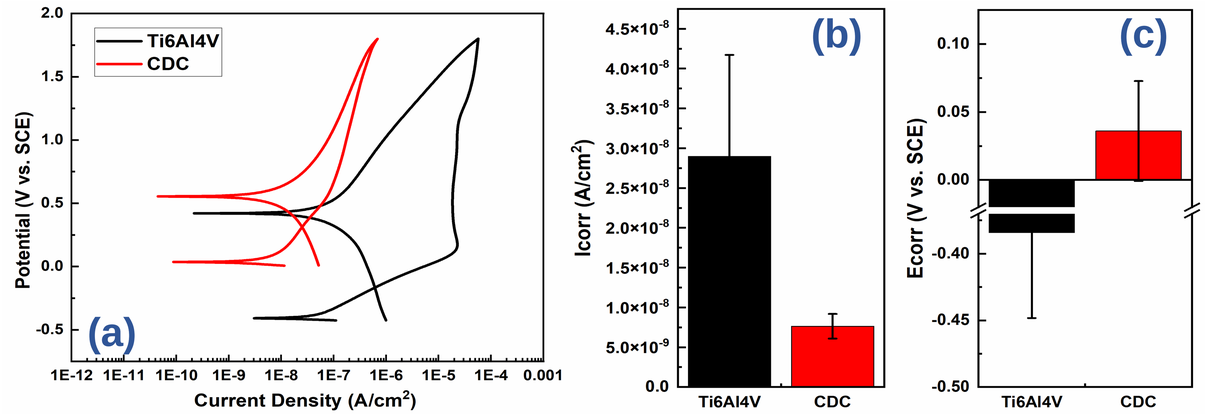

Fig.3 (a) Potentialdynamic curves (b) Icorr, and (c) Ecorr of Ti6Al4 and the CDC.

2. Electrochemical Impedance Spectroscopy (EIS) Results

Fig. 4 shows the equivalent circuits utilized to model the electrical properties. In both circuits, constant phase elements was used instead of the ideal capacitor for a better fitting. In ***Fig.4(b),*** the polarization resistor and CPE simulate the double layer on the CDC film, and the components R_{layer} and CPE_{layer} present the diffusion layer between the CDC film and the substrate.

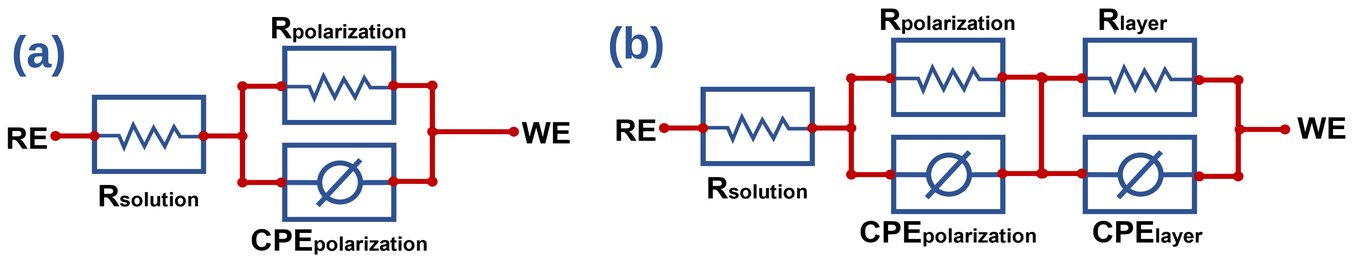

Fig.4 EIS model used for Ti6Al4V (a) and the CDC (b).

As shown in ***Fig.5***, the surface resistance of the CDC is significantly higher than that of the Ti6Al4V, which is consistent with the potentiodynamic results. Specifically, the polarization resistance of Ti6Al4V is around $1.5x10^6$ Ohms*cm^2, which is from the passive film on the surface, and the surface resistance of the CDC sample is about $2.75x10^8$ Ohms*cm^2, which may be mainly attributed to the stacked double layers on the surface.

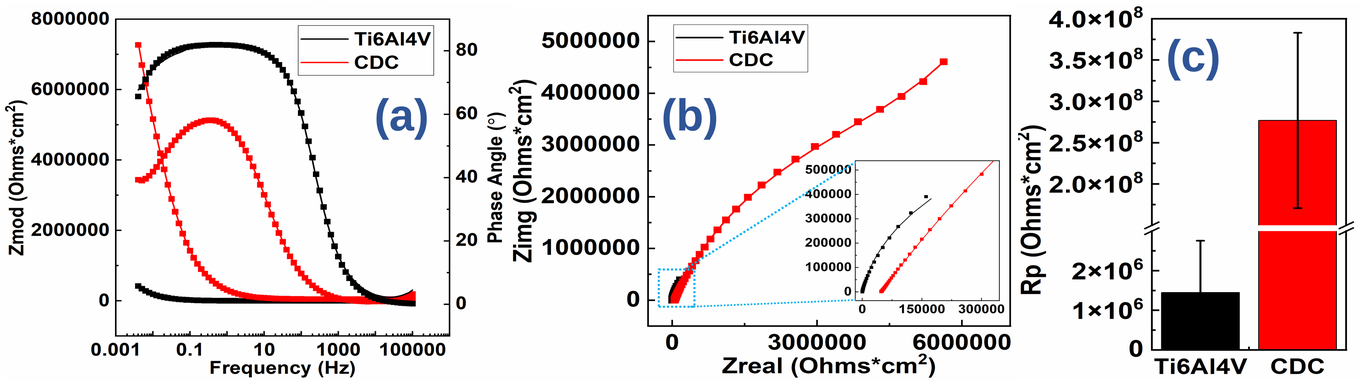

Fig.5 EIS results of Ti6Al4V and the CDC: (a) Bode plots(b) Nyquist plots, and (c) the surface resistance.

Conclusions

- The corrosion performance of the CDC was studied in comparison with Ti6Al4V.
- Since the prepared CDC is has a porous structure, the surface area was adjusted based on a precious report[3].
- According to the potentiodynamic and EIS results, the corrosion resistance of CDC is higher than Ti6Al4V.

Future Work

- ❑ The actual surface area of our CDC products is still needed, which will be achieved in the upcoming study.

Reference

1.Cheng, K et al., *Surf. Coatings Technol.* **2020**
2. Sun, Y et al., *Surf. Coatings Technol.* **2021**
3. Huang, *Science* **2015**, *3720.*

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