A design of self-generated Ti-Al-Si gradient coatings on Ti-6Al-4V alloy based on silicon concentration gradient

胡孝愿[1]，李发国[1,*]，施东明[1]，谢玉[2]，李智[1]，尹付成[1]
Xiaoyuan Hu[1], Faguo Li[1,*], Dongming Shi[1], Yu Xie[2], Zhi Li[1], Fucheng Yin[1]
1 湘潭大学Xiangtan University　2 中国宝武钢铁集团有限公司China Baowu Steel Group Corporation Limited
*Corresponding author: lifaguo@xtu.edu.cn

Introduction

Titanium alloys are widely applied on aero-engines in the aviation industry, because of their high specific strength, low density, good corrosion resistance, good formability, excellent welding performances, high machinability, etc. However, titanium and titanium alloys have poor high-temperature oxidation resistance, which limits their applications on high-temperature components.

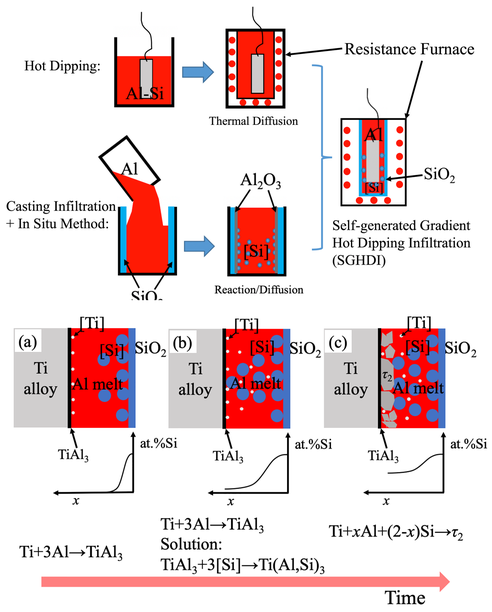
A method more effectively to improve the oxidation resistance of titanium alloys at high temperature is surface preparation coating, i.e. to prepare the coating with excellent oxidation resistance on the surface of titanium alloys. Aluminum alloy coating is used as an oxidation resistance coating. However, it has been proved that aluminum dipping on titanium alloy is easy to crack and flake off. Luckily, if silicon is added to the coating, the number of transverse cracks in the coating can be reduced. Thus, compared with the aluminum dipping layer, Al-Si layer is less brittle and not easy to flake off.

The main intermetallic compounds in Ti-Al system are Ti_3Al, TiAl, $TiAl_2$ and $TiAl_3$, among which only the $TiAl_3$ can form dense Al_2O_3 anti-oxidation protective film in the air to have good oxidation resistance. However, previous studies show that once the Ti-Al-Si coatings form on the titanium alloy's surface, the $TiAl_3$ phase layer is difficult to form. Therefore, we propose a method to form Si concentration gradient layers on the Ti-6Al-4V.

Experimental

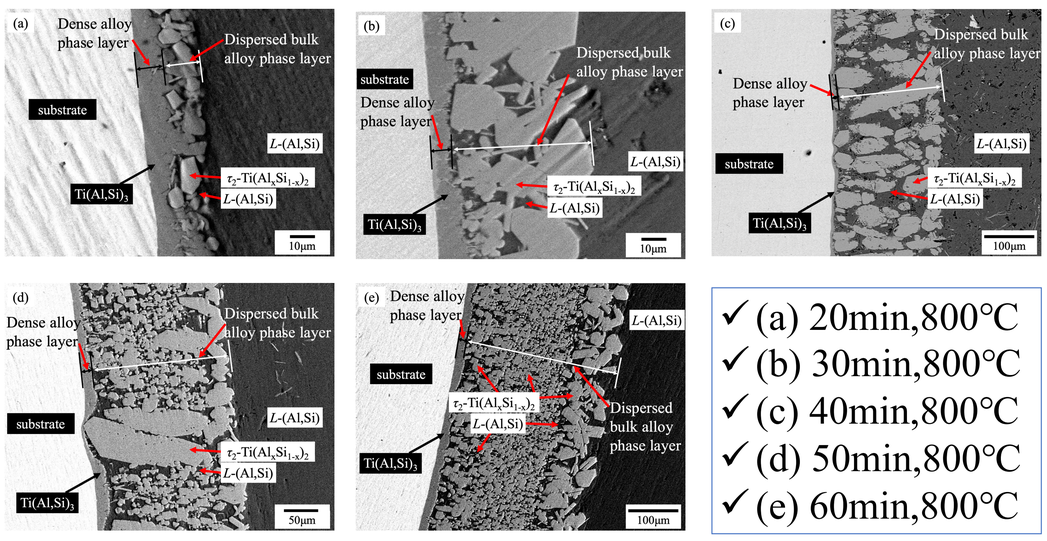
The preparation method of Ti-Al-Si gradient coating is a combination of the hot-dipping method, casting infiltration method, in-situ self-generated method, and is thus referred to as Self-generated Gradient Hot-dipping Infiltration (SGHDI) method.

Self-generated Gradient Hot-dipping Infiltration (SGHDI) was proposed to prepare Ti-Al-Si gradient coatings on Ti-6Al-4V alloy. The coating samples with different dipping time (20, 30, 40, 50 and 60 min) were prepared at the dipping temperature of 800 °C. The microstructure, phase structure and composition of the coating observed by X-ray diffraction (XRD), scanning electron microscope (SEM) and energy dispersive spectrometer (EDS).



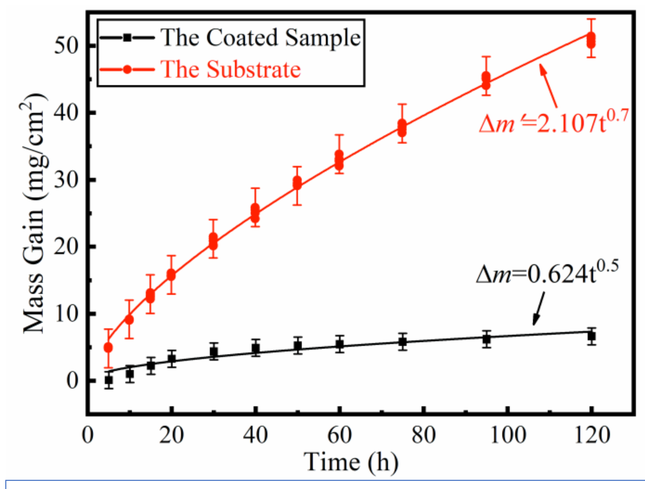
Results and Discussion

Microstructures and phase constitute



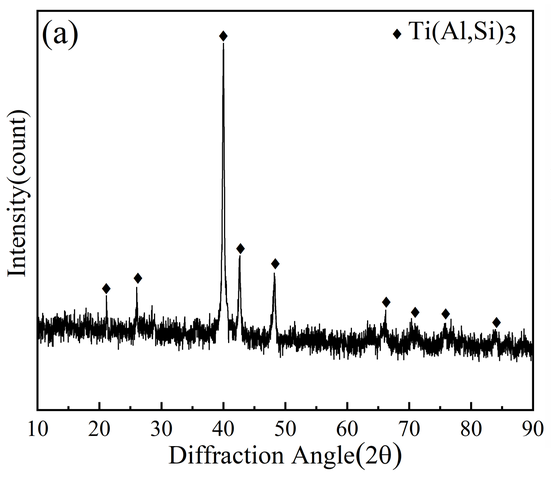
- ✓ (a) 20min,800°C
- ✓ (b) 30min,800°C
- ✓ (c) 40min,800°C
- ✓ (d) 50min,800°C
- ✓ (e) 60min,800°C

The oxidation kinetic curves

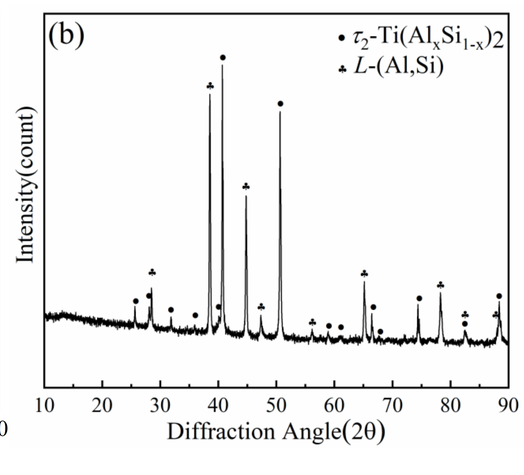


- ✓ The Ti-Al-Si gradient coatings can provide good oxidation resistance to the substrate at high temperature up to 800 °C.

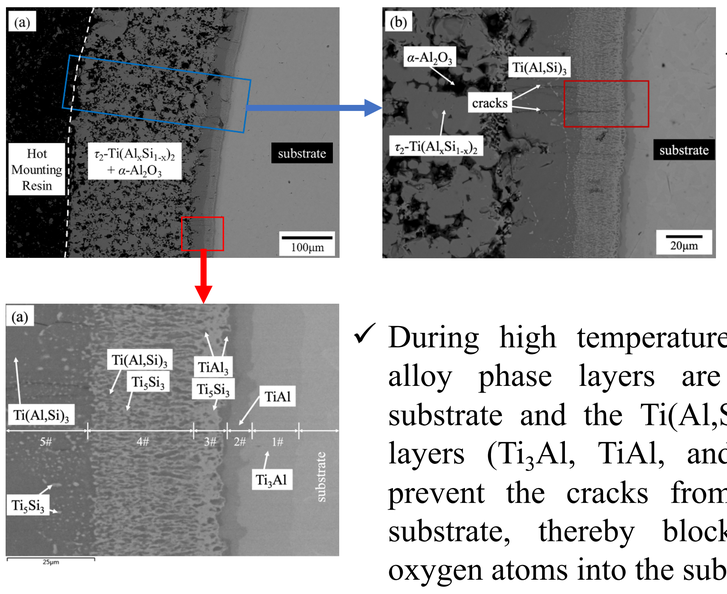
XRD of Dense alloy phase layer



XRD of Dispersed bulk alloy phase layer



Microstructures and phase constitute after oxidation



- ✓ The newly formed four phase layer :
  - ● Ti_3Al
  - ● TiAl
  - ● $TiAl_3 + Ti_5Si_3$
  - ● $Ti(Al,Si)_3 + Ti_5Si_3$
- ✓ During high temperature oxidation, three new alloy phase layers are formed between the substrate and the $Ti(Al,Si)_3$ layer. These phase layers (Ti_3Al, TiAl, and $TiAl_3 + Ti_5Si_3$) can prevent the cracks from propagating into the substrate, thereby blocking the diffusion of oxygen atoms into the substrate through cracks.

Introduction

- ✓ The silicon concentration gradient coatings are in the sequence of $Ti(Al,Si)_3$ phase, τ_2 phase + L - (Al,Si) phase, and L - (Al,Si) phase from the substrate.
- ✓ The Ti-Al-Si gradient coatings can provide good oxidation resistance to the substrate at high temperature up to 800 °C.
- ✓ During high temperature oxidation, three new alloy phase layers are formed between the substrate and the $Ti(Al,Si)_3$ layer. These phase layers (Ti_3Al, TiAl, and $TiAl_3 + Ti_5Si_3$) can prevent the cracks from propagating into the substrate, thereby blocking the diffusion of oxygen atoms into the substrate through cracks.

Experimental

This work was supported by Natural Science Foundation of Hunan Province of China (No. 2018JJ2392), Scientific Research Foundation of Hunan Provincial Education Department of China (No. 17C1518), National Natural Science Foundation of China (No. 51771160, No. 51971189) and Xiangtan university scientific research start-up fund project.