Yanpeng Xue, Tengfei Yu
University of Science and Technology Beijing
National Center for Materials Service Safety(NCMS)

SURFACE MODIFICATION AND COLORING MECHANISM OF TITANIUM ALLOY BY AC POLARIZATION

Abstract: Surface coloring technology plays a very unique role in the diversification of Ti applications. We report our new findings using AC polarization to fabricate chromatic passive films on Ti surface. Compared to passivation films formed using DC anodization, brighter and more uniform colors could be generated in a controlled manner by simply varying the waveform of AC polarization. The colored films fabricated by AC polarization were very dense without visible cracks or defects. DC anodization, AC sine polarization, and AC square polarization exhibited high light reflectivity in the wavelength range of 380–450 nm, 500–650 nm, and 400–500 nm, respectively. The composition distribution and formation process of colored films were analyzed in depth, which enabled our further understanding of the electrochemical coloration mechanism on Ti surface. The thickness of DC anodization, AC sine polarization, and AC square polarization were 161 nm, 203 nm, and 165 nm, which corresponded to the colors of oxford blue, pale yellow, and light blue, respectively. In addition, the corrosion resistance measurements further revealed that the films with lower surface roughness prepared by AC polarization presented great protective effect on the Ti matrix.

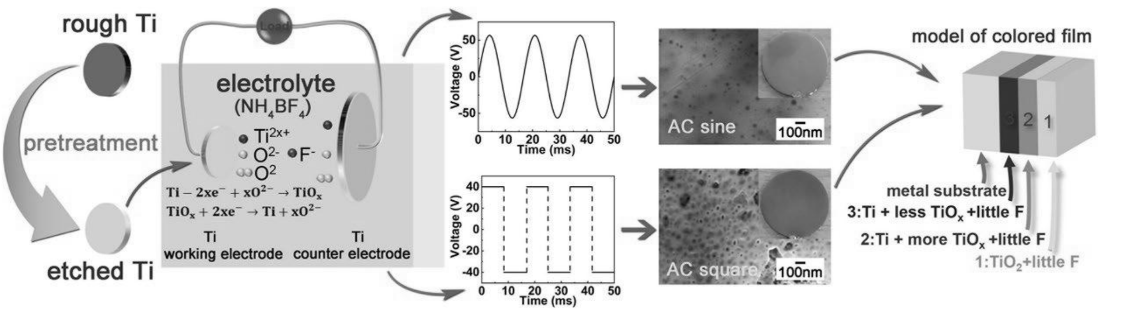

Fig.1 Titanium coloration-variation of external stimuli

However, the underlying coloration mechanism for electrochemical coloration technology has not been systematically investigated and verified. Our new finding based on spectrophotometer characterization reveals that the color of oxide film is determined by the diffuse reflection light. The coloration mechanism, attributed to the selective absorption of visible light by the TiOx semiconductor film, is therefore proposed and confirmed. This absorption originates from electron transitions from the impurity levels to the conduction band. Oxide films of various colors exhibit particular absorption peaks, along with specific flat band potentials and charge carrier densities. The energy differences between the conduction band minimum and the Fermi level (E_C-E_F) of oxide films with orange, red, blue, and green colors are 1.77 eV, 1.50 eV, 1.25 eV, and 0.76 eV, respectively, corresponding to the redshift of their visible light absorption peaks.

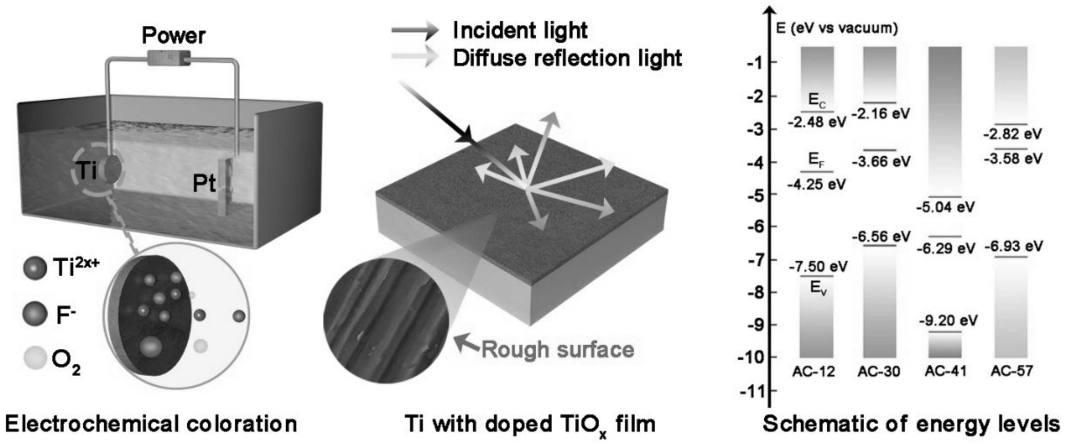

Fig.2 Electrochemical coloration mechanism of titanium surface

This new discovery provides a new understanding of Ti coloration mechanism and promotes the development of related processes and potential applications.

Keywords: Titanium; AC polarization; Surface modification; Oxide film; Coloration mechanism.

REFERENCES

1. Tengfei Yu, Yanpeng Xue*, Wanyuan Gui, Man Zheng, Benli Luan*, A new understanding on titanium coloration-variation of external stimuli and in-depth mechanism analysis. Surface and Coatings Technology, 450(2022) 128999.

2. Tengfei Yu, Yanpeng Xue*, Man Zheng, Benli Luan*, A new understanding on the electrochemical coloration mechanism of titanium surface. Journal of Materials Research and Technology 35 (2025) 5770–5781.