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Isothermal Oxidation-Induced Surface Functionalization of TiZrNbAl Alloy: Implications for Bioactivity and Corrosion Resistance

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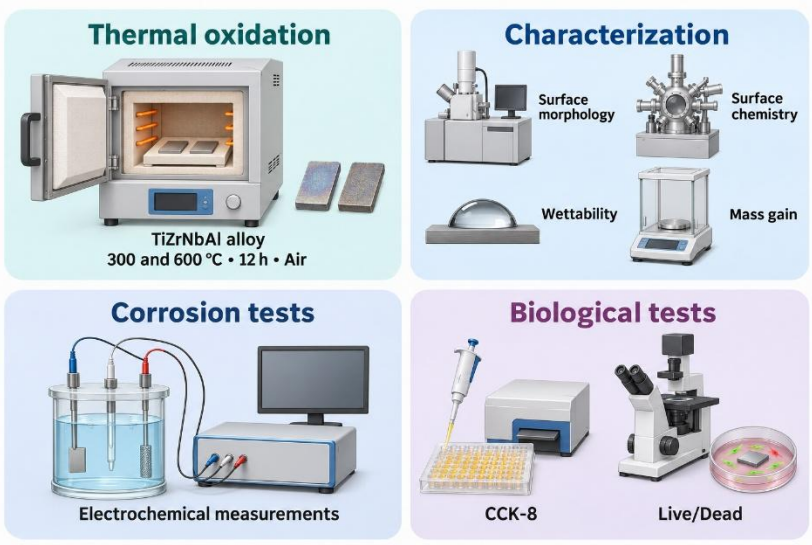
Introduction

Ti-based medium-entropy alloys are promising candidates for biomedical applications; however, their performance depends on both bulk properties and surface interactions with the physiological environment. Thermal oxidation can modify the composition and morphology of surface oxide layers, influencing corrosion behavior and cell–material interactions. This study evaluates isothermal oxidation at 300 and 600 °C as a surface functionalization strategy for TiZrNbAl, focusing on the relationships between surface characteristics, corrosion resistance, and in vitro biological response.

Objective

To evaluate the effects of isothermal oxidation on the surface properties, corrosion resistance, and in vitro biological response of the new medium-entropy TiZrNbAl alloy.

Materials and Methods



Results and Discussions

Oxidation at 600 °C produced greater mass gain and more heterogeneous surface features than at 300 °C. XPS identified Ti–O, Zr–O, Nb–O, and Al–O contributions at both temperatures.

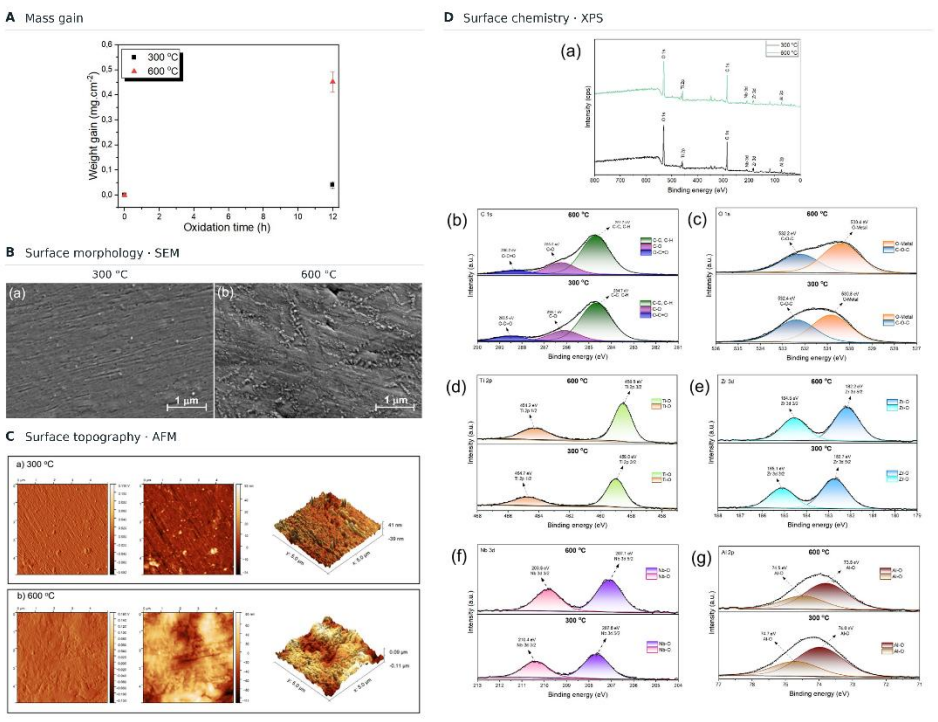
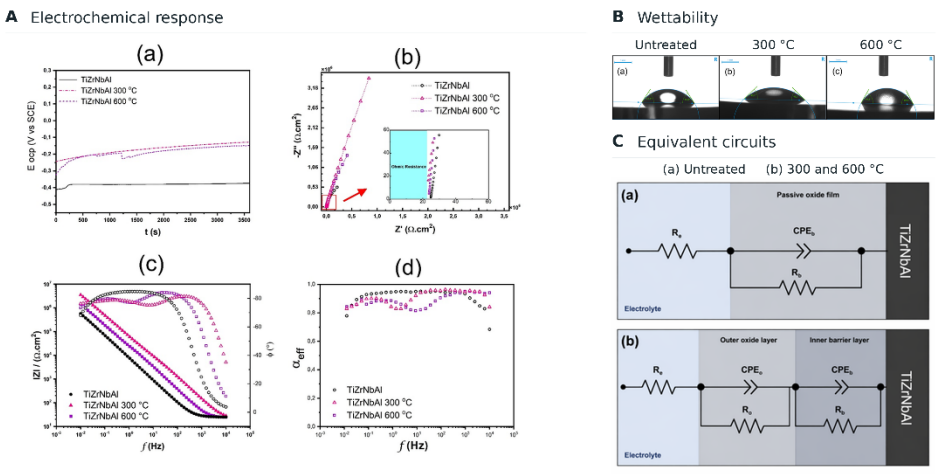


Figure 1. Oxidized TiZrNbAl (300/600 °C, 12 h): (A) mass gain; (B) SEM; (C) AFM; (D) XPS.

Oxidation shifted the OCP toward more positive values and increased low-frequency impedance relative to the untreated alloy. The 300 °C condition exhibited the highest measured low-frequency |Z| and the lowest contact angle.



D Fitted EIS parameters

Condition	R_e (Ω.cm²)	Q_o (Ωs$^{-\alpha}$.cm²)	α_o	R_o (kΩ.cm²)	Q_b (Ωs$^{-\alpha}$.cm²)	α_b	R_b (kΩ.cm²)	χ^2
Untreated	24.89	-	-	-	1.42E-05	0.95	1674	0.000107
300 °C	24.39	3.35E-06	0.91	6241	9.78E-07	0.96	14	0.000402
600 °C	23.78	8.09E-06	0.88	7625	5.32E-06	0.95	1.64	0.000495

Figure 2. TiZrNbAl: (A) OCP/EIS, (B) wettability, (C) equivalent circuits, and (D) EIS fitting parameters.

Both conditions showed mean metabolic activity above 100% of the negative control, with no significant differences between temperatures. Live/Dead images showed predominantly viable cells and greater apparent cell coverage at 300 °C.

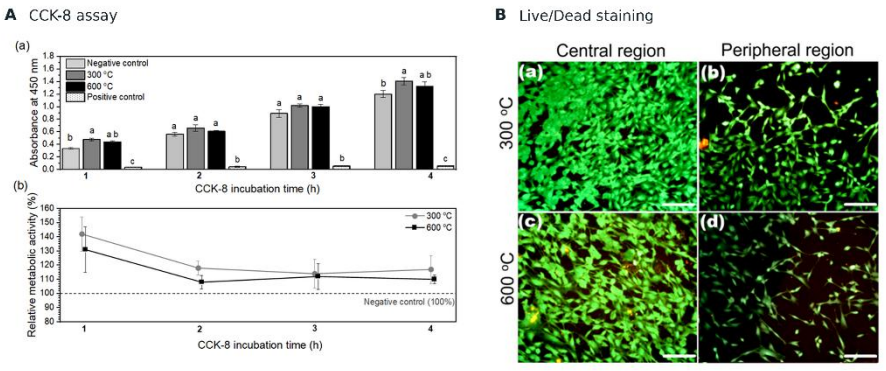


Figure 3. Biological response of oxidized TiZrNbAl: (A) CCK-8 and (B) Live/Dead staining (green: live; red: dead).

Conclusions

Isothermal oxidation improved the electrochemical response of TiZrNbAl while maintaining cytocompatibility. The 300 °C treatment combined the highest low-frequency impedance with greater wettability and favorable cell coverage, making it a promising condition for biomedical surface functionalization.

References

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CAPES
LAB FERT
LEPMI Grenoble - Chambéry