

High-Temperature Oxidation of Novel Ti-based Ti-Mo-Ta-Cr-Al Refractory Compositionally Complex Alloys: Effect of Al Addition and Oxidizing Atmosphere

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Refractory compositionally complex alloys (RCCAs) are attracting increasing interest as potential alternatives to conventional Ni- and Ti-based alloys for high-temperature structural applications. However, when optimized for elevated-temperature performance, many RCCAs suffer from pronounced room-temperature brittleness and/or poor high-temperature oxidation resistance, which severely limits their practical applicability. Our previous studies revealed strong perspectives of Ti-rich Ti-Mo-Ta-Cr-Al RCCAs with respect to balanced properties including stable single-phase disordered A2 structure after prolonged thermal exposure, room-temperature compressive plasticity and exceptional strength retention up to 1000 °C [1,2]. This alloy design strategy addresses key limitations of existing high-temperature materials, including (i) multiphase TiAl-based alloys, which offer attractive specific strength but suffer from oxidation limitations above ~750 °C, and (ii) Ni-based alloys, given the significantly lower density of Ti-rich RCCAs (7–8 g cm⁻³).

In the present study, the high-temperature oxidation behavior of Ti-rich Ti-Mo-Ta-Cr-Al RCCAs with varying Al contents is systematically investigated between 800 and 1000 °C in both dry air and water vapor atmospheres. In both environments, the alloys form multilayered oxide scales predominantly composed of rutile- and corundum-structured oxides (see Fig. 1). Increasing the Al content (up to 10 at.%) markedly improves oxidation resistance by shortening the transient oxidation stage, whereas water vapor accelerates oxidation through enhanced transport of oxidizing species with increased internal oxidation. At temperatures above 900 °C, volatilization of MoO₃ and internal oxidation become pronounced. Overall, the results demonstrate that Ti-rich RCCAs can retain effective oxidation resistance up to 900 °C through appropriate control of alloy chemistry. These findings not only clarify the role of Al and water vapor in controlling oxidation mechanisms but also provide design guidelines for the development of novel Ti-rich RCCAs with balanced mechanical and oxidation performance for high-temperature applications.

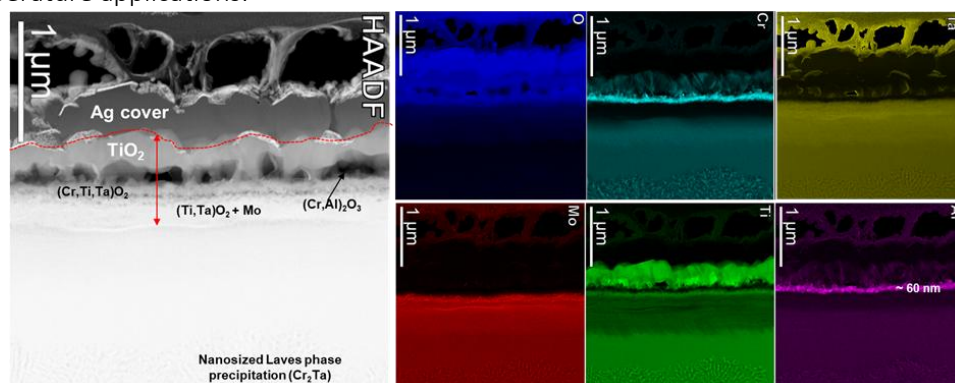


Figure 1. TEM-HAADF image and corresponding EDS elemental maps of the 44Ti–20Mo–15Ta–15Cr–6Al (at.%) alloy after oxidation in air at 800 °C for 48 h, revealing the formation of a thin (~1 μm), multilayered oxide scale.

References

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- [2] C. Tang, A. Radi, M. Dürrschnabel, U. Jäntsche, M. Klimenkov, A. Kauffmann, M. Heilmaier, C. Schroer, B. Gorr, J. Alloy. Metall. Syst. 12 (2025) 100217.