Very Long Term Oxidation of Titanium Aluminides Investigated

Titanium aluminides (TiAl) are of great interest for intermediate-temperature (600 to 850 °C) aerospace and power-generation applications because they offer significant weight savings over today's nickel alloys. TiAl alloys are being investigated for low-pressure turbine blade applications, exhaust nozzle components, and compressor cases in advanced subsonic and supersonic engines (ref. 1).

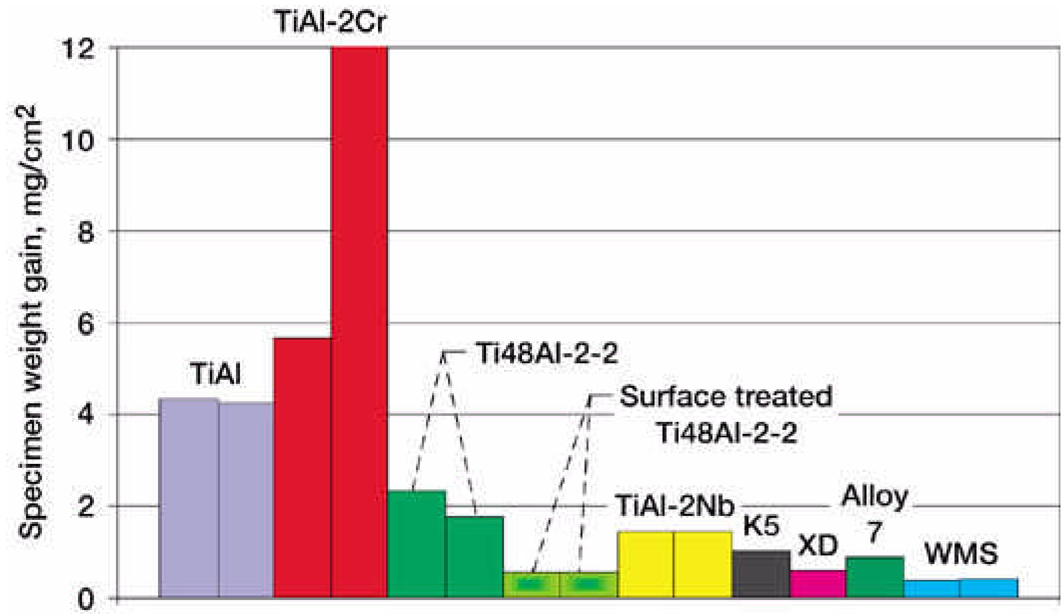
Significant progress has been made in understanding the fundamental aspects of the oxidation behavior of binary TiAl alloys (refs. 2 and 3). However, most of this work has concentrated on short term (<1000 hr), high-temperature (900 to 1000 °C) exposures. Also, there is not much data available in the literature regarding the oxidation behavior of the quaternary and higher order engineering alloys. This is especially true for the very long term, low-temperature conditions likely to be experienced during aerospace applications.

An investigation at the NASA Glenn Research Center at Lewis Field was undertaken to characterize the long-term oxidation behavior of various model and advanced titanium aluminides for periods up to 7000 hr at 704 °C in air using a high-resolution field emission scanning electron microscope. Also, a unique surface treatment technique (ref. 4) developed to improve the oxidation resistance of TiAl was evaluated. The alloys included in this investigation are listed in the table. The table also shows typical alloy compositions and the specific weight changes and scale thickness measured for each alloy after exposure to 700 °C for 7000 hr in air.

COMPOSITIONS, WEIGHT GAINED, AND SCALE THICKNESS FOR MODEL AND ENGINEERING TiAl ALLOYS EXPOSED TO 700 °C FOR 7000 HR IN AIR

Alloy	Composition, at.%						Weight change/area, mg/cm^2	Scale thickness, μm
	Al	Ti	Cr	Nb	Mn	W		
TiAl[a]	48.07	51.93	-----	-----	-----	-----	4.28	20
TiAl-2Cr[b]	47.99	50.01	2.00	-----	-----	-----	10.29	150
TiAl-2Nb	47.99	50.01	-----	2.00	-----	-----	1.43	12
TiAl-2Cr-2Nb	48.03	47.97	2.00	2.00	-----	-----	2.04	15
Surface-treated TiAl-2Cr-2Nb	48.03	47.97	2.00	2.00	-----	-----	.57	6
XD	47.39	49.24	2.04	1.14	0.21	-----	.86	9

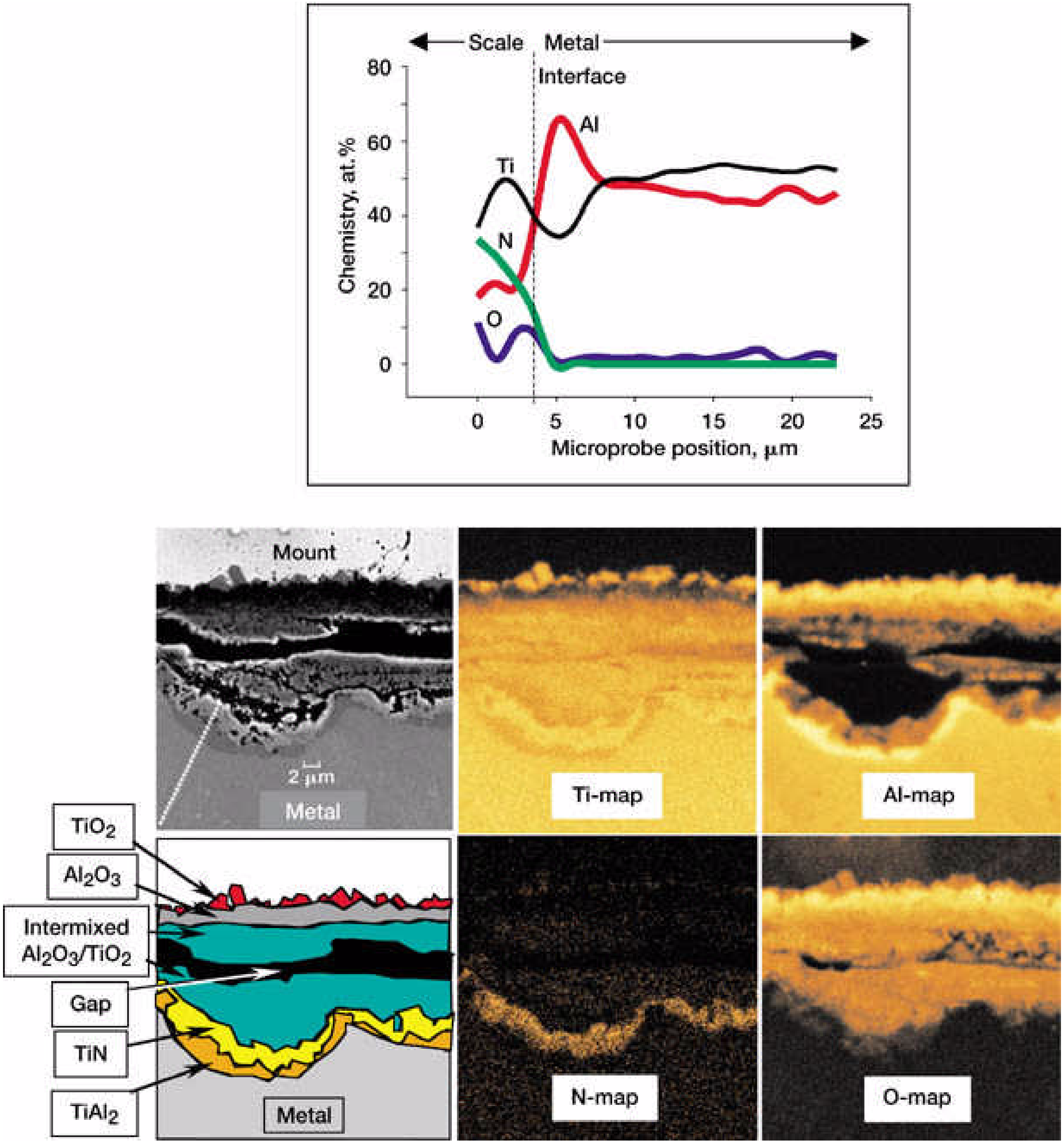
K5	46.5	48.3	2	3	-----	0.2	1.05	6
Alloy 7	46	48	-----	5	-----	1.0	.40	5
WMS	47	50	-----	2	1	.5	.61	4
[a]Spalled. [b]Reacted with alumina boat.								



Specimen weight gain for model and advanced g-TiAl alloys after isothermal exposure to 704 °C for 7000 hr in air. Duplicate tests were done for TiAl, TiAl-2Cr, Ti48Al-2-2, surface-treated Ti48Al-2-2, and TiAl-2Nb.

The response to the long-term exposure is reflected in the specimen weight gained for the different alloy compositions (see the bar chart and the table). The binary TiAl alloy is the only alloy where the scale did not adhere but tended to spall off. Cr, which is normally added to the alloy for enhanced mechanical properties, was extremely detrimental to oxidation resistance. The presence of Nb as a ternary or quaternary addition was extremely beneficial, minimizing the weight gained even when Cr was present in the alloy. The TiAl-2Cr-2Nb alloy benefited further from phosphoric acid surface treatment (ref. 4), which significantly reduced the oxidation rate. The more advanced alloys, which contain a higher number of added elements, showed reduced oxidation rates.

All the alloys formed complex alloy scales that required detailed microscopy analyses. Microprobe spectrometry and high-resolution scanning microscopy were used to reveal the key features of the alloy scales. The following figure shows a typical cross-section describing the complex multilayered scale as well as elemental maps and linescan plots describing the chemistry variations through the scale thickness for a binary TiAl alloy. These microstructural differences are being used to explain and predict the oxidation response that advanced TiAl alloys will exhibit in actual service.



Typical microstructure, elemental maps, and linescans observed in a binary TiAl alloy after exposure to 704 °C for 7000 hr in air.

References

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