Oxidation of \(\gamma\)-TiAl Intermetallic Coated with Electrodeposited Nickel–La\(_2\)O\(_3\) Composite Films

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A coating of nickel with La\(_2\)O\(_3\) particles was electrodeposited on the surface of \(\gamma\)-TiAl to improve its high-temperature oxidation resistance. The experimental results showed that contrary to the oxidation of bare specimens, the electrodeposited Ni–La\(_2\)O\(_3\) composite-coated ones exhibited much better resistance to both isothermal and cyclic oxidation in air at 1000 and 900°C. For the oxidation of the Ni–La\(_2\)O\(_3\) composite-coated \(\gamma\)-TiAl EPMA/EDX micro-analyses revealed that after the composite film had been thoroughly oxidized, a La\(_2\)O\(_3\)-rich NiO layer close to the gas–scale interface and two alumina-rich layers, with one beneath the NiO layer and the other adjacent to the \(\gamma\)-TiAl matrix, were produced in the scale. The results indicated that the preferentially formed La\(_2\)O\(_3\)-doped NiO layer retarded the growth of rutile and favored the formation of two alumina-rich layers. The mechanism of the effect of the electrodeposited Ni–La\(_2\)O\(_3\) composite on the oxidation behavior of \(\gamma\)-TiAl is discussed in detail.

**KEY WORDS:** oxidation; \(\gamma\)-TiAl intermetallic; electrodeposited Ni–La\(_2\)O\(_3\) composite film.

**INTRODUCTION**

TiAl intermetallic compounds such as \(\alpha_2\)-Ti\(_3\)Al and \(\gamma\)-TiAl have a high strength-to-weight ratio at high temperature and, therefore, are of interest as high-temperature structural materials. However, the intermetallics have poor oxidation resistance at temperatures exceeding about 700°C because

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of the rapid growth of a nonprotective TiO$_2$ scale, as well as the lack of a long-lasting, protective alumina scale. There is also evidence for the formation of Ti$_2$AlN and TiN layers beneath the outer oxide scale, which leads to stresses and the creation of microcracks in the scale.$^1$ More attention has been paid to improving the oxidation resistance of the intermetallics. At present, several techniques have been used such as: (1) addition of Hf, Nb, Cr or other alloying elements,$^2$–$^5$ (2) implanting Nd ions into the surface layer,$^6$ and (3) adding a protective coating to the surface.$^7$–$^{10}$ The goal is to promote a continuous, dense, and adhesive oxide scale formed on the intermetallics during oxidation. Taking into consideration that the cyclic-oxidation resistance of the intermetallics has not been obviously improved by small alloying additions of Hf and Nb, and large additions of these elements (especially Nb, Cr, etc.) have a deleterious effect on mechanical properties, the introduction of a protective coating on the surface of the intermetallics is a preferred method by many researchers. Several years ago, it was reported that both aluminum diffusion and MCrAl (M = Ni, Co) microcrystalline coatings had a positive role in reducing the isothermal oxidation rate of the intermetallics.$^7$–$^{10}$ However, for the aluminum diffusion coating, a brittle TiAl$_3$ phase is formed during the aluminizing process of the intermetallics, which may lead to through-coating cracking during cooling. For MCrAl microcrystalline coatings, a number of pores, formed by agglomerated “Kirkendall” voids from diffusion of Ni or Co with base elements such as Ti and Al in the substrate during oxidation, are created at the interface of the oxide scales and, as well, at the interface of the coatings and the substrate. These pores cause a decrease in cyclic-oxidation resistance.$^{10}$ Therefore, there are many problems that need to be resolved before these coatings can be put in service.

In previous work,$^{11}$ the authors developed an electrodeposited Ni–La$_2$O$_3$ composite coating by the codeposition of nickel with tiny La$_2$O$_3$ particles. Experimental results showed that the codeposited film has superior oxidation resistance because of the formation of a La$_2$O$_3$-modified NiO scale, which has a much slower growth rate in comparison to the La$_2$O$_3$-free NiO scale grown on pure Ni and Ni-plated Ni. Interest here is focused on the effect of electrodeposited Ni–La$_2$O$_3$ composite films on the oxidation resistance of the $\gamma$-TiAl intermetallic.

**EXPERIMENTAL PROCEDURES**

Ti–50 at.% Al (nominal chemical composition) intermetallic was melted using a vacuum-induction furnace with CaO crucibles, and then cut into small specimens with dimensions of 20×10×1 mm. The specimens were abraded to 800-grit silicon-carbide paper and then plated electrolessly with