ALUMINIZING OF ALLOY 690 AND ALLOY 800, THEIR MICROSTRUCTURAL CHARACTERIZATION AND PROPERTY EVALUATION

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Abstract

For superalloy 690, the objective of the present investigation is primarily to develop diffusion barrier coatings on the alloy surface for enhanced service life of metallic melter pot as well as electrode in Joule-heated ceramic melter pot in nuclear waste immobilization process. In addition, to explore the possibility of uses of aluminide coatings at elevated temperatures (up to 1273 K) by evaluating their different properties where tensile strength is of secondary consideration. In case of superalloy 800, the objective has been to develop aluminide coatings for applications up to around 1273 K. This includes development of aluminide coatings of Fe2Al5 and FeAl and their characterization with an aim in mind that this iron aluminide coating with the formation of Al2O3 on it may find application in fusion reactor programme. Based on experiments and understanding, a few important points of this study are summarized as follows:

1. Pack aluminization of substrates of superalloy 690 with high Al-containing pack (10 wt.% Al) at 1273 K results in formation of multilayer including nickel aluminides and chromium aluminide that is attributed to inward diffusion of Al and outward diffusion of Ni and Cr. For low Al-containing pack (2 wt.% Al) of superalloy 690, multilayer predominantly NiAl type phase on the uppermost surface forms due to outward diffusion of Ni. For superalloy 800 substrates, pack aluminization with high Al-containing pack (10 wt.% Al) at 1273 K shows formation of multilayer including iron aluminides, which could be attributed to inward diffusion of Al and outward diffusion of Fe, Ni and Cr.

2. Superalloy 690 substrates pack aluminized at 1273 K with high Al-containing pack (10 wt.% Al) indicates high hardness values of the aluminides. Wear tests of aluminized alloy sample at load level of 15 N with different frequencies show good adherence of surface coating. For superalloy 690 specimens pack aluminized with low-Al containing pack (2 wt.% Al), an increase in microhardness with Al-content has been noticed for multilayer (mainly aluminides). Scratch test (adherence test) at a constant load level of 2 N along the cross-section of aluminized sample indicates good adherence of multilayer.

3. In case of superalloy 800 substrates pack aluminized with 10 wt.% Al, microhardness of aluminide has been found to increase with Al-content. Scratch test of aluminized specimen at load levels ranging from 0.9 to 10 N shows good adherence of aluminide coatings.

4. Based on the computational results and understanding, a few interesting points of ab-initio modeling can be stated as (i) First-principle calculations on Ni(111)/NiAl(110) interface has indicated strong adhesion, (ii) Ideal work of adhesion, \( W_{\text{ad}}^{\text{ideal}} \) = 3684 mJ/m²; lowest bound value, (iii) Strong metallic Ni d Ni d interaction and covalent Ni d Al p mixing of states give rise to strong adhesion at the Ni(111)/NiAl(110) interface and (iv) For Cr-doped interface, Ideal work of adhesion, \( W_{\text{ad}}^{\text{ideal}} \) = 3524 mJ/m² that is slightly lower as compared to that with pure Ni substrate.

5. Good oxidation resistance has been noticed for pack aluminized superalloy 690 substrates at 1273 K in air, which is attributable to formation of a thin Al2O3 layer. A fairly good oxidation resistance has also been exhibited by pack aluminized superalloy 800 specimens under similar experimental conditions.

6. In borosilicate melt, superalloy 690 is oxidized and a thick, continuous Cr2O3 layer forms at the glass/alloy interface because of low solubility of Cr2O3 in borosilicate melt.

7. A good stability of aluminide coatings with Al2O3 layer for superalloy 690 substrates in borosilicate melt at 1248 K is attributed to modification of glass composition at the coating/glass interface that is believed to have induced by partial dissolution of alumina from preexisting Al2O3 layer.
List of publications in peer-reviewed journals:
1. ‘Characterization of aluminides formed on superalloy 690 substrate’
2. ‘Formation and characterization of aluminide coatings on Alloy 800 substrate’
3. ‘Thermally grown oxide layer on aluminized superalloy 690 substrate and its stability in nitrate-based environment’
4. ‘Formation of diffusion barrier coating on superalloy 690 substrate and its stability in borosilicate melt at elevated temperature’
5. ‘Formation of aluminides on Ni-based superalloy 690 substrate, their characterization and first-principle Ni(111)/NiAl(110) interface simulations’