The Preparation and High Temperature Oxidation Behavior Research of Al/Al_2O_3 Film on Fe-Al Alloy

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Abstract: Dipping process combined with sol-gel method was successfully use to prepare Al/Al_2O_3 films on the Fe-Al alloys. Oxidation thermodynamics, XRD and SEM results showed the same conclusion that, the Al component dipped on the surface of Al_2O_3 film obtained by sol-gel method could obviously improve the the high-temperature oxidation resistance properties of the Fe-Al alloy obviously.

In modern social, Metal materials are widely used in the industrial and technological fields, so most modification of materials are focused on the metallic. For example, the works for the high-temperature alloys include doping active elements(Al, Si, et.al) into the matrix, which will oxide first and the obtained thin films (Al_2O_3, Si_2O_3, et.al) on the outermost layer of the alloys can prevent the further oxidation of the inner matrix[1-3]. The works also include the surface modification of the high-temperature alloy, which means protective thin films (Al_2O_3, Si_2O_3, et.al) will be prepared on the surface of the alloy by magnetron sputtering[4], plasma spraying[5], thermal spraying[6] and also sol-gel method[7]. The sol-gel method has distinctive advantages, but the process usually needs long time to repeat the dipping and pulling procedure to obtained the required thickness of the film. The research in this work, dipping of the Al powders on the Al_2O_3 thin films obtained by the sol-gel process was used, in order to improve the efficiency of the sol-gel method, which was hoped for keeping the protective function of the Al_2O_3 thin films obtained on the surface of the Fe-Al alloys.

Experimental

Fe-Al alloys used in this work were smelted in non consumable vacuum arc furnace from the Fe (99.99%) and Al (99.99%) powders, and then cut to pieces with surface area of 2 cm^2. X-ray diffractometer (XRD) was used to analyse the phase compositions of the materials obtained on the surface of Fe-Al alloy after oxidation on the temperature of 800 ^oC. Scanning electron microscope (SEM) and energy spectrometer (EDS) were used to observe the surface profile of the samples.

After washed in ethanol and acetone, the Fe-Al alloy was dipped into Al_2O_3 gel for 600 seconds, then pulled up with a speed of 2000 $mm \cdot s^{-1}$and following kept in air for 60 seconds. In the next step, the sample was dipped into Al powders in order to obtained well dispersed Al on every surface, then put the alloy into muffle furnace kept on 500 ^oC for 10 minutes. The above processes were repeated for 2 times to prepare the expected film.

To investigate the protective function of the film, the sample obtained was dealt with cyclic oxidation at 800 ^oC for 10 h.

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Results and Discussion

1) Oxidation thermodynamics

Fig.1 shows the oxidation thermodynamics of the Fe-Al alloys with Al/Al_2O_3 and Al_2O_3 films oxidized at 800 ^oC. The results indicate that, the two films all showed protective functions, because the mass gain of the samples were vary small. Dipping of Al powders improve the high-temperature oxidation resistance of the alloy more obviously, which had large mass gain at the beginning stage attributed to the active Al element, but less mass gain after 250 min. Oxides peeled from the alloy surface caused the negative growth of the mass gain.

2) XRD analysis

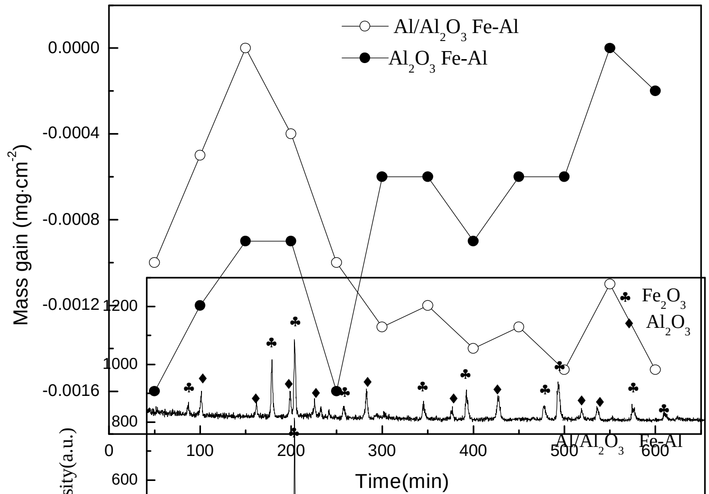

Fig.1 Oxidation thermodynamics of Fe-Al alloys covered by Al/Al_2O_3 and Al_2O_3 films oxidized at 800 ^oC

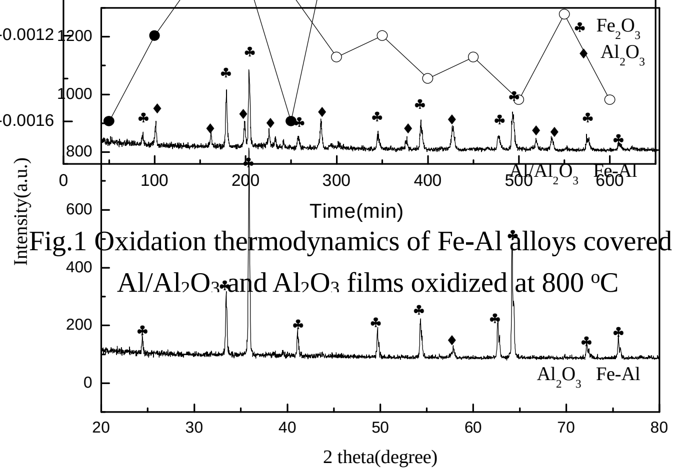

Fig.1 The XRD patterns of oxidized films on the surface of

Fig.2 shows the XRD patterns of oxidized films on the surface of Fe-Al alloys. The analysis of the results indicated that the oxidation products of the two kinds of samples were mainly composed of Fe_2O_3(33-0664) and Al_2O_3(10-0173). The dipping of Al powders lead to more complex forms of the oxidation, which included more Al_2O_3 phase. Therefore, the Al/Al_2O_3 covered Fe-Al alloy had better high-temperature resistance property, this result is agreed with the oxidation thermodynamics of the samples.

3) SEM morphology

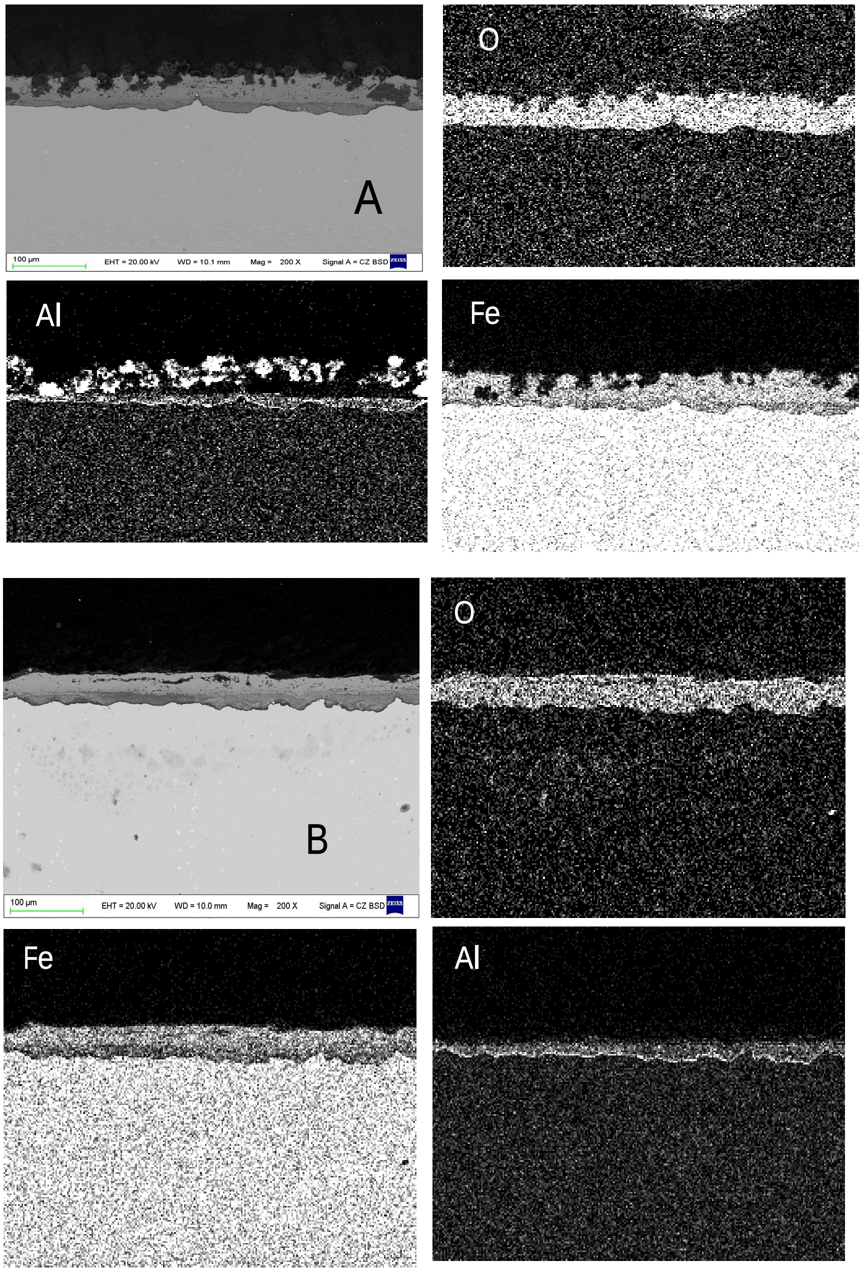

Fig.2 The cross-section morphology of the Fe-Al alloys covered by Al_2O_3 (A) and Al/Al_2O_3 (B) films oxidized at 800 oC for 10 h

Fig.3 showed the cross-section morphology of the Fe-Al alloy covered by Al_2O_3 (A) and Al/Al_2O_3 (B) films after oxidized at 800 oC for 10 h. From the results we can see that, the oxide films on the surface of the two kind of samples were similar, which were composed of Fe_2O_3 as outermost layer, mixture of Al_2O_3 and Fe_2O_3 as intermediate layer and Al_2O_3 as the innermost layer. Dipping of Al powders obtained relatively complete oxide layer, and a continuous Al_2O_3 in the innermost of the cross-section was achieved, which was desired for the high-temperature alloys.

Conclusions

(1) Dipping process combined with sol-gel method was successfully use to obtain Al/Al_2O_3

films on the Fe-Al alloys.

(2) The dipping of Al component improve the high-temperature oxidation resistance properties of the Fe-Al alloy obviously.

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