5 - 6 Beneficial Effect of Grain Refinement on the Oxidation Resistance of T91 Steel to Liquid Lead-bismuth Eutectic

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The performance degradation of structural materials caused by corrosion of the coolant lead-bismuth eutectic (LBE) alloy has become one of the most serious challenges facing the construction of lead-cooled fast reactors[1−3]. Grain refinement is a way to improve the corrosion resistance of steels[4−8]. However, its effect on the LBE corrosion behavior of steels is still very little studied. In this study, the surface grains of ferritic/martensitic steel T91 were refined using shot peening treatments. Corrosion experiments were then carried out with pristine T91 in oxygen-saturated liquid LBE at 550 ℃ to study their corrosion behaviour. These shot peened samples were labelled as refined grained (RG) samples and those without shot peening were labelled as pristine grained (TP) samples.

After the corrosion in oxygen-saturated liquid LBE at 550 ℃, the oxide layers formed on the TP and RG samples are similar in the structure, both having a bilayer structure consisting of an inner and an outer layer. Large volume cavities are present in the outer oxide layer of the TP sample, which are suspected to be infiltrated by LBE, whereas the cavities in the outer oxide layer of the RG sample are smaller in size by comparison. The average oxide layer thickness for TP and RG samples are 21.4 and 15.8 μm respectively (Fig. 1(a) and (b)). The thickness of the oxide layers for both TP and RG samples increases with increasing corrosion time, with 23 and 18 μm for TP and RG samples respectively after 310 h of corrosion, and 54 and 45 μm after 1 218 h of corrosion (Fig. (c)∼(f)). It is evident that grain refinement significantly enhanced the oxidation resistance of the T91 steel to liquid LBE.

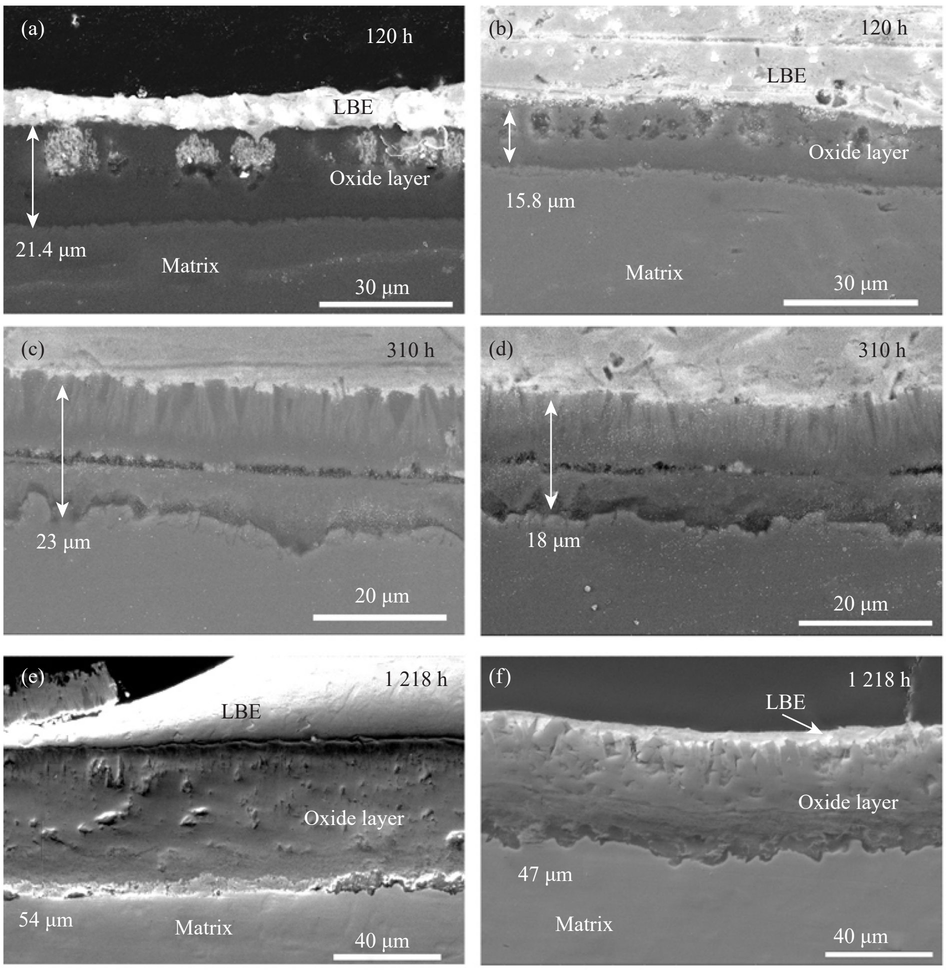

Fig. 1 (color online) Cross-sectional SEM images of the TP (a, c, d) and RG (b, d, f) samples after exposure to oxygen-saturated liquid LBE at 550 ℃ for 120 (a, b), 310 (c, d) and 1 218 h (e, f), respectively.

Figure 2 shows the EPMA measurements of the oxide layer cross-sections of the TP and RG samples after 602 h of corrosion in oxygen-saturated liquid LBE at 550 ℃. After 602 h of the corrosion, Cr-rich islands appear in the Fe-Cr spinel layer of both the TP and RG samples. It is notable that the density of the Cr-rich islands is higher in the RG sample than in the TP sample, indicating a higher Cr content in the spinel of the RG sample.

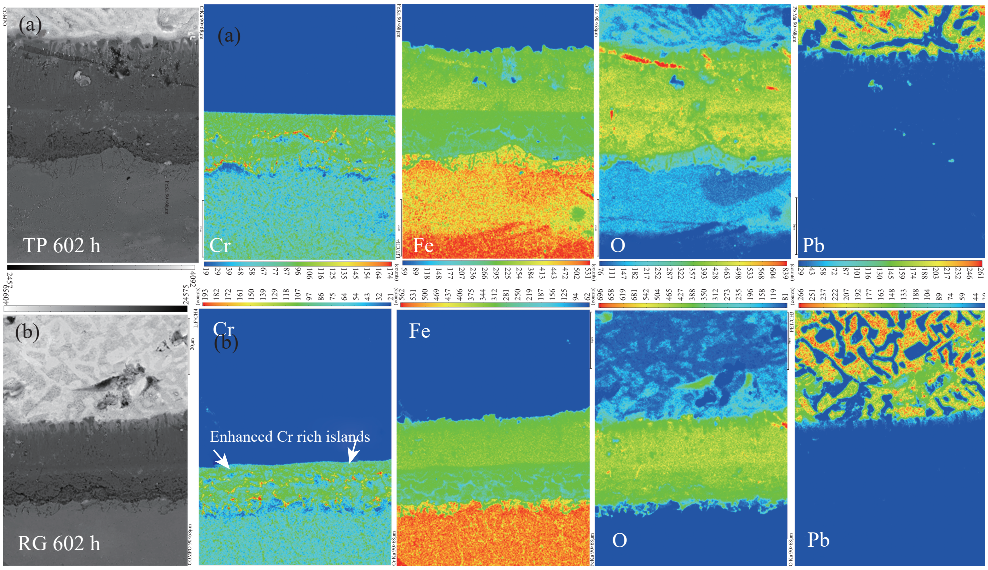

Fig. 2 (color online) EPMA images of cross section of TP (a) and RG (b) samples after 602 h of corrosion in oxygen-saturated liquid LBE at 550 ℃.

The results show that the oxidation resistance of T91 steel to liquid LBE is significantly enhanced by grain refinement due to the increase in grain boundaries enhancing the diffusivity of Cr, and the protective Cr-containing passivation film is generated more quickly at the early stages of oxidation.

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