



## Regular Article

# Formation of periodic layered structure between novel Fe-Cr-B cast steel and molten aluminum



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## ABSTRACT

During the interfacial reaction between novel Fe-Cr-B cast steel and molten aluminum the formation of a periodic layered structure was observed at the Cr-rich Fe<sub>2</sub>B/Al interface. The periodic layered structure was investigated by scanning electron microscopy and electron probe micro-analyzer. It was embedded in the Fe-Al intermetallics (reaction productions of the Fe substrate). Cr element had a key influence on the formation of PLS. A model describing the formation of periodic layered structure between novel Fe-Cr-B cast steel and molten aluminum is presented.

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It is known that the periodic layered structure (PLS) would form during eutectic solidification, which is also called pearlite. In recent year, novel PLSs formed during the interfacial reaction are reported. However, these two PLSs are different from each other. On the one hand, the PLSs formed during eutectic solidification is perpendicular to the precipitation interface while these PLSs in this study formed during the interfacial reaction were approximately parallel to the reaction interface, or perpendicular to inter-diffusion direction; On the other hand, the formation mechanism of the two PLSs was evidently different from each other. The former is caused by the supersaturated precipitation (such as C element), and the diffusion distance is very short. Yet, the latter is caused by the chemical reaction between diffusion couple; both of the diffusion components need to across the PLSs that have been formed, it is thus a long-range diffusion. So the PLS formed during the reactive diffusion process is a very interesting and complex phenomenon. It was firstly discovered in 1982 by Osinski and Vriend et al. in the reaction zone of the solid state diffusion couple of Fe<sub>3</sub>Si/Zn [1]. Since then, the PLS was observed in many material systems, such as Ni<sub>3</sub>Si/Zn [2–6], Cu<sub>x</sub>Ti<sub>y</sub>/Zn [7–9], SiO<sub>2</sub>/Mg [10–15], (Ni,W)/Al [16], U-Mo/Al [17], and so on. Most of the PLS above was formed during solid-state reactions, although it had been reported that the physical state of Zn had no effect on the PLS [3,4], there were few studies on the formation of PLS during solid/liquid reaction, especially during hot dip aluminizing.

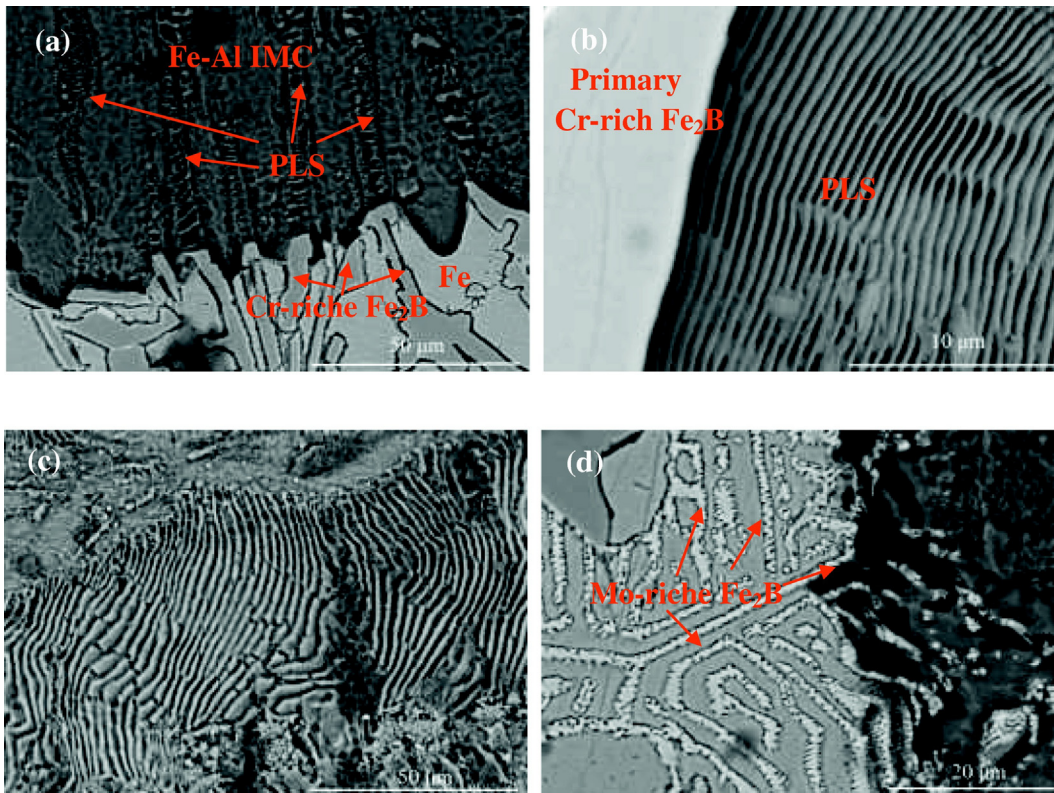
The materials used to form PLS were novel Fe-Cr-B cast steel containing 12 wt.% Cr, 6 wt.% Mn, 2 wt.% Mo, 3.6 wt.% B and 0.36 wt.% C

and aluminum (99.99 wt.%). About 3.0 kg pure Al was melted in the graphite crucible, and the apparatus for immersion tests was illustrated our previous study [18]. After the immersion test, the coupon was withdrawn (with some Al attaching on the uncoated surface) and cooled in air to room temperature. Then, specimens with residual aluminum were cut perpendicular and parallel to the solid/liquid interface for cross-sectional and longitudinal sectional metallographic examinations using standard grinding and polishing, respectively. The samples were then etched in a solution (4 ml HF + 4 ml HNO<sub>3</sub> + 92 ml H<sub>2</sub>O). The microstructures of each immersed specimen were observed on scanning electron microscopy (SEM) and transmission electron microscope (TEM) with an X-ray spectroscopy (EDS). Additionally, chemical line profiles from the surface were investigated using an electron probe micro-analyzer (EPMA).

The microstructures of Fe-Cr-B cast steel were mainly composed of Fe dendrite metal matrix and M<sub>2</sub>B-type borides (M = Fe, Cr, Mo, donated as Cr-rich Fe<sub>2</sub>B and Mo-rich Fe<sub>2</sub>B, respectively) with typical network eutectic structure. The cross-sectional and longitudinal sectional interfacial morphology of Fe-Cr-B cast steel immersed in molten aluminum for 8 h are shown in Fig. 1 and Fig. 2, respectively. As shown in Fig. 1, PLSs appeared at the interface between Cr-rich Fe<sub>2</sub>B and molten aluminum. Obviously, PLSs were formed during the reaction between Cr-rich Fe<sub>2</sub>B and molten aluminum, in terms of either the eutectic or primary Cr-rich Fe<sub>2</sub>B (as shown in Fig. 1a, b, c). It was also evident that Cr-rich Fe<sub>2</sub>B exhibited a much slower reaction rate than the Fe substrate with molten aluminum, which could be inferred from the additional broken of B–B and B–M (M=Fe, Cr) chemical bonds. On the other hand, at least one of these two bonds is much stronger than Fe–M metal bond. Accordance to the results of line scanning of EPMA, the content

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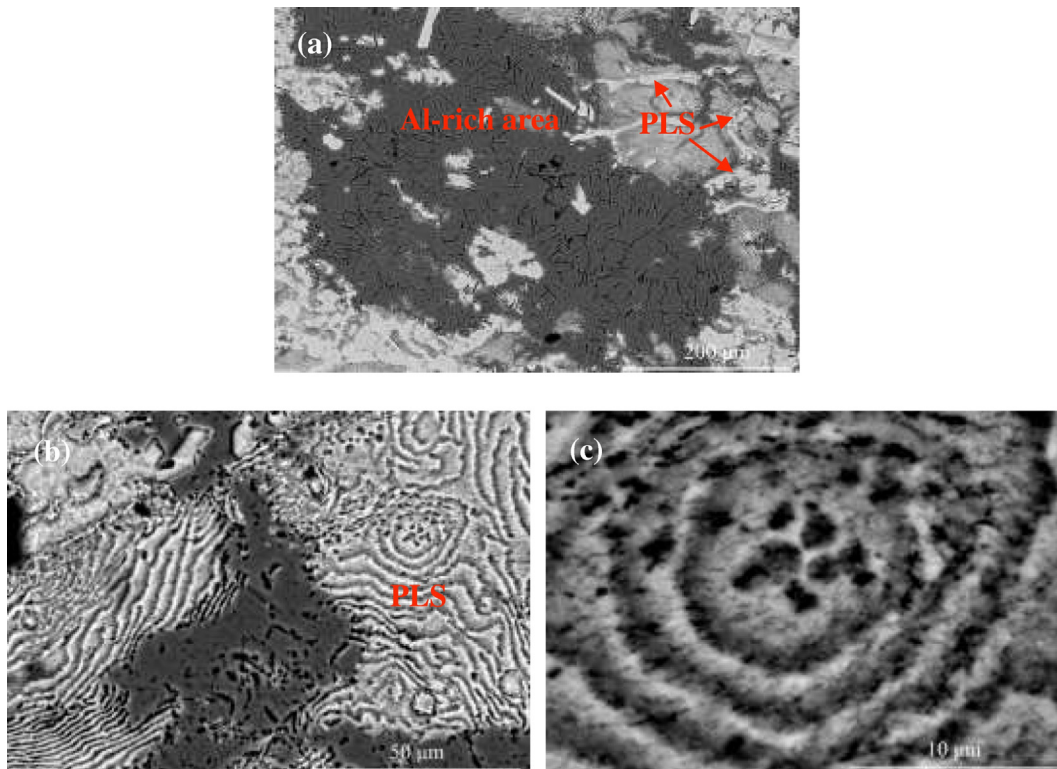
E-mail address: [xianman213@163.com](mailto:xianman213@163.com) (X. Zhang).



**Fig. 1.** Cross-sectional interfacial morphology of Fe-Cr-B cast steel immersed in molten aluminum for 8 h: (a) eutectic Cr-rich Fe<sub>2</sub>B, (b) primary Cr-rich Fe<sub>2</sub>B, (c) PLSs, (d) eutectic Mo-rich Fe<sub>2</sub>B.

variation of Fe and Cr in PLS was remarkably on the contrary. On the other hand, where the content of Fe was high, that of Cr was low. No cracks were observed in PLS. As shown in Fig. 2, PLSs still existed in

the longitudinal sectional microstructures. And part location of PLSs fractured during the reaction between Cr-rich Fe<sub>2</sub>B and molten aluminum, so that residual aluminum appeared among the fractured location



**Fig. 2.** Longitudinal sectional interfacial morphology of Fe-Cr-B cast steel immersed in molten aluminum for 8 h: (a) Al-rich area, (b) PLSs, (c) special structure.

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