

ADVANCED HEALING ARGENTS FOR SELF-HEALING CERAMICS

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ABSTRACT

Candidates of advanced healing argents for self-healing ceramics were determined in the present study. The advanced healing argents can induce the self-healing in wide temperature region compared to the silicon carbide as the original healing agent.

Self-healing ceramics are anticipated as one candidate of the next generation refractory materials for turbine blades instead of Ni-based superalloys, because the self-healing ceramics possess its high refractoriness, chemical stability and high mechanical reliability. In order to actualize the ceramic gas turbine blade, the most importance is to overcome the fracture induced by the foreign objective damage (FOD). It is difficult to prevent the occurrence of the FOD for the turbine blade, and FOD often leads to the critical fracture. Self-healing ceramic is one of the ceramic materials having high FOD resistance, because it is autonomically enable to heal the surface cracks introduced by FOD during service. Therefore, self-healing ceramics has enough high refractoriness and mechanical reliability to apply to the turbine blade of the next generation power plant and jet engine.

However, the reported self-healing ceramic, which the self-healing is induced by the high temperature oxidation of the dispersed silicon carbide particles [1], can perform the self-healing in only narrow temperature region, (1200 °C –1300 °C). The present authors [2] succeeded that the lower bound of the available temperature region is decreased by the nanometer-sizing of the dispersed SiC particles, while the nanometer-sizing of the dispersed SiC particles was found to decrease the maximum size of the healable crack. Thus, the present study discovered the advanced healing argents instead of silicon carbide. For the discovery, the potentials of aluminum based binary alloys were surveyed for the advanced healing argents.

The thermodynamic stabilities such as melting point, of the all aluminium based binary alloys (324 species) were firstly investigated. 86 alloys were selected if the melting point is higher than 1400 °C, corresponding to the heat resistance temperature of alumina as the general ceramic matrix. The selected alloys were ranked by the order of Clarke number of the element. As a result, TiAl, Nb-Al alloys (Nb₃Al, Nb₂Al, NbAl₃) and Mo-Al alloys (Mo₃Al, Mo₃Al₈) were determined to be candidates of the advanced healing argents.

The oxidation kinetics of Mo₃Al₈ (including 5 mol% Mo₃Al), NbAl₃ (including 15 mol% Nb₂Al), TiAl alloys were also estimated by means of TG-DTA analysis, as shown in Fig. 1. All the peak-temperatures of the alloy's oxidations, T_p , that were obtained under constant heating rates, b , were ~300 K lower than that of SiC. However, the formed oxide from Mo₃Al₈ (including 5 mol% Mo₃Al) alloy was gas phase. Thus, Mo₃Al₈ (including 5 mol% Mo₃Al) alloy was determined to be unsuitable for the healing agent because the vapour phase oxide cannot fill the space between the crack walls. Moreover, the gradient of the plots corresponds to the apparent activation energy of the high temperature oxidation. Thus, TiAl particle and NbAl₃ (including 15 mol% Nb₂Al) particle were also

found to exhibit lower activation energy of its oxidation than SiC particle. The vertical axis described as $\ln(b/T_p)$ is equivalent to the rate constant of reaction. Ceramics containing within SiC particles can be healed at 1200 °C in 10 h. At this situation, the rate constant of reaction is $\ln(b/T_p)=-14$. If the values of T_p when $\ln(b/T_p)=-14$ is defined as the lower bound of the available temperature region for self-healing, the temperatures of TiAl and NbAl₃ (including 15 mol% Nb₂Al) were evaluated to be 893 °C and 729 °C, respectively. Therefore, TiAl and NbAl₃ (including 15 mol% Nb₂Al) alloys were determined to be the most attractive candidate for advanced healing agent which can induce the self-healing at lower temperatures than SiC.

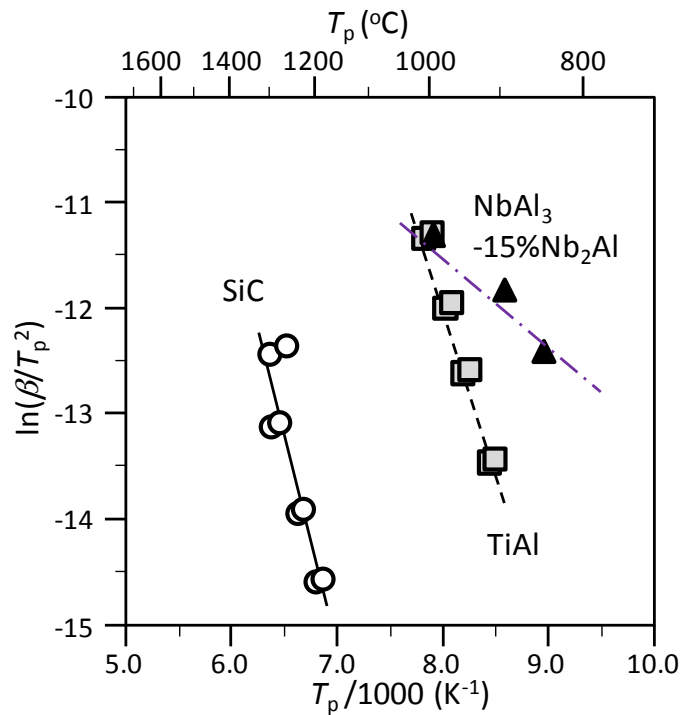


Figure 1 High temperature oxidation behaviours of the selected aluminium binary Alloys

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