

High-Temperature Oxidation of Macro- and Nano-Composites Made of Al₂O₃ Matrix and Ni Particles

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INTRODUCTION

Functionally graded materials (FGMs) are promising materials for high-temperature applications. Surface zone of heat-resistant FGMs can be regarded as ceramics dispersed metal particles. When oxide ceramics are used as the matrix, metallic particles will be oxidized by oxygen diffusing through the matrix at high temperatures. As almost metals expand by oxidation, the matrix receives stress from oxidized dispersoid. Finally the matrix will be fractured. The aim of this paper is to establish a kinetic model of oxidation of ceramic composites dispersed with metallic particles. In this study, Al₂O₃ matrix composites dispersed with Ni particles are used as a model material with a contribution of cation diffusion during high-temperature oxidation.

EXPERIMENTAL

Two different Al₂O₃ matrix composites dispersed with 5 vol% Ni (Ni/Al₂O₃) were produced for oxidation experiments at high-temperatures. One was a macro-composite, which was prepared by sintering a powder mixture of Al₂O₃ (0.3 μm) and Ni (10 μm) by mixing with a mortar. Another was a nano-composites, which was prepared by sintering a powder mixture made from a slurry with Al₂O₃ powder (0.3 μm) and aqueous solution of Ni(NO₃)₂. Ni Particle size of the nano-composites was approximately 200 nm. The samples were sintered by pulsed electric current pressure-sintering. The sintered bodies had at least 99 % of the theoretical density.

Sintered samples were exposed in air at temperatures ranging from 1200 to 1350°C. To examine the oxidation behavior, X-ray diffraction (XRD) and scanning electron microscopy (SEM) were carried out.

RESULTS AND DISCUSSION

Figure 1 shows the cross-sectional views of samples oxidized at 1300°C for 3 d. In the surface zone in depth of 100 μm of macro-composite, Ni particles disappear completely or partially and an oxidation product forms. XRD revealed that the oxidation product was NiAl₂O₄. A nano-composite has an oxidized zone with 200 μm in depth. A surface NiAl₂O₄ layer is also observed in both composites. The NiAl₂O₄ layer is an evidence of the existence of outward diffusion of Ni ion during high-temperature oxidation. Growth of oxidized zone obeyed the parabolic law in the both composites. Figure 2 shows temperature dependence of parabolic rate constant, k_p , on Al₂O₃ composites with Ni particles. The nano-composites have higher than the macro-composites. Higher oxidation rate of nano-composites is caused by finer grain size of Al₂O₃ matrix, because grain boundary diffusion dominates diffusion of polycrystalline Al₂O₃. The apparent activation energy corresponds to approximately 400 kJmol⁻¹ and is similar in the Al₂O₃ matrix composites. This means that oxidation of Al₂O₃ matrix composites with non-oxide particles are dominated by diffusion

process at grain boundaries of Al₂O₃ matrix.

CONCLUSIONS

High-temperature oxidation of Al₂O₃ matrix composites dispersed with Ni particles was investigated. An oxidation product was NiAl₂O₄. Growth of oxidized zone obeys parabolic law. Oxidation rate of nano-composite of Ni/Al₂O₃ has higher than the macro-composites, however the apparent activation energy was similar to the macro-composite.

REFERENCES

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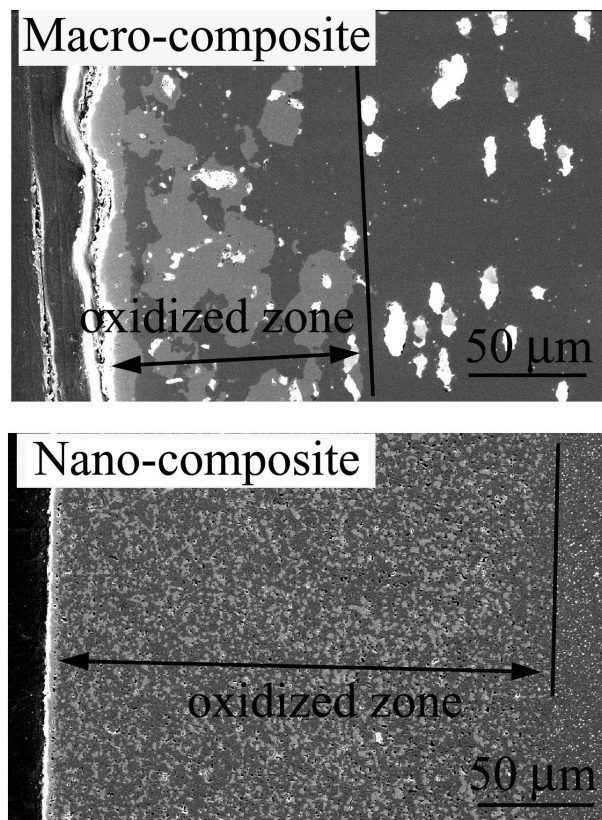


Figure 1 Cross section of Ni/Al₂O₃ oxidized at 1300°C for 3 d in air. (a) macro-composite and (b) nano-composite.

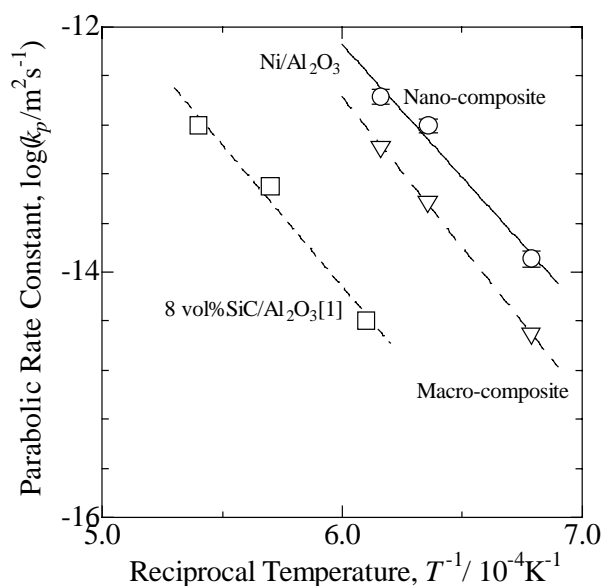


Figure 2 Temperature dependence of parabolic rate constant, k_p , on growth of oxidized zone of Ni/Al₂O₃.