The Fabrication and Characteristics of Gd_2O_3 Particle Reinforced Aluminum Matrix Composite

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1. Introduction

Neutron absorbing materials are very important for spent nuclear fuel (SNF) management, such as SNF transport and SNF storage. Neutron absorbing materials not only maintain sub-criticality but also conduct roles of mechanical support and heat spreader.

Recently, B_4C reinforced composite is used for neutron absorbing materials because of its high neutron absorbing capacity [1] and structural integrity. However, B_4C reinforced composite has its limitation of brittleness. When contents of B_4C increased, the brittleness of B_4C reinforced composite also increases [2].

Gd_2O_3 is the most promising candidate for replacing B4C due to its superior neutron absorbing ability. Gd has 60 times higher thermal neutron capture cross section so that it has 15 times better neutron capture ability than B_4C when Gd_2O_3 is used for reinforcement of composite.

By adopting Gd_2O_3 as a reinforcement of composite, 15 times smaller reinforcement contents are needed than B_4C composite for making neutron absorbing materials that have same neutron capture ability which means the composite can maintain its own ductility and thermal conductivity.

However, characteristics of Gd_2O_3 and Gd_2O_3 reinforced composites have to be investigated to check its feasibility for using actual neutron absorbing materials. The characteristics that should be checked are mechanical properties, thermal properties, and chemical reaction between matrix alloys.

In this study, bulk Gd_2O_3 and Gd_2O_3 reinforced composite were fabricated and characterized by Vickers hardness test, tensile test and scanning electron microscope (SEM).

2. Experimental procedure

2.1 Sample preparation

The fabrication procedure of bulk Gd_2O_3 consists of the following steps. First, Gd_2O_3 powder of 1 μm diameter was compacted by a uni-axial press with 400 MPa pressure and sintered at 1500℃ for 1, 2, 3 hours in air mood.

The fabrication procedure of bulk Gd_2O_3 consists of the following steps. 20 μm, 60 μm, and 100 μm sized Gd_2O_3 powder were mixed with aluminum alloy 7075 powder with 1.5 : 98.5 ratio by a 3D mixer, 40 RPM. The mixtures were pressurized at 50 MPa for sintering in a spark plasma sintering machine, heated to 450℃ for 5 minutes and held for 5 minutes.

2.2 Hardness test

The surface of bulk Gd_2O_3 and Gd_2O_3 reinforced composite for hardness test was polished to 2000grit using SiC polishing paper. The hardness was measured through Vickers hardness tester.

2.3 Tensile test

For the tensile test, the sintered samples were cut to a size of 2.7 * 2.0 * 11 cubic mm. Then, the tensile test was performed using a universal testing machine (UTM, Instron 5583, Instron Corporation, USA). At this time, the test was performed following ASTM E8.

2.4 Microstructure

The dispersion of the reinforcement and the microstructure of the specimen were observed with a scanning electron microscope (SEM). To determine the mode of failure of the material, the fracture surface after the bending test was also observed with SEM.

3. Result

3.1 Hardness test

The bending test has not yet been carried out.

3.2 Tensile test

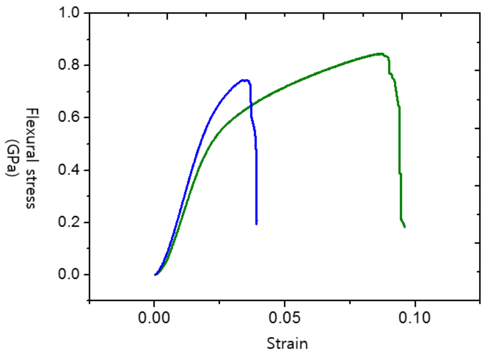

Fig. 1. Comparison of Gd_2O_3 1.5 vol% reinforced composite (green) and B_4C 20 vol% composite (blue) in bending test.

The tensile test has not yet been carried out, but according to bending test results (Fig. 1), the maximum strength is increased and maximum strain increased almost twice.

3.3 Microstructure

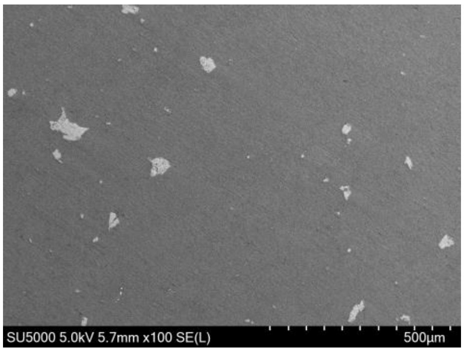

Fig. 2. Cross section image of 1.5 vol% Gd_2O_3 composite.

The Gd_2O_3 reinforecd composite shows well - dispersed microstructure and no macro scale secondary phase (Fig. 2).

4. Conclusion

In this study, characteristics of bulk Gd_2O_3 and Gd_2O_3 reinforced composite were investigated. The bending test result shows that two times higher maximum strain than 20 vol% B_4C reinforced composite. The microstructure analysis shows the well dispersion of Gd_2O_3 and no macro secondary phase.

In conclusion, Gd_2O_3 reinforced composite has no disadvantages in terms of mechanical strength and interfacial chemical reaction with aluminum 70705 matrix.

With proper further studies, Gd_2O_3 reinforced composite can replace the B4C reinforced composite as a next generation neutron absorbing material.

5. Acknowledgments

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