

Effects of Micro- and Nano-B₄C Fillers on Mechanical Properties of Epoxy Composites

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1. Introduction

Use of nuclear energy always requires safe and efficient transportation and storage of the radioactive wastes. In this regard, development of light and durable materials to shield various radiations is very important. In order to shield neutrons emitted from the spent nuclear fuel, a composite system of epoxy resin & B₄C filler has been introduced [1]. In this system, high concentration of hydrogen and boron in epoxy matrix can effectively attenuate high-energy neutrons and absorb thermal neutrons, respectively [2,3]. However, adding fillers into the epoxy matrix has been known to deteriorate the mechanical properties of the epoxy composite because the volume occupied by fillers is equal to the loss volume of matrix resin and adhesion between the particles and the epoxy resin is in general poor [4].

The deterioration of mechanical properties of the boron-epoxy composite makes its application as a neutron shielding material difficult. It should provide a mechanical reliability to endure exterior stresses including sudden deformation, friction and thermal shock, etc. Thus, it is a key issue in producing an epoxy-filler composite to suppress mechanical deterioration while maintaining the shielding capability simultaneously.

In this study, micro- and nano-B₄C particles were dispersed in the three-different epoxy matrix systems. The mechanical properties of the composites were compared with the pure epoxy resin to assess the change of mechanical deterioration. The effect of B₄C particle size on the mechanical properties of the epoxy composites was also investigated.

2. Methods and Results

2.1 Materials Preparation

A bisphenol-A type epoxy resin (YD127, Kukdo chem., Korea) and two hardeners (polyamide type G-0331 and cycloaliphatic amine type KH-816, Kukdo Chem., Korea) were mixed in three-different ways. Thus, three different types of epoxy matrix were prepared in this study. The epoxy matrices were named as YK, YG or YKG based on the hardener compositions applied to the matrix systems. In the epoxy matrices, micro-B₄C (~10 μm, Kojundo Chem., Japan) and nano-B₄C (~0.5 μm, Kojundo Chem., Japan) were dispersed at each epoxy matrix. Figure 1 shows SEM images of micro- and nano-B₄C particles used in the experiment.

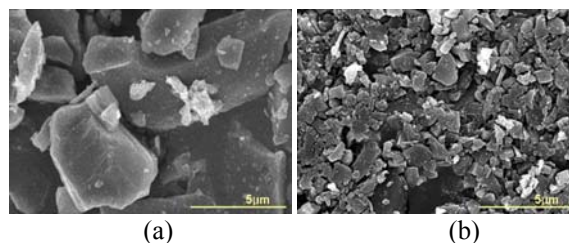


Figure 1. SEM images of the (a) micro-B₄C particles and (b) nano-B₄C particles

In order to suppress the foams and the pores in the epoxy and hardener mixtures, commercial defoamer (Antifoam, Dow Corning Inc., USA) was applied. In Table 1, the compositions of pure epoxy matrix as well as B₄C composites are summarized.

Table 1. Compositions of pure epoxy matrix and B₄C composites

	Resin (YD127)	Poly amide hardener (G0331)	Cycloaliphatic amine hardener (KH-816)	Defoamer (Antifoam)	Filler
YK	100phr		55phr	1phr	
YG	100phr	45phr		1phr	
YKG	100phr	20phr	25phr	1phr	
YK +micro B ₄ C	100phr		55phr	1phr	micro B ₄ C 1.5wt%
YG +micro B ₄ C	100phr	45phr		1phr	micro B ₄ C 1.5wt%
YKG +micro B ₄ C	100phr	20phr	25phr	1phr	micro B ₄ C 1.5wt%
YK +nano B ₄ C	100phr		55phr	1phr	nano B ₄ C 1.5wt%
YG +nano B ₄ C	100phr	45phr		1phr	nano B ₄ C 1.5wt%
YKG +nano B ₄ C	100phr	20phr	25phr	1phr	nano B ₄ C 1.5wt%

A mixture of epoxy resin, hardener and B₄C particles was mixed by a rotating blade in the sealed chamber of the epoxy mixing instrument (Dispermat, Reichshof Inc., Germany). During mixing, the chamber was continuously evacuated by a vacuum pump to extract the air bubbles in the epoxy mixture. The rotation speed of the blade was maintained in the range of 65 to 70 rpm, and the mixing time was 15 min. After mixing, the epoxy mixtures were placed in a drying oven and cured for 20 h at 50 °C. Cured epoxy matrices and composites

had no foams inside and showed no defects on the surface. However, in terms of the dispersion status, both micro- and nano-B₄C particles were relatively well dispersed in the YK and YKG matrices, while agglomerated B₄C was observed in the YG matrix as shown in the optical microscope images of the micro-B₄C composites in Figure 2.

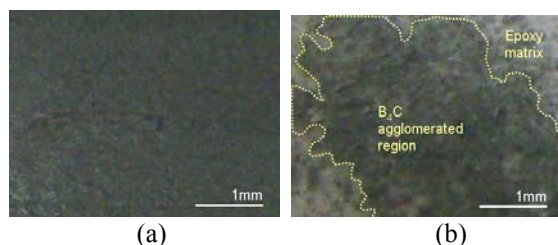


Figure 2. Optical microscope images of the micro-B₄C dispersed (a) YKG and (b) YG.

2.2 Mechanical Properties of the Epoxy Composites

To assess the change of mechanical properties, dumbbell-shaped tensile specimens of pure epoxy matrices and composites were prepared by pouring the samples into a Si rubber mold, then cured at 50°C for 20h. The dimension of tensile specimen and test method follow the ASTM D638-08 specifications. The thickness of the tensile specimens was 2.8 ± 0.2 mm. For each measurement, six tensile specimens were prepared. A versatile instrument (Instron 3000, Instron Inc., USA) to apply mechanical stresses was used for the tensile test.

In Figure 3, the average tensile strengths of YK, YG and YKG matrixes as well as their micro-B₄C composites are plotted. Small symbols above and below plots denote the maximum and minimum the measured tensile strengths. The numbers in parentheses present relative values of tensile strength to those for pure matrixes.

In all types of specimens, brittle fracture was dominant, and elongation rates of specimens were less than 2%. In the pure epoxy matrixes, YKG had the largest tensile strength, followed by YK and YG, respectively.

In YK and YG matrixes, an addition of 1.5wt% micro-B₄C filler resulted in decrease of tensile strengths, approximately 5% for YK matrix and 4.3% for YG matrix compared to pure matrixes. It is assumed that the drop of tensile strength in YG matrix is attributed to the agglomeration of B₄C particles shown in Figure 1.

Compared to YK and YG matrixes, YKG matrix maintained its tensile strengths regardless of an addition of micro-B₄C fillers. The reason why YKG matrix was able to maintain its tensile strength after the addition of B₄C fillers is not clear yet. A possible explanation may include that B₄C fillers were dispersed more uniformly at YKG matrix, and thus, the fillers did not make a larger agglomeration which might serve as a spot of stress concentration.

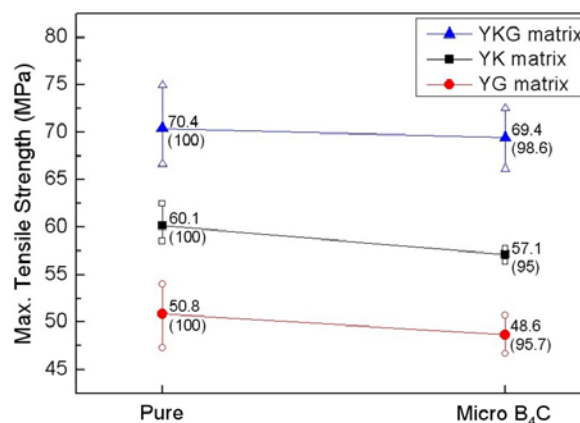


Figure 3. Tensile strengths of YK, YG and YKG matrixes and their composites

3. Conclusions

Three types of samples, pure epoxy matrixes, their micro- and nano-B₄C composites were prepared. An agglomeration of B₄C particles was observed on the surface of the YG composite while the dispersion of the B₄C particles in the other resins was observed better. Tensile tests were performed for YK, YG, and YKG matrixes and their composites. Consequently, YKG produced the highest tensile strength. And B₄C filler in the composites might cause decrease of the tensile strengths for YK and YG matrixes while maintained for YKG matrix as expected from the degree of particles dispersion. Mechanical properties of the micro- and nano-B₄C epoxy composites in depth will be given at the conference.

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