Mechanisms of the reaction of nuclear graphite with air

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1. Introduction

Nuclear graphite has valuable properties such as low atomic number, high specific strength and stiffness, high heat resistance and high thermal shock parameters. As a result, they have been used widely in nuclear reactors especially in high temperature. Also, graphite has ideal properties for nuclear reactor is an excellent solid moderating material with irradiation performance.

However, the mechanical properties of graphite are generally known to be degraded by oxidation, in which the air and water ingress causes the graphite to be oxidized.

Moreover, the oxidation graphite is a one of the important analyzing factor for nuclear reactor's safety and life time. In some accident scenarios for nuclear reactors, nuclear graphite is exposed to air at high temperature. The reaction of nuclear graphite with air is known that oxidation behavior is controlled by three different regimes. They are the chemical regime, the in-pore diffusion controlled regime and the boundary layer controlled regime (Luo Xiaowei, 2004; O'Brien et al,. 1988)

At low temperature, oxidizing gas and graphite reacted very slowly. The oxidized depth of graphite was very large. The chemical reaction mechanism was predominated at this regime. In contrast, Boundary layer reaction is preferred at high temperature. The surface of graphite is severely attacked by oxygen rather than interior graphite body.

The purpose of this study is to evaluate the mechanism of air oxidation for nuclear graphite (IG-110). And activation energy was observed by oxidation temperature

2. Experimental

The nuclear graphite was IG-110 produced by TOYO Tanso Co. Ltd., Japan. IG-110 was isotropic, fine-grained nuclear graphite. The dimension of specimen was 6mm*6mm*6mm.

The apparatus used for thermo-gravimetric analysis was TG-SDTA 851e model (Mettler Toledo Company). That is working from ambient to 1600°C

The oxidation experiment was performed at 600~1300°C. The oxidant was dry air (water content <2ppm). The atmosphere was used kept with N_2 until target oxidation temperature. The first oxidation test was performed to 1300°C for detecting weight loss and oxidation rate. The second oxidation test was performed at 600, 800 and 1000°C to 2wt% loss for detecting microstructure of nuclear graphite after oxidation.

3. Results and discussion

Fig. 1 shows the oxidation rate(%/min) of nuclear graphite(ig-110) up to 1300°C. Oxidation rate was depended on the temperatures. The oxidation was begun from approximately 450°C, increased rapidly to 950°C and then increased slightly above the temperature.

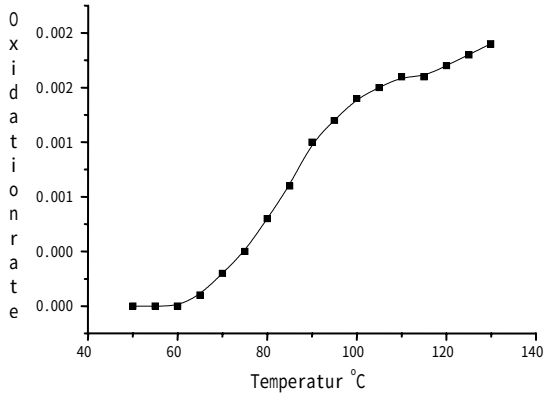

Fig. 1 Oxidation rate(%/min) of nuclear graphite as a function of temperature

Fig. 2 shows the activation energy of nuclear graphite specimen as a function of temperature. The activation energy was different at 567~730°C, 730~950°C and 950~1311°C respectively. This different activation energy was attributed three-oxidation regime comprising chemical reaction, in-pore diffusion controlled regime, boundary layer controlled regime.

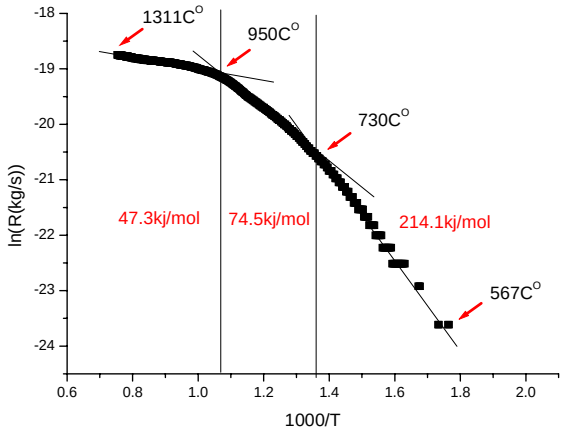

Fig. 2 Activation energy of nuclear graphite as a function of temperature

Fig. 3 shows the SEM images of surface morphology of graphite after oxidation. The weight loss was 2wt% at 600, 800 and 1000°C, respectively. Surface oxidation was fast at higher temperatures rather than at lower temperatures. The oxidation was occurred on graphite surface mainly at high temperature comprising a boundary layer reaction regime.

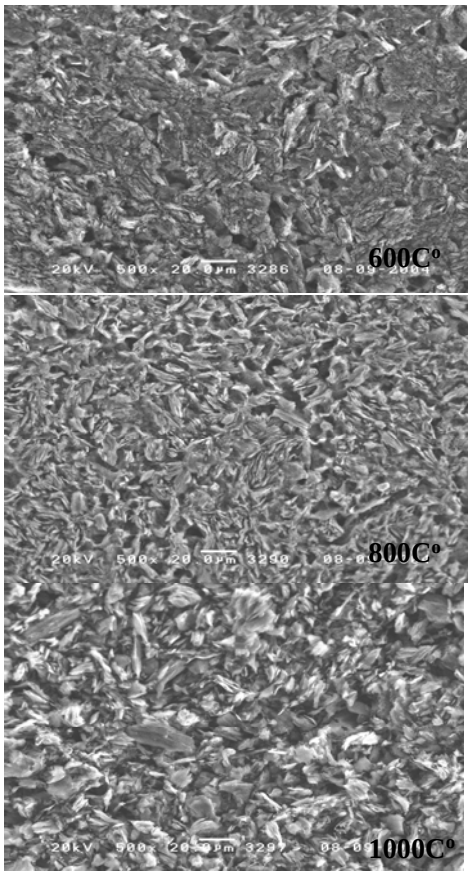

Fig. 3 SEM of nuclear graphite surface after oxidation (oxidation weight : 2wt %)

4. Conclusion

The oxidation was observed with 3-types as a function of temperature from 450°C to above 950°C. Activation energy showed at different regime of 567~730°C, 730~950°C and 950~1311°C due to three-oxidation regime

The surface oxidation was fast at higher temperatures rather than at lower temperatures. The oxidation was occurred on graphite surface mainly at high temperature that is boundary layer reaction regime.

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