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Change in Electrical Resistivity of Nuclear Graphite during Compression Test

Eung-Seon Kim*, Ji-Seon Song, Sung-Deok Hong, Yong-Wan Kim
Korea Atomic Energy Research Institute, 989-111 Daedeok-daero, Yuseong-gu, Daejeon, 305-353
**Corresponding author: kimes@kaeri.re.kr*

1. Introduction

Graphite will be used in a very high temperature gas-cooled reactor not only as a moderator and reflector but also as a major structural component owing to its excellent neutronic, thermal, and mechanical properties. During normal operation and accidents, these graphite components are subjected to various mechanical and thermal stresses so that investigation on the mechanical properties and fracture mechanism of nuclear graphite is needed [1, 2]. Normally, electrical resistivity of the material has strong relationship to its microstructure so that it can be efficiently used to clarify the fracture mechanism. In this study, the change in electrical resistivity of a nuclear graphite during compression test was examined.

2. Experimental

2.1 Materials and Specimen

The nuclear grade graphite IG-110 used in this study is produced by Toyo Tanso Co. Ltd., Japan. The petroleum coke based IG-110 is near-isotropic superfine-grained graphite produced by the isostatic molding method. The main properties of the material are summarized in Table 1. For compression tests, we used a rod type specimen with a dimension of 10 mm in diameter and 20 mm in length.

Table I: Main properties of IG-110

Property	Unit	IG-110
Density	g/cm^3	1.77
Porosity	%	20
Grain size	μm	20
Anisotropic ratio		1.04

2.2 Electrical Resistivity Measurement

The electrical resistivity was measured at room temperature using an ordinary potentiometric technique. The specimen was dried for 2 hr at 110°C, cooled to room temperature in a desiccator, and stored in a desiccator until tested. The means for applying current and potential terminals to the specimen was depicted in Fig. 1. Potential contacts to the specimen were made by using edges of steel wire of 0.5 mm in diameter. Silica plates were used for electrical insulation between the test piece and the jig. Compression tests were performed using an Instron model 5867 at room temperature at a strain rate of 8.3×10^{-5}/s.

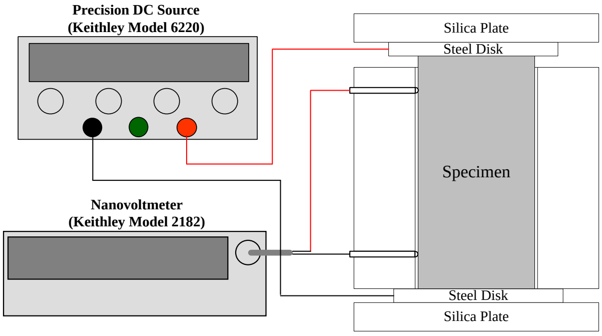

Fig. 1. Schematic diagram of the measurement technique

3. Results and Discussion

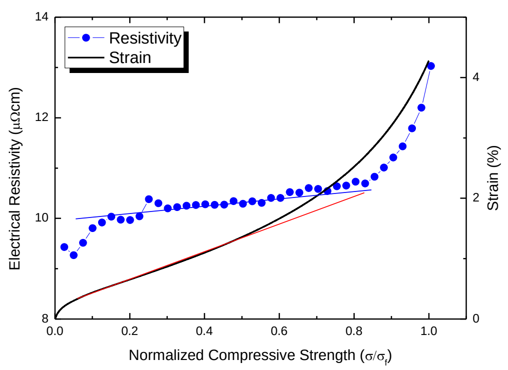

Fig. 2. Relation between electrical resistivity change and stress-strain during compression test

Change in resistivity during compression tests of IG-110 is shown in Fig. 2 where the strains calculated from the movement of the crosshead of the test machine are shown as a function of the normalized compressive stress.

The stress above which the marked resistivity increase is observed coincides with that where non-linearity of the stress-strain relationship becomes appreciable. It is found that the value of this stress is 0.5 to $0.6\sigma_f$, where σ_f is the compressive strength of the material. The fact that the formation or growth of optically resolvable cracks occurs at stress levels higher than 0.5 to $0.6\sigma_f$ has already been shown in the previous investigations [3, 4].

Meyer and Buch showed that the growth of cracks occurred along basal planes within the filler, not in the binder region [5]. At lower stresses (at most $0.1\sigma_f$), when the basal plane of the filler is parallel to the axis of applied stress, the deformation of microcracks, crack and pore results in increase in resistivity. In the case the basal plane is normal to the stress axis, the resistivity is decreased. In the isotropic graphite IG-110, resistivity-increasing and decreasing by the deformation of cracks and pores are believed to be in balance during the elastic deformation below $0.6\sigma_f$. To understand the between electrical resistivity change and stress-strain during compression test, the effect of compressive pre-stress on the porosity and surface area will be measured and analyzed in near future.

4. Summary

The nuclear graphite investigated in the present experiments showed an abrupt increase in resistivity when applied compressive stress increased to about $0.5\sim0.6\sigma_f$ where the non-linearity of the stress-strain curve became more pronounced. The increase in resistivity is attributed to the formation or growth of cracks.

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