Measurement of the Optical Anisotropy Factor of Simulated TRISO-coated Fuel Particles Using a Polarized Photometry

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1. Introduction

The TRISO(tri-isotropic)-coated fuel particle for a HTGR(high temperature gas-cooled reactor) with a diameter of about 1 mm is composed of a nuclear fuel kernel and outer coating layers. The coating layers consist of a buffer PyC(pyrolytic carbon) layer, inner PyC(I-PyC) layer, SiC layer, and outer PyC(O-PyC) layer as shown in Fig. 1[1], [2]. The anisotropy of pyrolytic carbon layers can be easily measured by an optical reflectance index using a polarized photometry[1]-[5]. The optical anisotropy factor of an I-PyC layer and an O-PyC layer of the simulated TRISO-coated fuel particles was measured by the developed photometer.

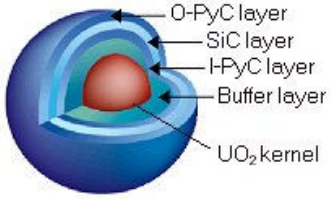

Fig. 1. Structure of a TRISO-coated fuel particle.

2. Optical Anisotropy Factor

Anisotropy of pyrolytic carbon layers of TRISO-coated fuel particles is one of the most important parameters to be measured. TRISO-coating layers can be destroyed by a large crystallographic anisotropy during irradiation. Hence, the coating layers of TRISO particles should be crystallographically isotropic. OPTAF(optical anisotropy factor) is used to measure the anisotropy of the pyrolytic carbon layers of the TRISO-coated fuel particles instead of BAF(Bacon anisotropy factor). OPTAF is the ratio of the maximum reflection index , R_{max}, over the minimum reflection index, R_{min}, of polarized light as the equation (1)[4]. OPTAF is more applicable to the TRISO particles than BAF which makes use of X-ray. The OPTAF is related with the BAF as the following equation (2)[4].

$$OPTAF = \frac{R_{max}}{R_{min}} \quad (1)$$

$$OPTAF = \frac{1 + \eta_c + \eta_c BAF}{2\eta_c + BAF} \quad (2)$$

Where, η_c is 3.52 which is the anisotropy factor of mono-crystalline graphite. Fig. 2 shows the relation between the OPTAF and the BAF for PyC material[4].

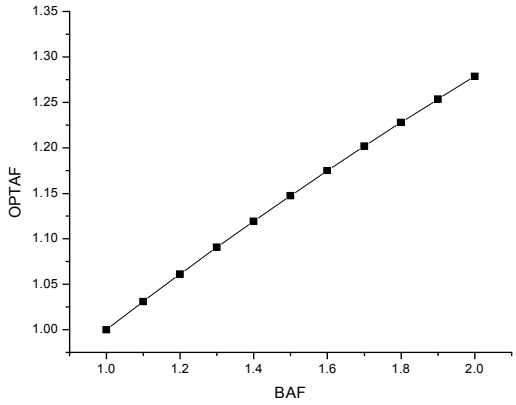

Fig.2. The relation of the OPTAF and the BAF.

3. Measurement of OPTAF

To measure the OPTAF of a sample, a polarization filter or a sample should be rotated. In the experiment, the polarization filter was rotated to constantly maintain the measurement area. The measurement area could not be maintained constantly during the rotation of the sample because of a mechanical error of the rotator for the sample. The optical source is a mercury lamp with a wavelength range of 250~580 nm. The diameter of the measurement area is about 13 μm for the magnification ratio of 200 in the microscopic photometer[5]. The OPTAF was measured in the I-PyC layer and O-PyC layer for five simulated TRISO-coated fuel particles as a sample batch. Four measurement positions were selected on each layer as shown in Fig. 3.

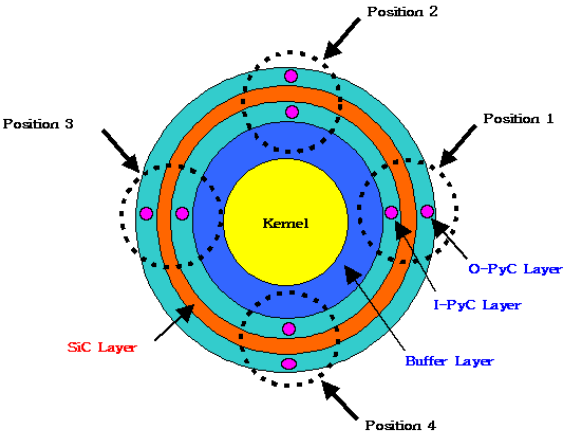

Fig.3. Measurement area of the optical anisotropy factor.

4. Result of Experiment

The optical reflectance was measured on the measurement surface of a polished particle by rotating the polarizer from 0 to 360 degrees with a step of 30 degrees. The relative optical reflectance index was calculated based on the minimum level as shown in Fig. 4. The maximum level reveals the anisotropy of that position.

Fig. 5 shows the experimental results measured for 5 simulated TRISO-coated fuel particles in a sample batch. The anisotropy of the I-PyC layer ranged from 1.04 to 1.07. The mean value was 1.05. The anisotropy of the O-PyC layer ranged from 1.04 to 1.08. The mean value was 1.06.

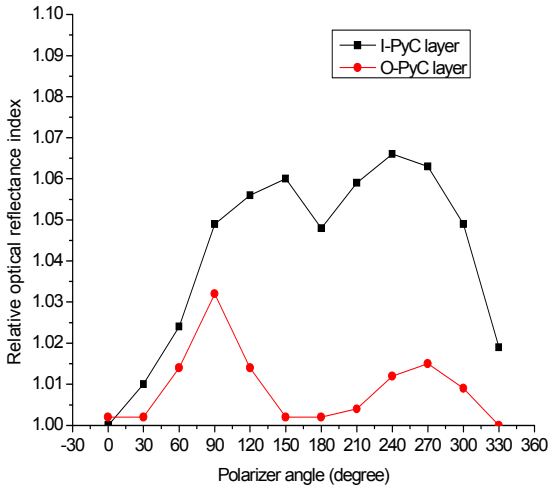

Fig. 4. The measured relative optical reflectance index according to the variation of polarizer angle on a sampled position for a simulated TRISO-coated fuel particle.

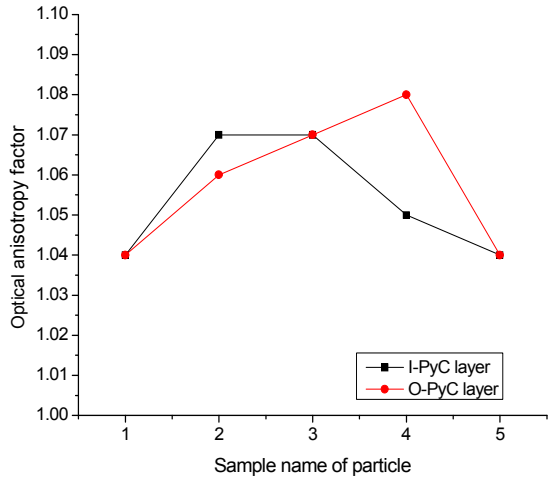

Fig. 5. The measured OPTAF for five simulated TRISO-coated fuel particles.

5. Conclusion

In this study, optical anisotropy factor of simulated TRISO-coated fuel particles was measured by the photometer system with a polarized optical microscope, light source and detector. The experimental results are as follows.

- Polarization filter was rotated to constantly maintain the measurement area with a spot diameter of 13 μm constantly.
- The OPTAF of the I-PyC layer was 1.05, which means 1.16 of BAF. The OPTAF of the O-PyC layer was 1.06, which means 1.20 of BAF.
- The optical anisotropy factor was successfully measured for the simulated TRISO-coated fuel particles. The measurement technology will be applied to evaluate the anisotropy of the pyrolytic carbon layers of TRISO-coated fuel particles.

Acknowledgement

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