Development of Real-Time Measurement System for Emission and Absorption of Visible Light during Heavy Gamma-Ray Irradiation

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Abstract

A system for the real-time measurement of the visible light emission from and absorption by a material in an intense gamma-ray field was developed. The combination of direct visual observation and optical spectrophotometric analysis is expected to provide powerful clues for elucidating various phenomena caused by irradiation effects.

Keywords: Real-time measurement, Gamma-ray irradiation, Silver nanoparticles, Real-time observation.

1. Introduction

The study of gamma ray-induced changes in material using offline methods may be time-consuming, expensive, and may involve a post-irradiation time delay effect. In this study, a system for continuously monitoring the optical absorption, and the color change of the material under exposure to gamma rays has been developed in our irradiation facility of OPU.

2. Experimental

A white light-emitting diode produced a visible light beam (400–700 nm) that passed through an irradiated specimen and was measured by an UV-Vis spectrophotometer through a long glass optical fiber. A video camera with 2 megapixel provided visual observation of the gradual color change of the irradiated specimens. Gamma-ray exposure experiment was performed using a 557 TBq Cobalt-60 source. The dose rate was measured with a small-sized ion chamber (PTW, type 31013). From calculation results, the light source and the detection fiber were successfully protected from irradiation using close shielding of lead blocks. In order to study the formation of silver nanoparticles (AgNPs) in detail, blue color dye (Brilliant Blue FCF) was added to the radiolytic medium to observe the interaction among radiation-introduced radicals in water, generated AgNPs (using silver powder precursor, 44 μm grain size), and dye molecules.

3. Results and discussion

Figure 1 shows the change of the absorption spectrum as a function of irradiation dose. During irradiation, the sample exhibited a yellow color and an absorption band located at around 430 nm that corresponds to the surface plasmon resonance absorption of AgNPs. The intensity of this band increased progressively with the increase of dose and shifted toward longer wavelengths. The peak absorption intensity at 630 nm, which represents the deep blue color, was considerably decreased. The dye deformation was inhibited during the formation of AgNPs. Meanwhile, the morphology/growth of AgNPs was affected by the fragmentation of the dye molecules during exposed to gamma rays. It was also found that the amount of generated AgNPs was reduced in the real-time mechanical stirring condition.

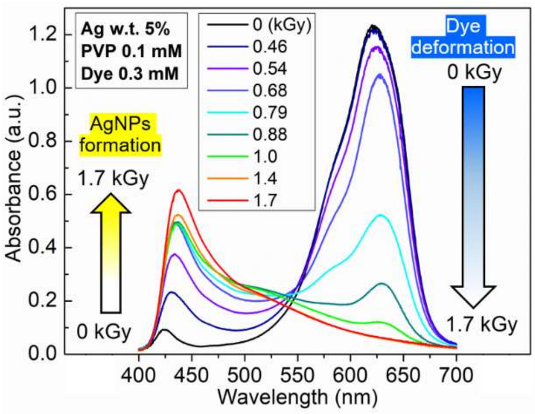

Figure. 1. Variation of absorption spectrum as a function of absorbed dose.

4. Conclusion

The feasibility of the real-time measurement system operating in a high dose field was validated. The irradiation effect was analyzed at a dose fidelity, with minimal need for specimens. The system has various advantages that are competitive with the conventional method: cost-effectiveness, minimal time consumption, and provision of timely/precise information.

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