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FTIR Trace of a HDPE Neutron Moderator Exposed to a Gamma Radiation

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1. Introduction

High density polyethylene is employed in the moderator of a neutron counter for a specific nuclear material accounting during a spent fuel processing in laboratories and radiochemical plants. Radiation effects of an HDPE moderator are not serious in the case of a nuclear material accounting without gamma emitting fission products in the final products such as a wet processing. But if the gamma emitting fission products include in a nuclear material such as during a dry processing, the HDPE moderator is affected by the gamma radiation emitting from the fission products in the material. Then, the neutron moderating power of the HDPE can be affected due to a molecular structure change, swelling, radiation-induced oxidation, etc. Therefore, it is required to confirm this variation of the neutron moderating power of the HDPE according to a radiation exposure for a correct analysis of the data acquired from a neutron measurement of nuclear materials.

2. Methods and Results

2. 1. Gamma Irradiation

HDPE neutron moderator structures were exposed to a gamma radiation in KAERI's (Korea Atomic Energy Research Institute) high level irradiation facility. The five HDPE structures were irradiated in the range of 10^5 - 10^9 rad by the gamma ray emitted from Co-60 with an energy of 1,173/1,332 keV. One HDPE structure was not irradiated, so we could use it as a reference for comparison purposes. The structures were rotated on the sample holder in the high level irradiation facility for a homogeneous exposure because of their voluminous structure.

2.1. FTIR Spectroscopy

Fourier transform infrared spectroscopy (FTIR) has become one of the favored techniques, from among a nuclear magnetic resonance spectroscopy (NMR), electron spin resonance spectroscopy (ESR), gel permeation chromatography (GPC), swelling analysis, and so on for analysing the effects of an ionizing radiation on polymer materials. In this test, a broadband infrared source was transmitted through a thin section on to the fresh HDPE and irradiated ones whose thicknesses were 200-300μm. Chemical species were activated by light at a specific frequency, so they would absorb the energy at this frequency.

2.3. Results

Fig.1 is a FTIR spectrum plotting of the six FTIR data sets obtained from the un-irradiated and irradiated HDPE moderators in order to clearly observe any differences, and the key frequencies used to identify the radiolytic yields in the HDPE were cited in the presentations given at conferences by researchers from the Cambridge Polymer Group.[1] Figs.2 and Fig.3 are the extended FTIR traces to observe the differences in detail. Trans vinylene group related to a cross-linking at wave number

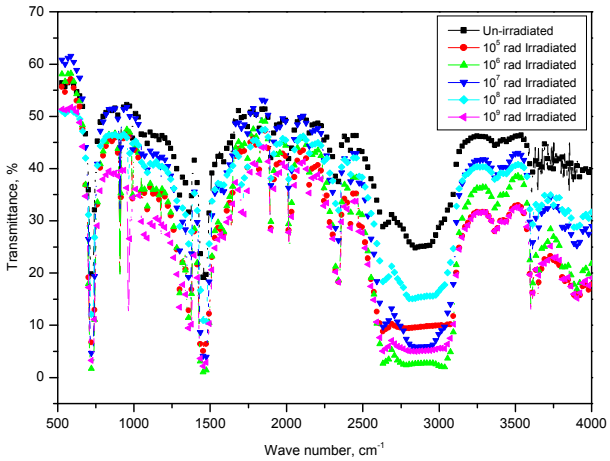

Fig.1. FTIR trace of the un-irradiated and irradiated HDPE at the range of 500-4,000 cm^{-1}.

965 cm^{-1} and a terminal vinyl group related to a cross-linking and scission at wave number 910 cm^{-1} were observed as shown in Fig.2. The un-irradiated HDPE moderator did not change its molecular structure at 965 cm^{-1}, while all of the irradiated moderators had changed their molecular structures at this wave number. It means that the trans vinylene group was produced due to a radiation exposure.

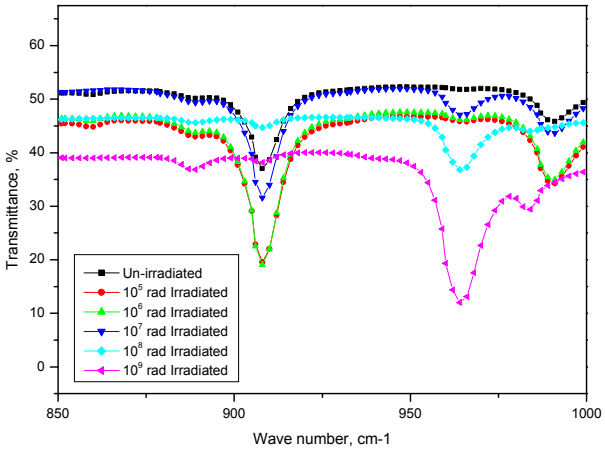

Fig.2. Extended FTIR trace of the un-irradiated/irradiated HDPE at the range of 850-1,000 cm^{-1}.

A peak of a methyl group stretching ($-CH_3-$) at 1,303 cm^{-1} was observed and a peak at 1,370 cm^{-1} associated with an amorphous region was also observed. These peaks seem to be produced by a thermal transformation of the HDPE fabrication process from PE powder because there is a peak of the un-irradiated HDPE as well as the irradiated ones. Also the carbonyl groups (C=O) related to an oxidation at 1,700 cm^{-1} were formed and a peak associated with a crystal region appeared at 1,897 cm^{-1} as shown in Fig.3.

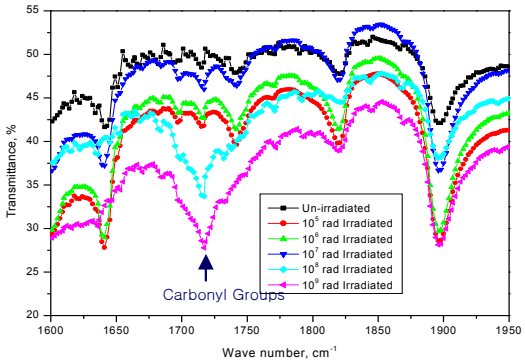

Fig.3. Extended FTIR trace of the un-irradiated/irradiated HDPE at the range of 1,600-1,950 cm^{-1}.

3. Conclusions

It was confirmed that the molecular structure of gamma irradiated HDPE had partially changed to the terminal vinyl groups, trans vinylene groups, and carbonyl groups, related to a cross-linking, scission, and oxidation as a result of the FTIR spectrum analysis.

Reference

[1] Stephen Spiegelberg, Analytical Techniques for Assessing the Effects of Radiation on UHMWPE, Cambridge Polymer Group, Inc., 1-9(2001).