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Relaxation of Radiation Effects on the Optical Transmission of Polymers

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ABSTRACT

Changes in optical transmission of polymers over time were studied to determine the factors contributing to relaxation of defect states induced by intense radiation doses. Samples of low density polyethylene (LDPE), polyether ether ketone (PEEK), and polypropylene (PP) received doses up to 500 MGy from an 8 MeV electron accelerator. These doses were intended to simulate long-term exposure of common spacecraft materials in geosynchronous orbit. Features and absorption edges in ~250 nm to 1000 nm UV to IR transmission spectra can be related to energies associated with various defects previously observed in these highly disordered materials. Recent work has suggested that such radiation-induced defect states are sensitive to atmospheric exposure and that the radiation-induced effects would begin to relax. Upon prolonged exposure, the material would return to its original state. These findings have called in to questions the usefulness of many previous studies of radiation effects on spacecraft materials. After irradiation, transmission spectra were collected as soon as the samples were exposed to oxygen and water vapor in the atmosphere. Between irradiation and the time data collection began, the samples were stored in anaerobic environments. The spectra were collected periodically over several weeks in order to allow for accurate comparisons and to determine the relation rates and final equilibrium states.

PURPOSE & HYPOTHESIS

Long-term exposure of polymers to radiation is known to cause defect states in the bonding of these polymers. While defect states are known to exist, not a lot of studies have been done to characterize their properties. One such property is the length of time that the defect states exists. It is believed that once a polymer is exposed to oxygen the defect states will begin to relax and the polymer will return to its original form. The purpose of this study was to quantify the time that it takes samples of low density polyethylene (LDPE), polyether ether ketone (PEEK), and polypropylene (PP) to relax and lose their irradiated properties. It is predicted that the time required for a polymer to relax and return to its original form is shorter than expected. It could take several weeks, days, or even hours. If this is true, then many tests and studies of irradiated polymers may not be accurate. In order to study the relaxation of polymers and better understand their properties, transmission data was collected and analyzed.

ACKNOWLEDGEMENTS

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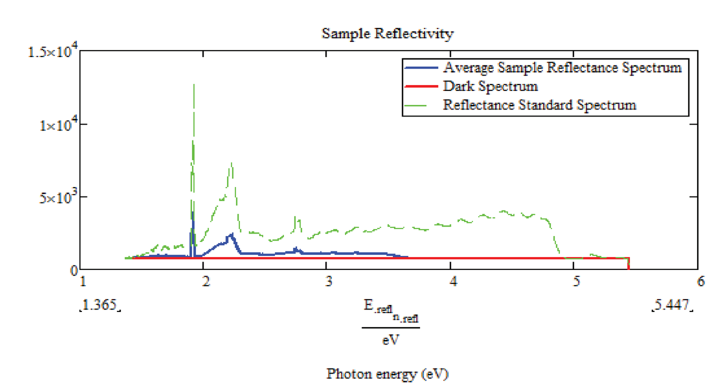
DATA

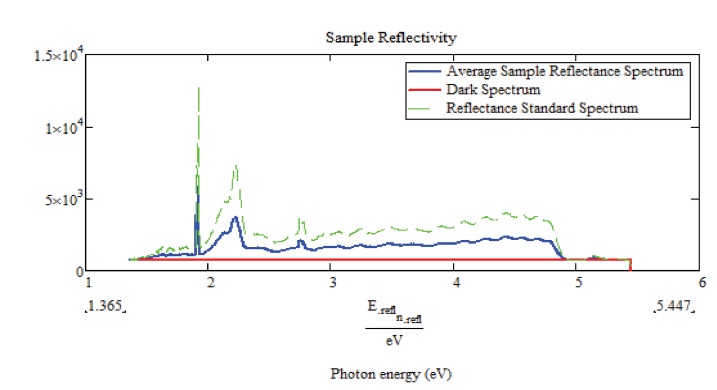
Non-Irradiated Transmission Spectrum

Polyether Ether Ketone (PEEK)



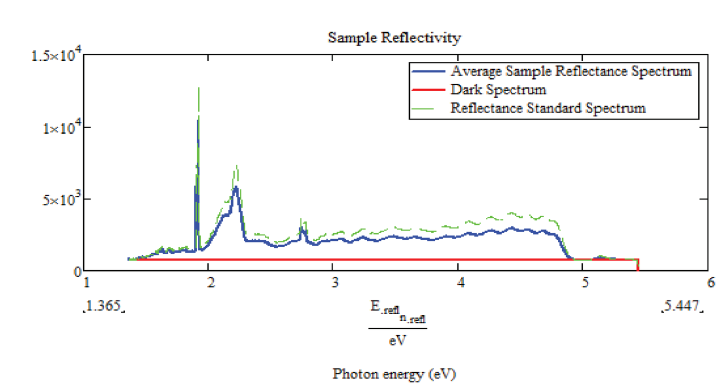
Graph 1: Transmission spectrum of non-irradiated polyether ether ketone

Polypropylene (PP)



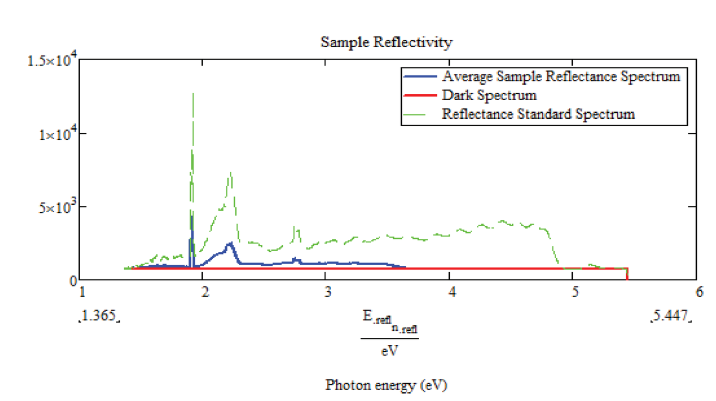
Graph 5: Transmission spectrum of non-irradiated polypropylene

Low Density Polyethylene (LDPE)

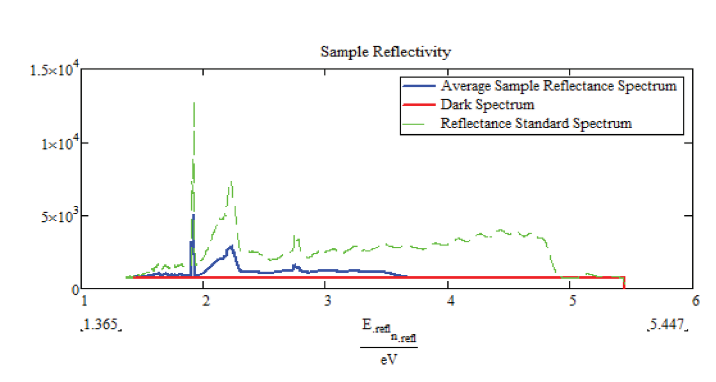


Graph 9: Transmission spectrum of non-irradiated low density polyethylene

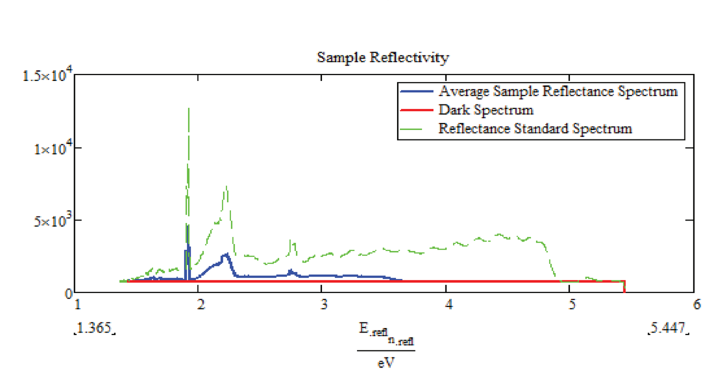
Irradiated Transmission Spectrum



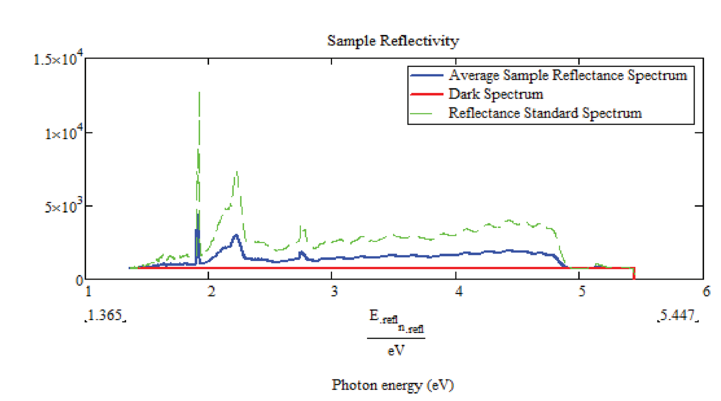
Graph 2: Transmission spectrum of irradiated polyether ether ketone after being exposed to oxygen for 8 minutes



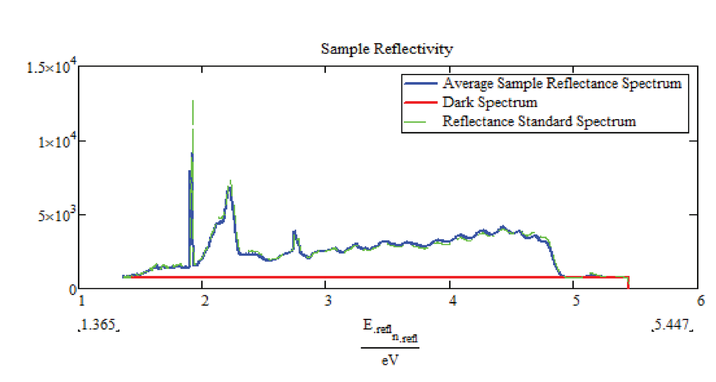
Graph 3: Transmission spectrum of irradiated polyether ether ketone after being exposed to oxygen for 64 minutes



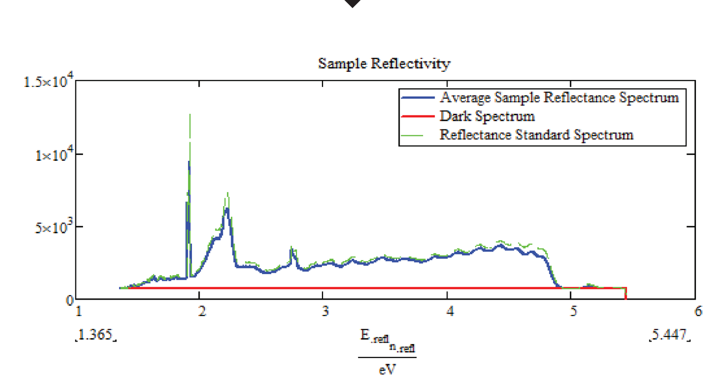
Graph 4: Transmission spectrum of irradiated polyether ether ketone after being exposed to oxygen for 1510 minutes



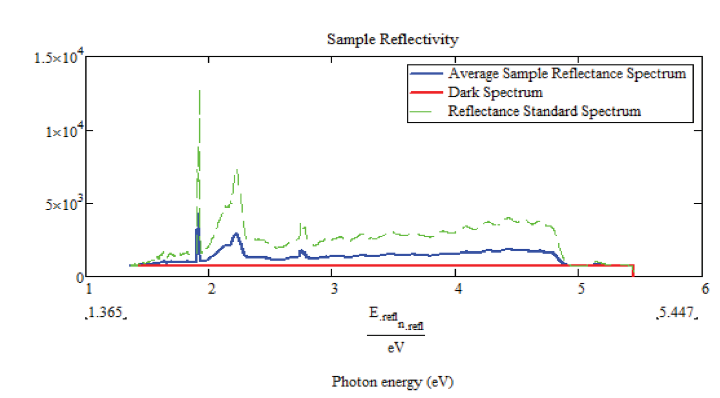
Graph 6: Transmission spectrum of irradiated polypropylene after being exposed to oxygen for 10 minutes



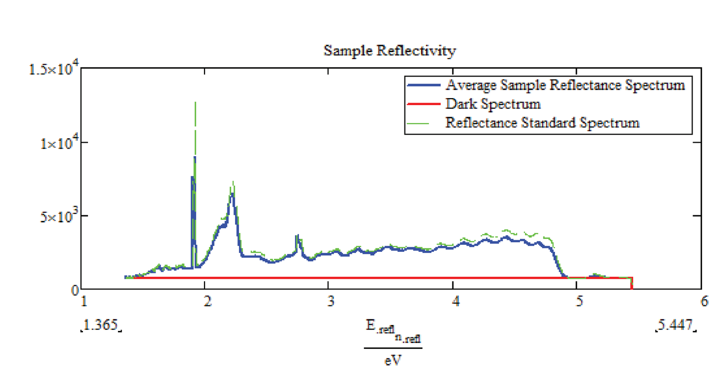
Graph 7: Transmission spectrum of irradiated polypropylene after being exposed to oxygen for 66 minutes



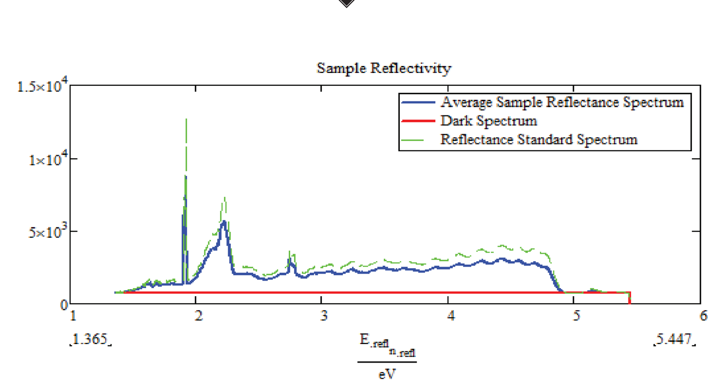
Graph 8: Transmission spectrum of irradiated polypropylene after being exposed to oxygen for 1512 minutes



Graph 10: Transmission spectrum of irradiated low density polyethylene after being exposed to oxygen for 13 minutes



Graph 11: Transmission spectrum of irradiated low density polyethylene after being exposed to oxygen for 68 minutes



Graph 12: Transmission spectrum of irradiated low density polyethylene after being exposed to oxygen for 1514 minutes

APPARATUS / METHODS

In order to collect transmission data, an Ocean Optics High-Resolution Spectrometer (HR 4000) was connected to a Remote UV light source using Ocean Optic's fiber optics cables. The spectrometer simultaneously exported the data to a program called SpectraSuite as seen in Figure 1. Samples were mounted to index cards, as seen in Figure 2. When data collection began, the samples were placed between the two fiber optic lines, as seen in Figure 3 and light from the light source passed through the sample. Light from the source was transmitted, reflected, and absorbed by the sample. The spectrometer measured the transmitted light and sent the data to the computer. Calculations were made using the equations in Figure 4.

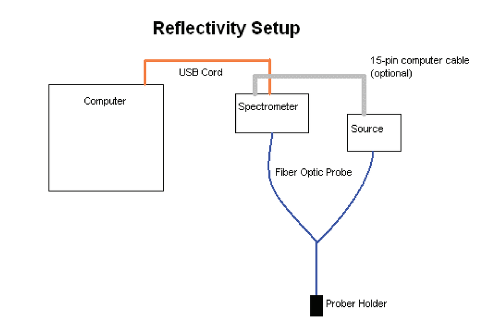


Figure 1: Experimental set up of the spectrometer and other components

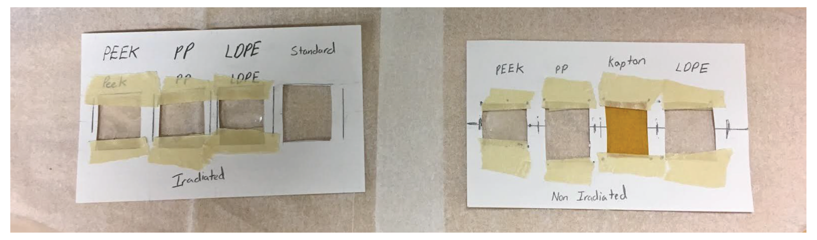


Figure 2: Samples mounted on Index cards so their transmission spectrums can be measured

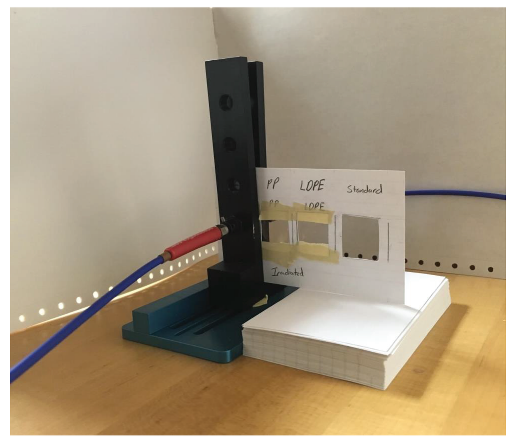


Figure 3: Samples placed between two optical fibers to measure their transmission spectrums

$$\%\ Total\ Transmission = \frac{I_{SR} - I_D}{I_N - I_D}$$

$$\%\ Change\ in\ Transmission = \frac{I_{SR} - I_D}{I_S - I_D}$$

Figure 4:

I_{SR} = Intensity of Transmitted Light from Radiated Sample

I_D = Intensity of Transmitted Light from Dark Sample

I_N = Intensity of Tranmsitted Light from No Sample

I_S = Intensity of Transmitted Light from Normal Sample

CONCLUSIONS

The data collected showed that the radiation effects on the transmission of polypropylene and low density polyethylene relaxed over time. In order to confirm the validity of this data and the exact time frame of the relaxation, the data will have to be analyzed and the experiment repeated. It does not appear that radiation changed the optical properties of polyether ether ketone; however, this may have been caused by a delay in the time between when samples were irradiated and the data collection began. The samples were stored in an anaerobic environment, but were briefly exposed to oxygen when being transferred from one anaerobic environment to another. This brief exposure combined with the delay in data collection could have resulted in the relaxation of the irradiation effects. In order to correct this error and validate the data, the experiment with be repeated and the data will undergo further analysis.