X ray- and UV-induced Free Radicals in Polycarbonate Urethane (PCU)

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Statement of Purpose: Polycarbonate urethane (PCU) is a material with medical implant applications similar to ultra-high molecular weight polyethylene (UHMWPE), such as to serve as hip liners or other related orthopedic components. As PCU is not yet a widely used biomaterial for such orthopedic applications, there are fewer studies in literature concerning it – especially those of our current interest – which is to evaluate effects of radiation; in particular, free radicals induced by ionizing radiation. We can advantageously perform X-irradiation, as well as UV (ultraviolet) treatments in-house, along with electron spin resonance (ESR) capabilities for free radical analysis, so we can therefore observe effects immediately after radiation exposure. Since we did not find previous studies which evaluate similar free radical production in PCU, this study may serve as a first in that regard.

Methods: Virgin (non-irradiated) PCU hip-liners were the materials used for this study. The hip liners were sectioned into small pieces of about 70 milligrams each for free radical analysis via electron spin resonance (ESR). Free radical testing was performed using a Bruker EMX X-band spectrometer operating at approximately 9.8 GHz. Samples were tested before and after radiation exposures. An Oriel® 250 Watt UV lamp was used to treat the PCU to UV-irradiation, and an American Scientific® X-ray machine operating at 50 kV, 40mA, with approximate average photon energy ~10 keV, was used for X-ray exposure.

Results: Before any radiation treatments, ESR tests for PCU did not indicate any presence of free radicals. When X-irradiated initially (30 minute X-ray exposure), free radicals were observed to have been produced, whose quantities for each tested specimens were unequal, although they all were from the same sample and underwent the same treatment. When a higher level of X-ray treatment was applied, a much larger quantity of radicals was observed, whose values did not vary very much. When a middle-level of X-ray treatment (60 minutes) was applied, radical observation were very similar to the 75-minute treatment ones, except slightly less intensity. When samples were irradiated with UV, there was a very small accumulation of free radicals. It was noticed that the PCU specimens turned quite yellow after UV-treatment (see figure 1). This arose suspicion of oxidation-related activity. We therefore UV-irradiated one set of specimens in nitrogen also to see if the lack of oxygen would keep the material from turning yellow.

Figure1. Yellowing of PCU (bottom) vs. non-irradiated PCU (top).

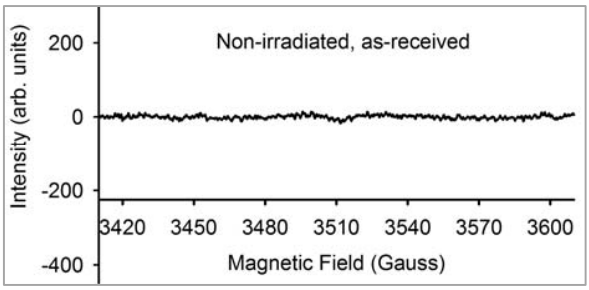

Figure 2. ESR spectrum showing no free radical in PCU before X- or UV- radiation exposure.

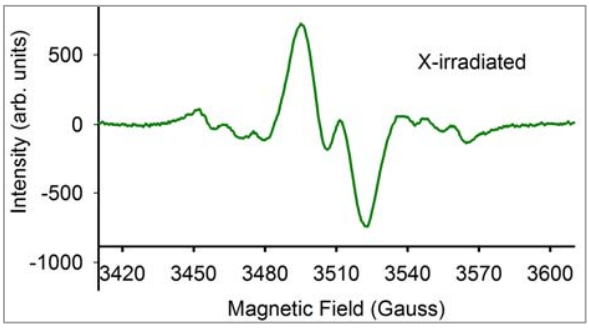

Figure 3. ESR spectrum of PCU showing major free radical presence after X-ray exposure.

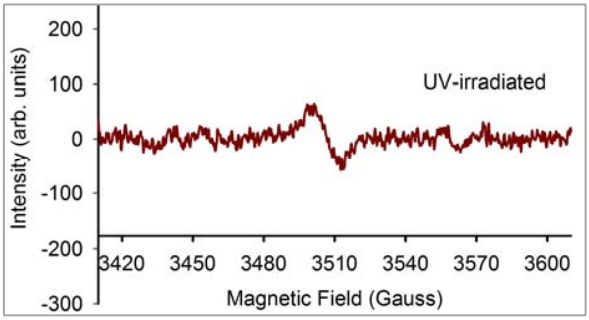

Figure 4. ESR spectrum of PCU showing major free radical presence after X-ray exposure.

Conclusion: This initial evaluation of radiation induced radicals in PCU resulted in significant radical accumulation in the material as a result of X-irradiation (figures 2 and 3), and a small quantity of free radicals were brought on by the UV-treatments (figure 4). There was no conclusive color change for samples treated with X-ray, but the specimens did turn yellow upon exposure to ultraviolet radiation. This could be beneficial information for future packaging of PCU; it is possible the materials may yellow over time if exposed to room light for extended time periods, which light-impermeable packaging may prevent. When UV-irradiation was performed in air vs. nitrogen, there did not appear to be any difference in yellowing, or in free radical content. For further study, it would be good to perform oxidation analyses following similar radiation exposures.