Gamma Radiation Sterilization: Its Effect on Polypropylene

Background

There exists today a wide variety of commercially available polypropylenes including homopolymers, random copolymers, and impact copolymers that are used in ever expanding applications. Many of these applications, including medical, require that the article be sterilized before use. The sterilization of polypropylene by Gamma Radiation is becoming one of the more common methods, and is often the choice for articles manufactured from polypropylene.

It is common knowledge that conventionally stabilized polypropylenes may not be suited for high-energy sterilization due to their loss of physical properties and discoloration that takes place immediately after sterilization, and which can further deteriorate with time. While these effects may be due to the inherent property of the polymer, the effects can vary significantly between varieties. Additionally, the addition of specialized additives can help to further mitigate these effects.

To provide further insight into the effect that Gamma Radiation on various forms of polypropylene, a select sample of homopolymer, random copolymer, and impact copolymer grades were subjected to gamma radiation at 28.1 to 34.8 kGy, a level appropriate for sterilization. After exposure, the physical properties of the samples were tested and compared to unexposed samples of the same material.

Experimental

In all, nine different grades of polypropylene were formulated and used for testing. These nine grades consisted of three Homopolymers, three Random Copolymers, and three Impact Copolymers. A base reactor powder was collected for each of the three forms of polymer and compounded in the lab with three different additive packages. The additive packages chosen were typical of what might be found in commercial grades of each form of polypropylene.

Additive package one consisted of a phenolic primary antioxidant, high performance phosphite secondary antioxidant, and acid acceptor. In additive package two, a Hindered Amine Light Stabilizer (HALS) was added to provide protection from the high energy radiation. In additive package three, the phenolic and phosphite antioxidants were replaced with a non-phenolic amine oxide.

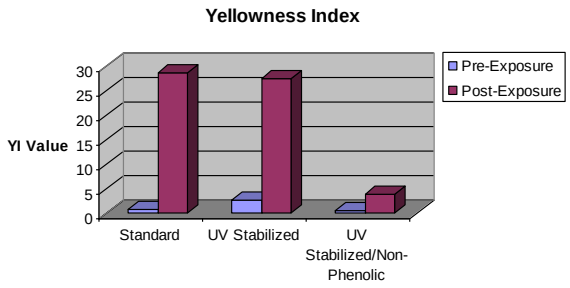
In addition to the basic additive packages mentioned above, additive package one for the homopolymer also contained a nucleator/clarifier, while additive package one for the random copolymer contained a sorbitol clarifier and antistat.

Effects of Radiation Exposure on Physical Properties

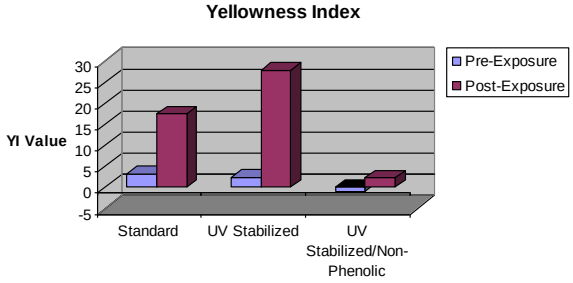
Yellowness Index

The yellowness index of each form of polypropylene increased after exposure to gamma radiation. The most dramatic increase occurred in the standard Homopolymer material. The least increase was noted in the non-phenolic Impact Copolymer.

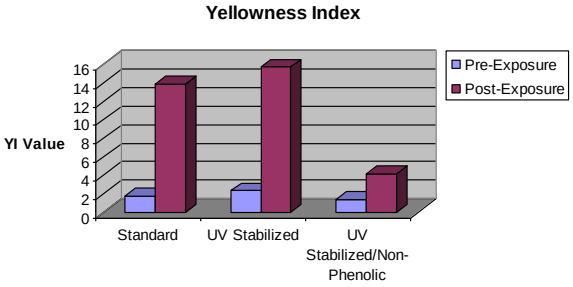
Homopolymer



Random Copolymer



Impact Copolymer



Tensile Strength

Gamma radiation had little effect on the tensile strength of each form of polypropylene tested, regardless of the

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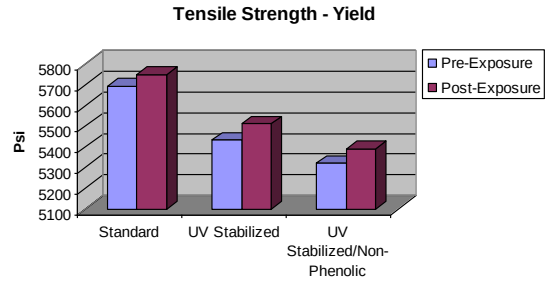
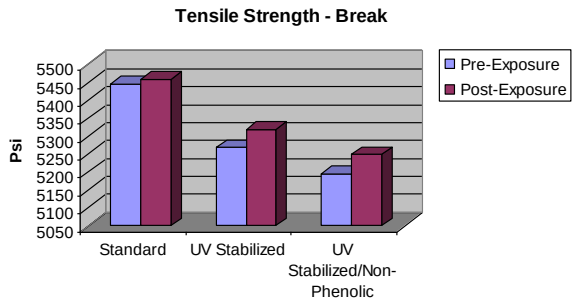
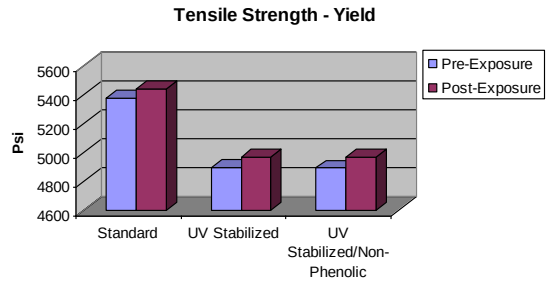
stabilization package. In all cases, tensile strength at yield and break changed by less the 2% after exposure.

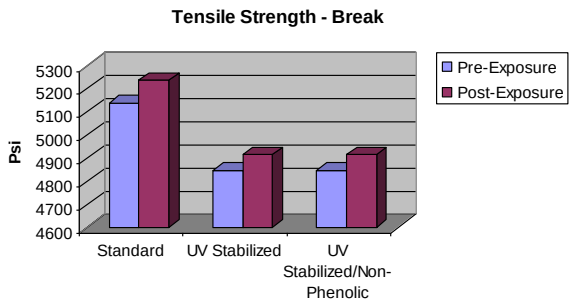
Homopolymer



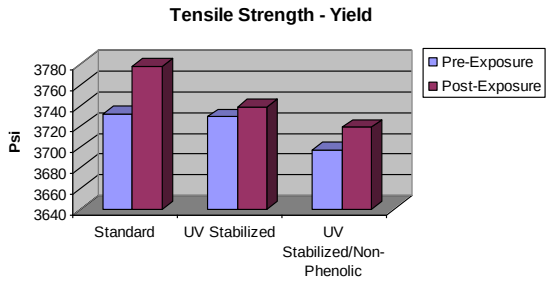


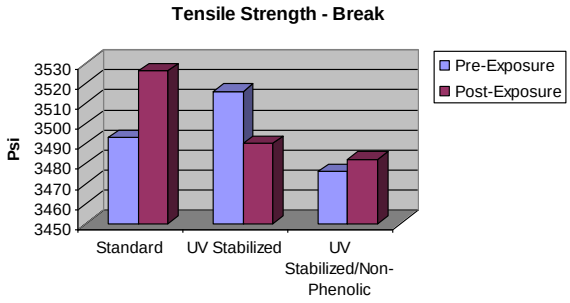
Random Copolymer





Impact Copolymer



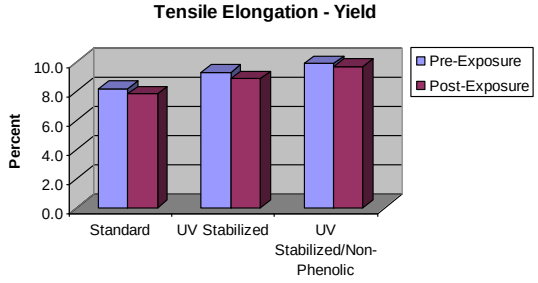


Tensile Elongation

Each form of polypropylene tested showed a slight decrease in tensile elongation at yield of up to 6% after exposure to gamma radiation. The reduction in tensile elongation was less for the Impact Copolymer compared to the Homopolymer or Random Copolymer.

In contrast, tensile elongation at break decreased significantly for each form of polypropylene tested, with the UV stabilized Random Copolymer showing the least amount of decrease.

Homopolymer



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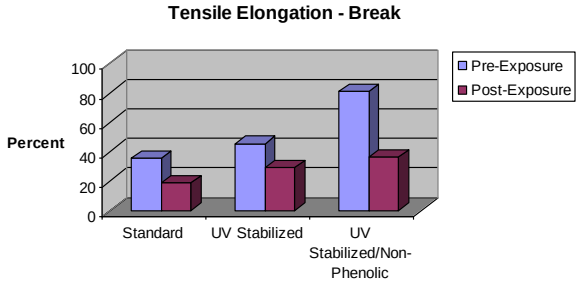
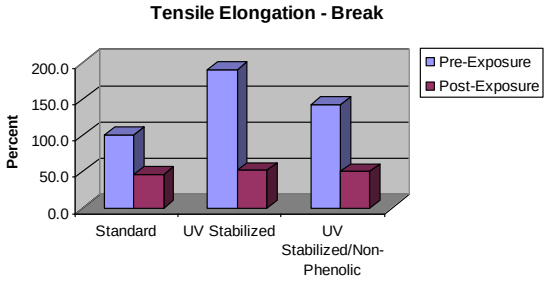
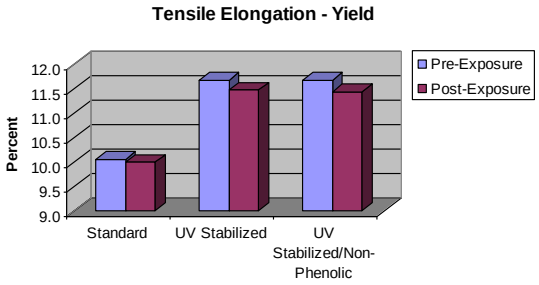
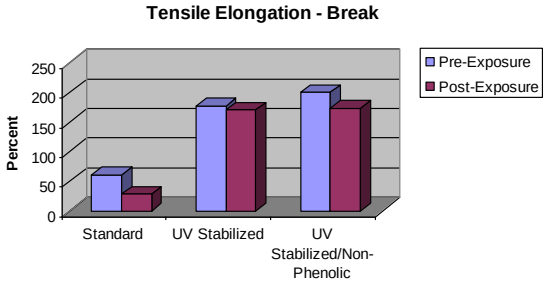


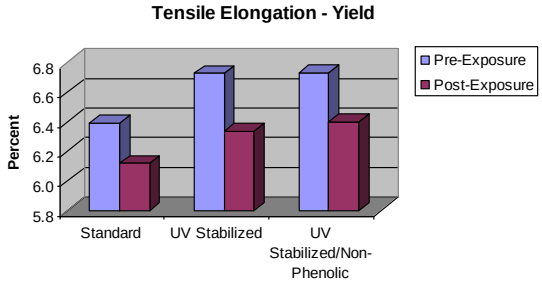


Random Copolymer





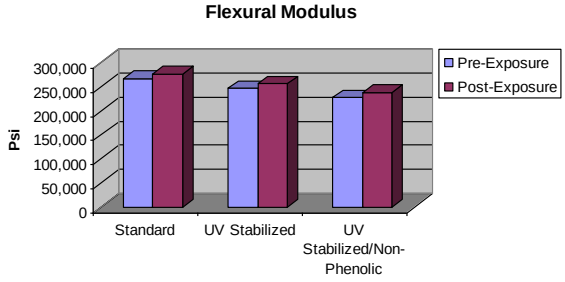
Impact Copolymer



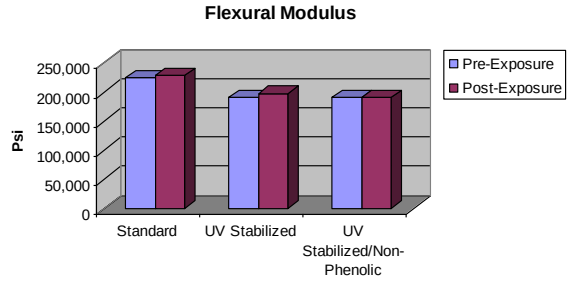
Flexural Modulus

Each form of polypropylene tested experienced less than a 6% increase in flexural modulus after exposure to gamma radiation.

Homopolymer



Random Copolymer



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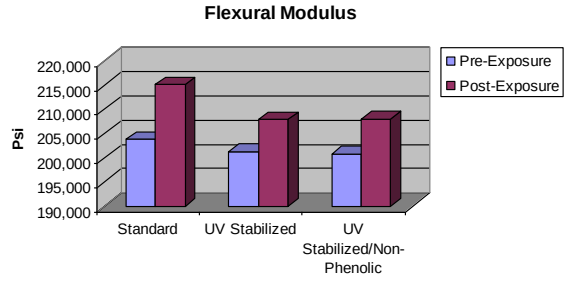

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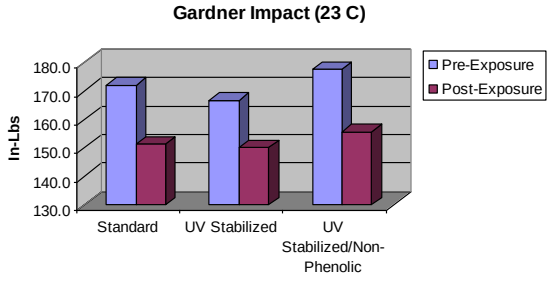
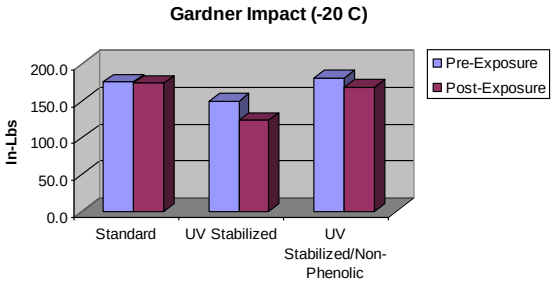
Gardner Impact

Gardner Impact testing was conducted on both the Random and Impact Copolymers at room temperature. Additionally, the Impact Copolymer was also tested at -20 deg C. As expected, both forms of polypropylene showed a decrease in impact strength. The decrease was relatively minor for the Impact Copolymer, generally ranging from 10 – 20% at both 20C and -20C. The Random Copolymer (not illustrated) suffered more than a 60% decrease in impact properties at room temperature.

Impact Copolymer





Conclusion

As shown in the above examples, it is clearly evident that exposure to gamma radiation can have a significant effect on the physical properties of Homopolymer, Random Copolymer, and Impact Copolymer polypropylenes. Some physical properties, such as tensile strength and flexural modulus are only moderately affected while other properties such as yellowness and impact resistance are affected to a much greater extent. In some cases, these effects can be mitigated by the use of UV stabilizers and, in the case of yellowness index, the use of a non-phenolic antioxidant package.

In selecting a polypropylene for an application that will be subjected to gamma radiation, it is important to recognize what physical properties are most important for that specific application. Since radiation sterilization will affect all material properties to some degree, the customer should take the time to verify that the properties of the material will meet their needs both before and after radiation exposure. It should also be noted that the effects of gamma radiation may increase over time and with repeated exposure.

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