

Gamma Radiation Resistance

Importance of Radiation & Sterilization

Most polymers can be degraded by photolysis to give lower molecular weight molecules. Electromagnetic waves with the energy of visible light or higher energy levels are usually involved in such reactions. These EMW include:

- Ultraviolet light
- X-rays and
- Gamma rays

Among several types of radiations used currently for material testing, gamma radiation is the most common because of its high availability in research or industrial irradiators.

Gamma radiations are used for sterilization processes in medical devices, food industry as well as in nuclear power plants or aerospace.

Gamma radiation resistance characterizes the ability of polymers to withstand sterilization methods

Radiation resistance is characterized by the half value dose of significant changes in mechanical properties such as elongation at break, flexural strength at break etc. of thermoplastics, elastomers, all aromatic polymers, as well as composite materials. The half-value-dose means the absorbed dose that reduces a property to 50% of its initial value under defined environments.

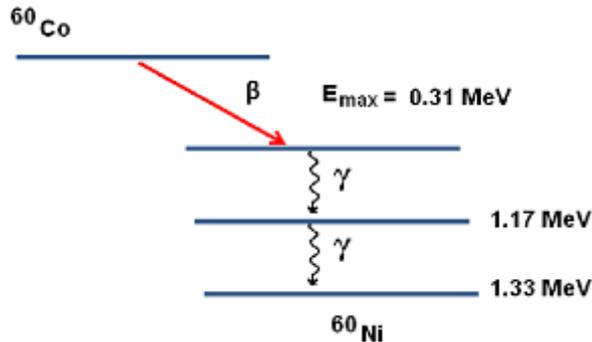
Loss of elongation is a commonly used to measure the effect of irradiation because it equates to a brittleness failure

Check out more on Gamma Radiation Resistance:

- » **Gamma Radiation Resistances of Various Polymers**
- » **Change in Mechanical Properties or Physical Appearance Upon Irradiation**
- » **Factors Impacting Radiation Resistance of Polymer**

Impact of Radiation on Mechanical Properties or Physical Appearance of Polymers

As mentioned above, polymer resins can tolerate gamma irradiation to varying degrees making them suitable for applications requiring sterility. The primary sources of industrial use gamma radiation are: **Cobalt 60 (^{60}Co) and Cesium 137 (^{137}Cs)**. They emit gamma rays during their radioactive decay.



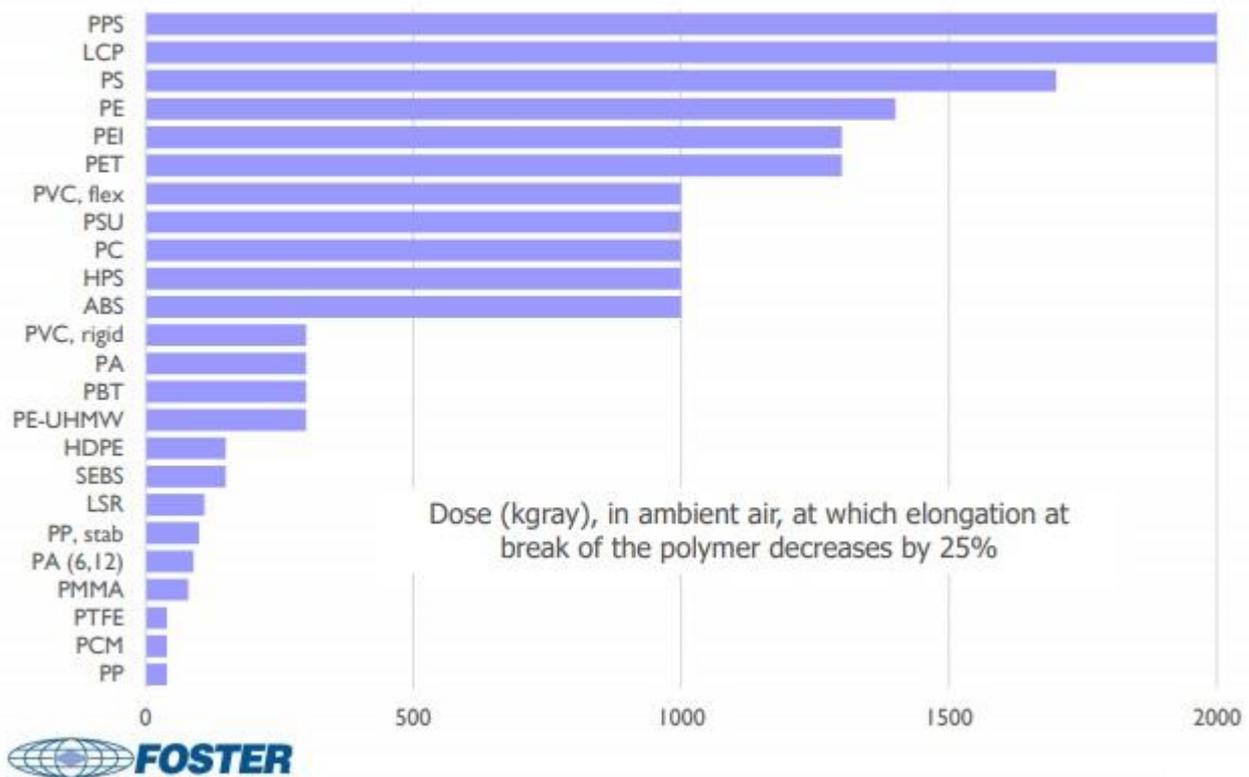
Gamma rays are a penetrating form of radiation which easily pass through plastics. They break the covalent bonds of DNA killing bacteria and other microbes exposed to the radiation.

Ionizing rays of gamma radiation can cause following changes in polymers:

- Discolor or yellowing effect
- Change in mechanical properties (varies by material)
- Crosslinking – increased tensile strength, decreased elongation
- Chain scission – reduced tensile strength and elongation

Each polymer reacts differently to ionizing radiation. Hence, overall dosage rate varies and must be limited according to the polymer.

Elongation Retention



(Source: Foster Corporation)

Irradiation and Polymers

- **Polyethylene** in general crosslinks on irradiation, although there is a chain scission mechanism as well. Crosslinking of PE upon irradiation increases its tensile strength. However, polyethylene can be stabilized to make it gamma radiation resistant. High-density polyethylene is not as stable as medium density polyethylene and low-density polyethylene, linear low-density polyethylene.
- Aromatic polymers (e.g. with benzene rings) are radiation resistant. Polymers such as **PET**, **PU**, **PSU**, **PC** etc. can easily be sterilized due to the presence of a benzene ring.
- Aliphatic polymers exhibit degrees of resistance depending upon their levels of unsaturation and substitution.
- Highly amorphous materials are generally radiation resistant then semi-crystalline polymers. The chain structure is capable of great ductility and they can tolerate many scissions without breaking up.

- Polymers with butylene backbone such as **ABS**, **PBT** etc. lose impact strength on irradiation.
- **Nylon** 10, 11, 12, and 6-6 are more stable than 6. Nylon film and fiber are less resistant.
- **Poly(methylmethacrylate)** can satisfactorily withstand a single radiation sterilization dose both in the high molecular weight cast sheet form and as a molded item. It is not, however, suitable for repeated doses.
- **Poly(vinyl chloride)** is suitable for single-dose radiation sterilization both in its unplasticized and plasticized forms.
- Thermosets such as **Phenol formaldehyde** and **urea formaldehyde** are both reasonably suitable for irradiation sterilization.
- Certain polymers such as fluoropolymers (**PTFE**, **PVDF**), **polyacetals**, **polypropylene** etc., however, do not stand up to gamma radiation exposure well for sterilization. PP undergoes slow degradation after irradiation.

Factors Affecting Gamma Radiation Resistance of Plastic

Radiation resistance of a material greatly depends on:

- Polymer formulation (Additives, reinforcement, crosslinking in elastomers etc.)
- Conditions of radiation exposure such as the environmental atmosphere, temperature, dose rate, mechanical stress, etc.

It is important to note that:

- Additives such as stabilizers, antioxidants in polymers can reduce the effects of irradiation on mechanical properties or physical appearance (non-yellowing). For example: tint-based stabilizers when added to PVC help counteract color change in the polymer.

Inorganic fillers increase radiation resistance of polymer while Organic fillers usually decrease radiation resistance.

Certain additives have a protective action and can reduce the effect of radiation on plastics

- Thin parts sections, films, fibers present in the product can allow excessive exposure thus causing polymer degradation.
- Molding which are strong in the axis of orientation but weak in the cross-flow axis becomes weaker after irradiation.

Gamma Radiation Resistances of Various Polymers

Polymer Name	Min Value (°C)
ABS - Acrylonitrile Butadiene Styrene	Good
ABS Flame Retardant	Poor
ABS High Heat	Good
ABS High Impact	Fair
ABS/PC Blend - Acrylonitrile Butadiene Styrene/Polycarbonate Blend	Good
ABS/PC Blend 20% Glass Fiber	Good
ABS/PC Flame Retardant	Poor
ASA - Acrylonitrile Styrene Acrylate	Good
ASA/PC Blend - Acrylonitrile Styrene Acrylate/Polycarbonate Blend	Good
ASA/PC Flame Retardant	Poor
ECTFE - Ethylene Chlorotrifluoroethylene	Good
ETFE - Ethylene Tetrafluoroethylene	Good
EVA - Ethylene Vinyl Acetate	Fair
FEP - Fluorinated Ethylene Propylene	Good
HDPE - High Density Polyethylene	Fair
HIPS - High Impact Polystyrene	Poor

HIPS Flame Retardant V0	Poor
LCP - Liquid Crystal Polymer	Good
LCP Carbon Fiber-reinforced	Good
LCP Glass Fiber-reinforced	Good
LCP Mineral-filled	Good
MABS - Transparent Acrylonitrile Butadiene Styrene	Fair
PA 11 - (Polyamide 11) 30% Glass fiber reinforced	Fair
PA 11, Conductive	Fair
PA 11, Flexible	Fair
PA 11, Glass Filled	Fair
PPA 11 or 12	Fair
PA 11, Rigid	Fair
PA 12 (Polyamide 12), Conductive	Fair
PA 12, Fiber-reinforced	Fair
PA 12, Flexible	Fair
PA 12, Glass Filled	Fair
PA 12, Rigid	Fair
PA 46 - Polyamide 46	Fair
PA 46, 30% Glass Fiber	Fair
PA 6 - Polyamide 6	Fair
PA 6-10 - Polyamide 6-10	Fair
PA 66 - Polyamide 6-6	Fair
PA 66, 30% Glass Fiber	Fair
PA 66, 30% Mineral filled	Fair
PA 66, Impact Modified, 15-30% Glass Fiber	Poor

PA 66, Impact Modified	Fair
PA 66, Impact Modified	Poor
Polyamide semi-aromatic	Fair
PAI - Polyamide-Imide	Good
PAI, 30% Glass Fiber	Good
PAI, Low Friction	Good
PAR - Polyarylate	Good
PARA (Polyarylamide), 30-60% glass fiber	Fair
PBT - Polybutylene Terephthalate	Good
PBT, 30% Glass Fiber	Good
PC (Polycarbonate)	Good
PC (Polycarbonate) 20-40% Glass Fiber	Good
PC (Polycarbonate) 20-40% Glass Fiber Flame Retardant	Poor
PC - Polycarbonate, high heat	Good
PC/PBT Blend - Polycarbonate/Polybutylene Terephthalate Blend	Good
PE - Polyethylene 30% Glass Fiber	Fair
PEEK - Polyetheretherketone	Excellent
PEEK 30% Carbon Fiber-reinforced	Excellent
PEEK 30% Glass Fiber-reinforced	Excellent
PEI - Polyetherimide	Good
PEI, 30% Glass Fiber-reinforced	Good
PEI, Mineral Filled	Good
PESU - Polyethersulfone	Good
PESU 10-30% glass fiber	Good

PET - Polyethylene Terephthalate	Good
PET, 30% Glass Fiber-reinforced	Good
PET, 30/35% Glass Fiber-reinforced, Impact Modified	Fair
PET, 30/35% Glass Fiber-reinforced, Impact Modified	Poor
PETG - Polyethylene Terephthalate Glycol	Good
PE-UHMW - Polyethylene -Ultra High Molecular Weight	Fair
PFA - Perfluoroalkoxy	Good
PI - Polyimide	Excellent
PMMA - Polymethylmethacrylate/Acrylic	Good
PMMA (Acrylic) High Heat	Good
PMMA (Acrylic) Impact Modified	Fair
PMMA (Acrylic) Impact Modified	Good
PMP - Polymethylpentene	Good
PMP 30% Glass Fiber-reinforced	Good
PMP Mineral Filled	Good
POM - Polyoxymethylene (Acetal)	Fair
POM (Acetal) Impact Modified	Fair
POM (Acetal) Low Friction	Fair
POM (Acetal) Mineral Filled	Fair
PP - Polypropylene	Poor
PP - Polypropylene 10-20% Glass Fiber	Poor
PP, 10-40% Mineral Filled	Poor
PP, 10-40% Talc Filled	Poor

PP, 30-40% Glass Fiber-reinforced	Poor
PP (Polypropylene) Copolymer	Poor
PP (Polypropylene) Homopolymer	Poor
PP, Impact Modified	Poor
PPA - Polyphthalamide	Good
PPE - Polyphenylene Ether	Fair
PPE, 30% Glass Fiber-reinforced	Fair
PPE, Flame Retardant	Poor
PPE, Impact Modified	Fair
PPE, Impact Modified	Poor
PPE, Mineral Filled	Fair
PPS - Polyphenylene Sulfide	Good
PPS, 20-30% Glass Fiber-reinforced	Good
PPS, 40% Glass Fiber-reinforced	Good
PPS, Conductive	Good
PPS, Glass fiber & Mineral-filled	Good
PPSU - Polyphenylene Sulfone	Excellent
PS (Polystyrene) 30% glass fiber	Good
PS (Polystyrene) Crystal	Good
PS, High Heat	Good
PSU - Polysulfone	Good
PSU, 30% Glass finer-reinforced	Good
PSU Mineral Filled	Good
PTFE - Polytetrafluoroethylene	Good
PTFE, 25% Glass Fiber-reinforced	Good

PVDF - Polyvinylidene Fluoride	Good
SAN - Styrene Acrylonitrile	Good
SAN, 20% Glass Fiber-reinforced	Good
SMMA - Styrene Methyl Methacrylate	Good
SRP - Self-reinforced Polyphenylene	Good
XLPE - Crosslinked Polyethylene	Good