UV Light Resistance

UV Light and its Effect on Plastics

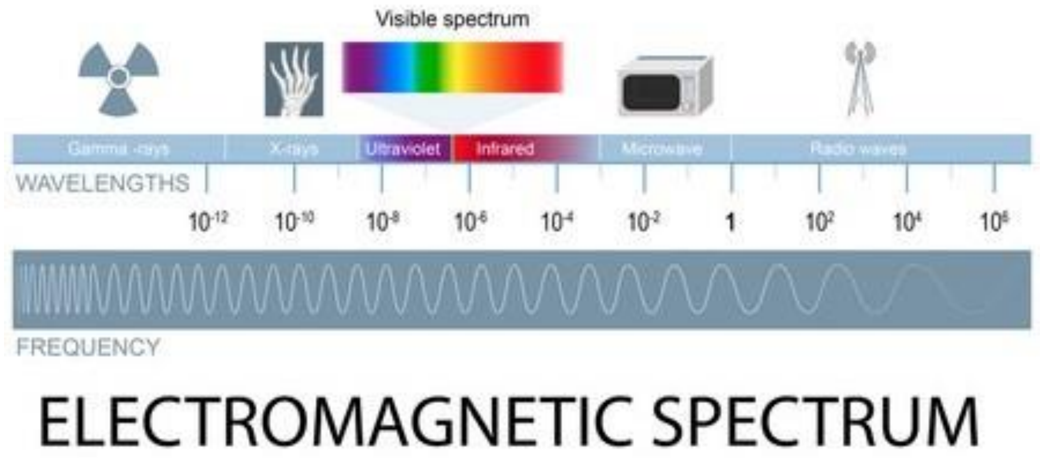
Ultraviolet (UV) light is probably the most damaging environment for plastics. Although to be fair to plastics, it attacks, to a greater or lesser extent, most other materials as well.

All applications of plastics which are used outdoors are therefore at risk, from roofing and window frames to vehicles.

UV light is part of the electromagnetic spectrum. It is at the higher end of energy compared to visible light and is followed in energy by X-rays and the Gamma rays.

UV energy absorbed by plastics can excite photons, which then create free radicals.

While many pure plastics cannot absorb UV radiation, the presence of catalyst residues
and other impurities will often act as receptors, causing degradation



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UV radiation attacks all types of polymers, but a few (such as acrylonitriles and **methyl methacrylates**) show better UV resistance than most.

It can cause color change and degradation of physical properties, especially in:

- **Polyolefins**
- Styrenics
- **Polyvinyl chloride (PVC)**
- **Polycarbonate (PC)**, and
- **Polyurethane (PU)**

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The effect is very familiar: discoloration, especially yellowing or whitening ('chalking'), is the most apparent. But, underneath, there is usually the beginning of a loss of physical properties such as:

- Impact strength
- Tensile strength, and
- **Elongation**

The UV breaks down the chemical bonds in a polymer in a process called photodegradation, which ultimately causes the change in appearance and deterioration in properties.

Hence, any attempt to design plastic parts without a clear understanding of the degradation mechanisms induced by the environment would result in a premature failure of the product.

How to Avoid Damage Caused by Ultraviolet (UV) Light?

The counter-measures to prevent/terminate oxidation of plastics by UV light include:

- Coating
- Introducing pigments which effectively screen out the rays, or
- Neutralizing the UV energy within the compound and dissipate it harmlessly

Also, there exists many more technologies such as polymeric stabilizers, concentrates and masterbatches, fine particle technologies etc. which help in preventing UV radiation from reaching the polymer and hence avoid damage.

(*please note that every technology is not discussed here*.)

Screening

The most effective screening pigment is carbon black (however its applications are limited to black-colored products). **Titanium dioxide** is used, but it is expensive. Calcium carbonate can also have a screening effect (but usually at a high loading, which might impair mechanical properties).

Absorption

UV absorbers are receptive to UV radiation but, while not themselves degrading rapidly, they convert UV energy and dissipate it harmlessly as heat. They prevent the oxidation caused by UV radiation, but should not be confused with antioxidants, which are not UV deactivators as such.

- Benzophenones are good general-purpose UV absorbers for clear polyolefin systems, and can also be used in pigmented compounds.
- Benzotriazoles are used mainly in polystyrene and PVC, but can also be used in acrylics and polycarbonates, and in polyurethanes and unsaturated polyesters. They also improve the light stability of **polyacetals**, urea, melamines and epoxies.

Stabilization

Ultraviolet stabilizers, unlike UV absorbers, inhibit the bond rupture by chemical means or dissipate the energy to lower levels that do not attack the bonds.

Quenchers

Quenchers reduce the UV energy by means of deactivating metal ions. In effect, they intercept the energy before it can break any molecular bonds, but in a different way from absorbers.

Scavengers

Scavengers act by inhibiting the free radicals generated by UV light, so stopping any further decomposition. The most important are **hindered amine light stabilizers (HALS)**. They are efficient scavengers and function by inhibiting the degradation of a polymer which has already formed free radicals.

HALS have the advantage that they bind additives to the polymer at the molecular level, so causing less antagonism towards other additives. They can be used with most polymers.

Polymeric HALS offer:

- Superior compatibility
- Low volatility
- Excellent resistance to extraction, and
- Contribute to heat stability

A combination of two high molecular weight grades gives a good balance of properties, for greenhouse film, which is the main **low density polyethylene** (LDPE) film use of HALS.

Synergists with HALS

In conjunction with other light stabilizers, HALS can exhibit synergistic effects, which are being actively explored. For example, some cyanoacrylate-based UV absorbers offer particular benefits (such as in **acrylonitrile butadiene styrene (ABS)** and **polyamide (PA)** and as individual components in rigid or plasticized PVC, polyurethane foams and **styrene butadiene (SB) rubber**).

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Methods to Predict Plastic Material Behavior in UV Light

There exist several test methods used to predict the behavior of a plastic material to UV light. These test methods can be used to characterize material performance when subjected to specific and well-defines factors. (*ofcourse there are several other methods as well, but they are not discussed here*)

However, it is also important to note that no one test can be employed to evaluate completely the effects of UV light on any material.

- ASTM D2565 - Standard Practice for Xenon-Arc Exposure of Plastics Intended for Outdoor Applications
- ASTM D 4459 - Standard Practice for Xenon-Arc Exposure of Plastics Intended for Indoor Applications
- ASTM G154 - Standard Practice for Operating Fluorescent Ultraviolet (UV) Lamp Apparatus for Exposure of Nonmetallic Materials
- ISO 4892 - Methods of Exposure to Laboratory Light Sources – is a four-part standard covering different light sources.
  - Part 1: General guidance
  - Part 2: Xenon-arc exposure
  - Part 3: Fluorescent UV exposure
  - Part 4: Carbon-arc exposure
- ASTM D 4329 - Standard Practice for Fluorescent Ultraviolet (UV) Lamp Apparatus Exposure of Plastics
- And many more…

UV Light Resistance Behavior of Various Polymers

Ratings in the table below are based on an overall qualitative assessment.

Polymer Name	Value
ABS - Acrylonitrile Butadiene Styrene	Poor
ABS Flame Retardant	Fair
ABS Flame Retardant	Poor
ABS High Heat	Poor
ABS High Impact	Poor
ABS/PC Blend - Acrylonitrile Butadiene Styrene/Polycarbonate Blend	Fair
ABS/PC Blend 20% Glass Fiber	Fair
ABS/PC Flame Retardant	Poor
ASA - Acrylonitrile Styrene Acrylate	Good
ASA/PC Blend - Acrylonitrile Styrene Acrylate/Polycarbonate Blend	Good
ASA/PC Flame Retardant	Poor

ASA/PVC Blend - Acrylonitrile Styrene Acrylate/Polyvinyl Chloride Blend	Good
CPVC - Chlorinated Polyvinyl Chloride	Fair
ECTFE - Ethylene Chlorotrifluoroethylene	Good
ETFE - Ethylene Tetrafluoroethylene	Good
EVA - Ethylene Vinyl Acetate	Poor
FEP - Fluorinated Ethylene Propylene	Good
HDPE - High Density Polyethylene	Poor
HIPS - High Impact Polystyrene	Poor
HIPS Flame Retardant V0	Poor
Ionomer (Ethylene-Methyl Acrylate Copolymer)	Good
LCP - Liquid Crystal Polymer	Good
LCP Carbon Fiber-reinforced	Good
LCP Glass Fiber-reinforced	Good
LCP Mineral-filled	Good
LDPE - Low Density Polyethylene	Fair
LLDPE - Linear Low Density Polyethylene	Fair
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, Rigid	Fair
PA 11 or 12	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	Poor
PA 66, 30% Glass Fiber	Poor
PA 66, 30% Mineral filled	Poor
PA 66, Impact Modified, 15-30% Glass Fiber	Poor
PA 66, Impact Modified	Poor
Polyamide semi-aromatic	Fair
PAI - Polyamide-Imide	Excellent
PAI, 30% Glass Fiber	Excellent
PARA (Polyarylamide), 30-60% glass fiber	Good
PBT - Polybutylene Terephthalate	Fair
PBT, 30% Glass Fiber	Fair
PC - Polycarbonate	Fair
PC (Polycarbonate) 20-40% Glass Fiber	Fair
PC (Polycarbonate) 20-40% Glass Fiber, Flame Retardant	Poor
PC - Polycarbonate, high heat	Fair
PC/PBT Blend - Polycarbonate/Polybutylene Terephthalate Blend	Fair
PC/PBT blend, Glass Filled	Fair

PCTFE - Polymonochlorotrifluoroethylene	Good
PE - Polyethylene 30% Glass Fiber	Fair
PEEK - Polyetheretherketone	Good
PEEK 30% Carbon Fiber-reinforced	Good
PEEK 30% Glass Fiber-reinforced	Good
PEI - Polyetherimide	Fair
PEI, 30% Glass Fiber-reinforced	Fair
PEI, Mineral Filled	Fair
PESU - Polyethersulfone	Fair
PESU 10-30% glass fiber	Fair
PET - Polyethylene Terephthalate	Fair
PET, 30% Glass Fiber-reinforced	Fair
PET, 30/35% Glass Fiber-reinforced, Impact Modified	Poor
PETG - Polyethylene Terephthalate Glycol	Fair
PE-UHMW - Polyethylene -Ultra High Molecular Weight	Fair
PFA - Perfluoroalkoxy	Fair
PI - Polyimide	Excellent
PMMA - Polymethylmethacrylate/Acrylic	Good
PMMA (Acrylic) High Heat	Good
PMMA (Acrylic) Impact Modified	Fair
PMP - Polymethylpentene	Fair
PMP 30% Glass Fiber-reinforced	Fair
PMP Mineral Filled	Fair
POM - Polyoxymethylene (Acetal)	Poor

POM (Acetal) Impact Modified	Poor
POM (Acetal) Low Friction	Poor
POM (Acetal) Mineral Filled	Poor
PP - Polypropylene	Fair
PP - Polypropylene 10-20% Glass Fiber	Fair
PP, 10-40% Mineral Filled	Fair
PP, 10-40% Talc Filled	Fair
PP, 30-40% Glass Fiber-reinforced	Fair
PP (Polypropylene) Copolymer	Fair
PP (Polypropylene) Homopolymer	Fair
PP, Impact Modified	Poor
PPE - Polyphenylene Ether	Fair
PPE, 30% Glass Fiber-reinforced	Fair
PPE, Flame Retardant	Poor
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	Good
PS - Polystyrene	Poor
PS - Polystyrene, 30% Glass Fiber	Poor
PS (Polystyrene) Crystal	Poor

PS, High Heat	Poor
PSU - Polysulfone	Fair
PSU, 30% Glass finer-reinforced	Fair
PSU Mineral Filled	Fair
PTFE - Polytetrafluoroethylene	Good
PTFE, 25% Glass Fiber-reinforced	Good
PVC - Polyvinyl Chloride	Good
PVC (Polyvinyl Chloride), 20% Glass Fiber-reinforced	Good
PVC, Plasticized	Fair
PVC, Plasticized Filled	Fair
PVC Rigid	Fair
PVDC - Polyvinylidene Chloride	Fair
PVDF - Polyvinylidene Fluoride	Good
SAN - Styrene Acrylonitrile	Poor
SAN, 20% Glass Fiber-reinforced	Poor
SMA - Styrene Maleic Anhydride Flame Retardant V0	Poor
SRP - Self-reinforced Polyphenylene	Good
XLPE - Crosslinked Polyethylene	Good