TECHNICAL WHITEPAPER

# UV Properties of Plastics:
## Transmission & Resistance

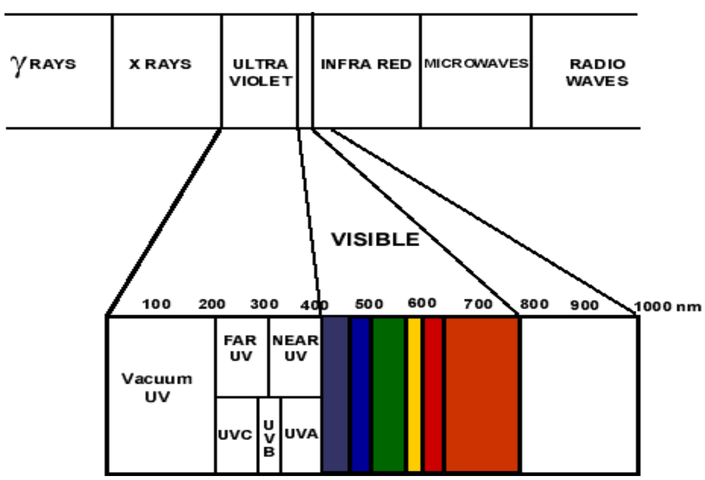
### Introduction

We are all no doubt aware of the main effect of ultraviolet (UV) radiation on ourselves – how many of us have ended up with a red nose after a day out in the sun? Our skin is not the only organic structure to suffer; even polymers will be affected to some degree by exposure to sunlight and ultraviolet radiation. The main problem is that so many parameters affect the level of exposure, and there are several ways of providing resistance to the effects.

### UV Radiation and the Electromagnetic Spectrum

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 – see diagram.

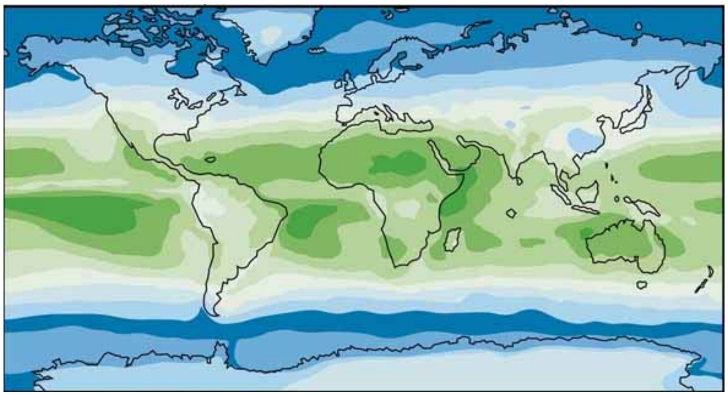
**Electromagnetic Spectrum**




UV radiation is split into three different types as described in the table below.

| DESCRIPTION | WAVELENGTH RANGE (nm) | COMMON EFFECT |
|---|---|---|
| UVA | 320 - 400 | SKIN TANNING |
| UVB | 280 - 320 | SKIN BURNING |
| UVC | 100 - 280 | GERMICIDAL |

One of the main problems when considering the effect of UV rays on polymers is the intensity related to: stratospheric ozone, clouds, altitude, the position of the sun height (time of day and time of year), and reflection. The complexity of the effects can be seen in a global plot of UV levels – dark green being the highest:



It is also important to remember that actual ambient temperature and humidity will accelerate any effect of the intensity level.

## The Main Effects on Polymers Exposed to UV

All types of UV can cause a photochemical effect within the polymer structure, which can be either a benefit or lead to degradation of some sort to the material. Note that compared to our skin, the higher energy UVC is more likely to affect plastics.

**Degradation.**

The main visible effects are a chalky appearance and a color shift. The component surface may also become brittle. I can vouch for these effects as found in my children's red polypropylene (PP) monkey bars. After a few years in the garden the extruded pipes retained their full color, while the injection molded clamp parts became white and cracked. Other components likely to be affected by solar exposure include stadium seats, outdoor furniture, greenhouse films, window frames and automotive parts.

Some plastics have been exposed to much harsher radiation levels than we experience on earth. Components in the Hubble Space Telescope (HST) and the International Space Station (ISS) require plastics that can survive the demands of outer space. Fluoropolymers such as FEP and polyimides like Kapton are plastics which have been successfully used for the HST and ISS.

The above effects are predominantly in the surface layer of the material and are unlikely to extend to depths above 0.5mm into the structure. However, stress concentrations caused by the highly brittle nature of some commodity plastics may well lead to a complete failure of the component.

**Benefits.**

Many of us will be using of the main benefits from UV radiation of protective polymeric coatings, such as polyurethane-acrylates, on exterior automobile components, which have been cured by UV. A more local benefit for many people will be the UV radiation in counter top purifiers and water coolers which is often assisted by the good transmission properties of FEP (Fluorinated Ethylene Propylene) tubing and its ability not to degrade. Melt-processable FEP is also used as a protective coating on UV lamps for electronic fly killers, where the coating allows for excellent transmission (only around 4% loss for a 0.25mm film). There are also many applications for UV, including curing of inks on plastic substrates, and UVC radiation for sterilization of components.

## Interaction of UV Radiation and Plastics

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 free radical receptors, and degradation occurs. It only takes a very small amount of impurity for the degradation to occur, e.g. trace parts per billion values of sodium in polycarbonate (PC) will initiate color instability. In the presence of oxygen, the free radicals form oxygen hydroperoxides that can break the double bonds of the backbone chain leading to a brittle structure. This process is often called photo-oxidation. However, in the absence of oxygen there will still be degradation due to the cross-linking process, which is the effect for plastics used for the Hubble Space Telescope and International Space Station.

Unmodified types of plastics that are regarded as having unacceptable resistance to UV are POM (Acetal), PC, ABS and PA6/6. Other plastics such as PET, PP, HDPE, PA12, PA11, PA6, PES, PPO, PBT and PPO are regarded as fair. Note that a PC/ABS alloy is graded as fair. Good resistance to ultraviolet rays can be achieved from polymers extruded by Zeus such as PTFE, PVDF, FEP, and PEEK™.

PTFE has particularly good UV resistance because it has the very strong carbon-fluorine (C-F) bond (almost 30% higher than the carbon-hydrogen (C-H) bond), which is the common side bond that surrounds the carbon (C-C) backbone in the helix and protects it. There is also the fact that most fluoropolymers do not have the light absorbing chromophore impurities in their structure that can act as an initiator for photo-oxidation. The only plastics found with excellent resistance are the imides. Polyimide (PI) as used in the Hubble Space Telescope, and polyetherimide (PEI).

One useful interaction of UV and plastics can be as fluorescent whitening agents (FWA). In natural light many polymer products can appear to have a yellow appearance. By including a special additive, the UV light absorbed is then emitted in the 400-500 nm range (the blue region of visible light), which causes it to appear whiter. Compared to other additives they only need to be added at small levels, typically 0.01 – 0.05 % by weight.

## How to Avoid UV Degradation

There are several ways of avoiding UV degradation in plastics – by using stabilizers, absorbers or blockers. For many outdoor applications, the simple addition of carbon black at around a 2% level, will provide the protection for the structure by the blocking process. Other pigments such as titanium dioxide can also be effective. Organic compounds such as benzophenones and benzotriazoles are typical absorbers which selectively absorb the UV and re-emit at a less harmful wavelength, mainly as heat. The benzotriazole type is good, as it has a low color and can be used at low dose rates below 0.5%.

The other main mechanism for protection is to add a stabilizer, the most common being a HALS (Hindered Amine Light Stabilizer). These absorb the excited groups and prevent the chemical reaction of the radicals.

In practice, the various types of additives used are in combinations, or are compounded into the original polymer to be produced as a special grade for UV protection. It may be attractive to add antioxidants to some plastics to avoid photo-oxidation, but care must be taken that the antioxidant chosen does not act as an UV absorbent, which will actually enhance the degradation process.

## Testing of Components

The weathering of components is most often associated with outdoor products, but there can also be UV radiation from indoor strip fluorescent lighting where the covers should be resistant to degradation and adverse coloring. Accelerated aging is a common technique for assessing long-term damage, with the product being exposed to artificial light from various sources. The exposure often takes place at an elevated temperature and can be cycled with periods of high humidity.

There are several standards which regulate the type and levels of illumination, e.g. ASTM D 2565 (Standard Practice for Xenon Arc Exposure of Plastics Intended for Outdoor Applications).

Others are, with abridged descriptions, ASTM D 4329 (Fluorescent lamp), ASTM D 4459 (same as 2565 but for Indoor Applications), SAE J1960 (automotive exteriors with Xenon arc), ISO 4892-2 (Xenon arc) and ISO 4892-3 (Fluorescent). However, none of the standards give a required standard for the properties of the product at the end of the exposure period.

Several major users derive their own criteria. An example is the Weathering of Plastic Pipes (Report TR18/99) by the Plastic Pipe Institute, which warns of the large differences in environment for different locations in the USA. Another is for plastic lumber where the hardness of the outer skin must not have changed by more than 10% after 500 hours of exposure.

In the list above there are standards for exposure in indoor applications. This is very relevant for plastics used in fluorescent light casings, where the illuminant spectrum contains UV radiation. There will be an obvious effect of discoloration if a non-stabilized polymer is used.

## Summary

If a product is to be exposed to direct sunlight then the designer or engineer must specify suitable testing standards and make sure the plastic has appropriate formulation to maintain the desired long-term properties. Including additives in the polymer melt process may provide protection, or if volumes are sufficiently high, the additives can be pre-compounded into the resin.

Fluoropolymers such as PTFE, FEP, PFA and other resins extruded at Zeus offer good resistance to UV radiation. For more information concerning materials that may be suitable for your specific application, contact your Zeus Technical Account Manager for immediate assistance or visit our website at www.zeusinc.com for additional data.

## How Zeus Can Help

With a technical inside and outside sales force backed up with engineering and polymer experts, Zeus is prepared to assist in material selection and can provide product samples for evaluation. A dedicated R&D department staffed with PHD Polymer chemists and backed with the support of a world-class analytical lab allows Zeus an unparalleled position in polymer development and customization.

Since 1966 Zeus has been built upon the core technology of precision extrusion of high temperature plastics. Today, with a broad portfolio of engineered resins and secondary operations, Zeus can provide turnkey solutions for development and high-volume supply requirements.

## Contact Us

Visit **http://www.zeusinc.com** for more information about our products and capabilities, or give us a call at (toll-free) **1-866-272-4118**