Chemistry of Polymer Photodegradation

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Outline

- Introduction
- UV radiation & effect on polymers
- Photodegradation of plastics
- Effect on polypropylene properties
- Role of additives in polymers
- Comparative study between un-stabilized & stabilized polypropylene
- Conclusion

Introduction

- Outdoor service life of common polymers is limited due to susceptibility to UV radiation.
- UV radiation is part of the electromagnetic spectrum.
- Any depletion in the stratospheric ozone layer and there by increase in sunlight will therefore tend to decrease the service life.
- The factors influencing the degradation are depending on nature of polymer, amount of solar exposure, ambient temperature and humidity.

Degree of photodegradation depend on wavelength of solar radiation, surface temperature & atmospheric humidity

Spectrum Bandwidth

X-ray	0.01 – 100 nm
UV-ray	100-400 nm
Visible-ray	400-780 nm
IR-ray	780-1,00,000 nm
Microwave-ray	1,00,000 & Beyond nm

The wavelength is measured in billionth of a meter and called as Nanometer (nm)

UV Radiation & Spectrum

- UV light is part of the electromagnetic spectrum.
- It is at the higher end of visible light.

- UV radiation is split into three different types, such as:

Type	Wavelength Range (nm)
UVA	320 – 400
UVB	280 – 320
UVC	100 - 280

Effect Of UV Radiation

- All type of UV radiation can cause photodegradation within the polymer structure.
- Presence of UV-A/B in solar energy is more responsible for photodegradation of polymer.
- Also the surface temperature of polymer exposed to direct sunlight are often accelerate degradation.
- Higher the ambient temperature and humidity cause higher UV-B radiation, causing significant increase in the rate of photodegradation.

Unsterilized Plastics are susceptible to degradation

Photodegradation Of Plastics

Effect of direct exposure to sunlight

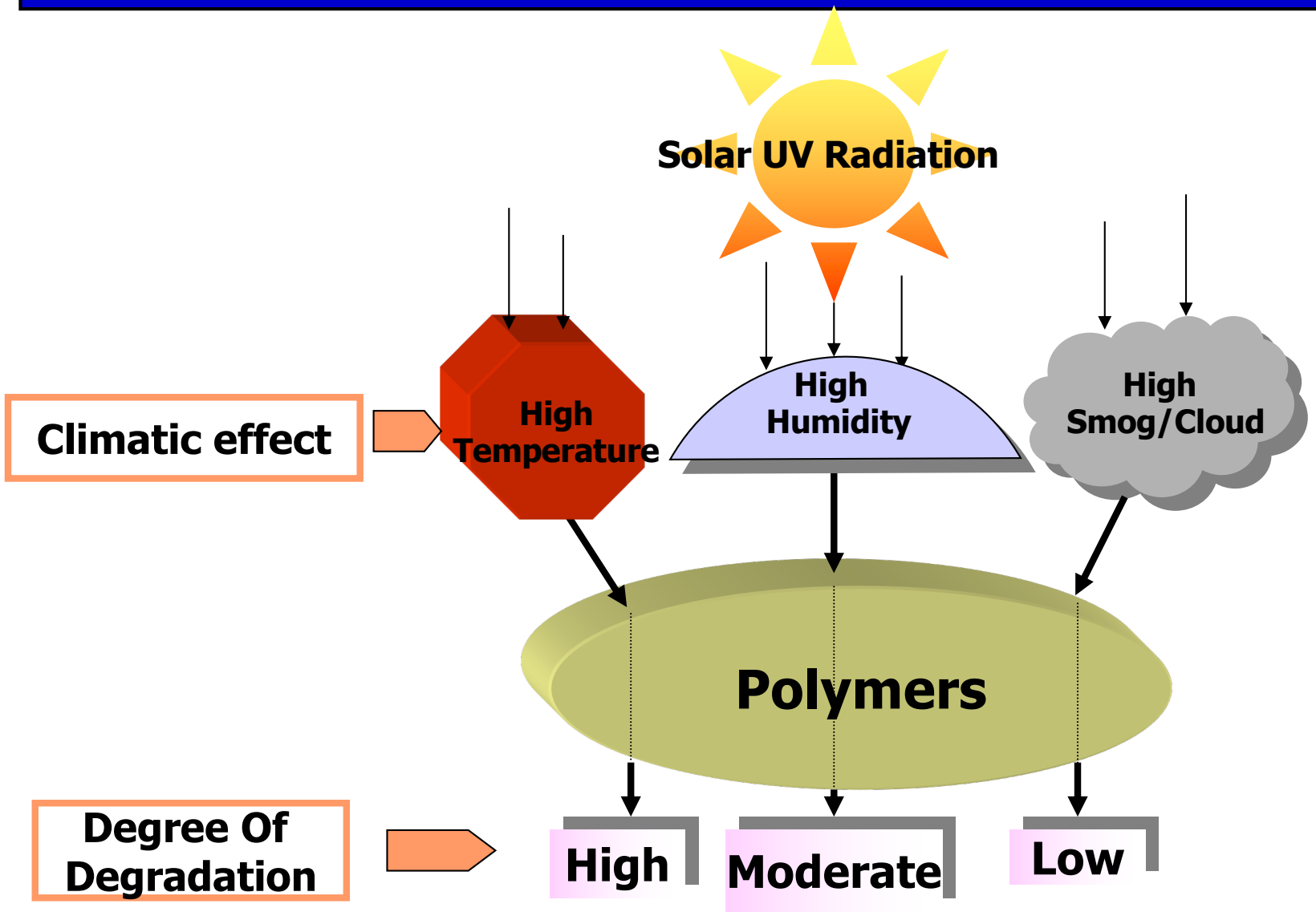
- Photodegradation due to absorption of UV light enhance breaking of tertiary hydrogen-carbon bond and reducing molecular weight.
- Presence of atmospheric oxygen and heat inhibits thermal oxidation degradation.
- Thermal degradation may enhance in pigmented products due to absorption of solar IR wavelengths.
- Also degradation accelerates due to presence of metal from residual catalyst.

Mechanism of photodegradation differs from thermal degradation

UV Rays Sensitivity of Plastics (nm)

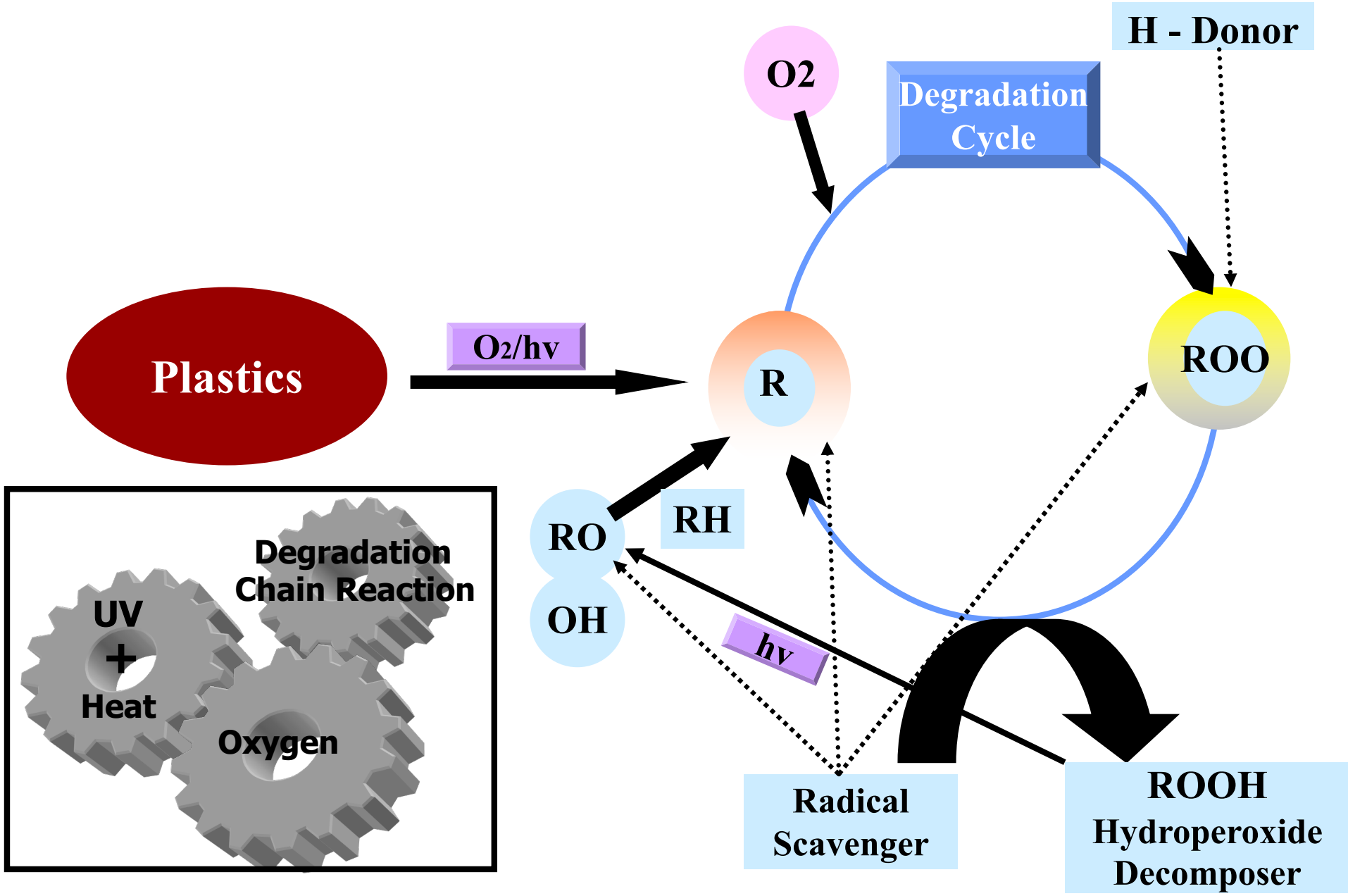
Material	Activation Spectrum
Acrylic	290-315
Acrylonitrile Butadiene Styrene (ABS)	300-385
Nylon (PA)	290-315
Styrene Acrylonitrile (SAN)	290-330
Polycarbonate (PC)	280-300
Polystyrene (PS)	310-325
Polyethylene (PE)	300-340
Polypropylene (PP)	290-370
Poly Vinyl Chloride (PVC)	320

Factors Influencing Photodegradation



Relationship between rate of degradation & temperature is exponential

Photodegradation Inhibition Model



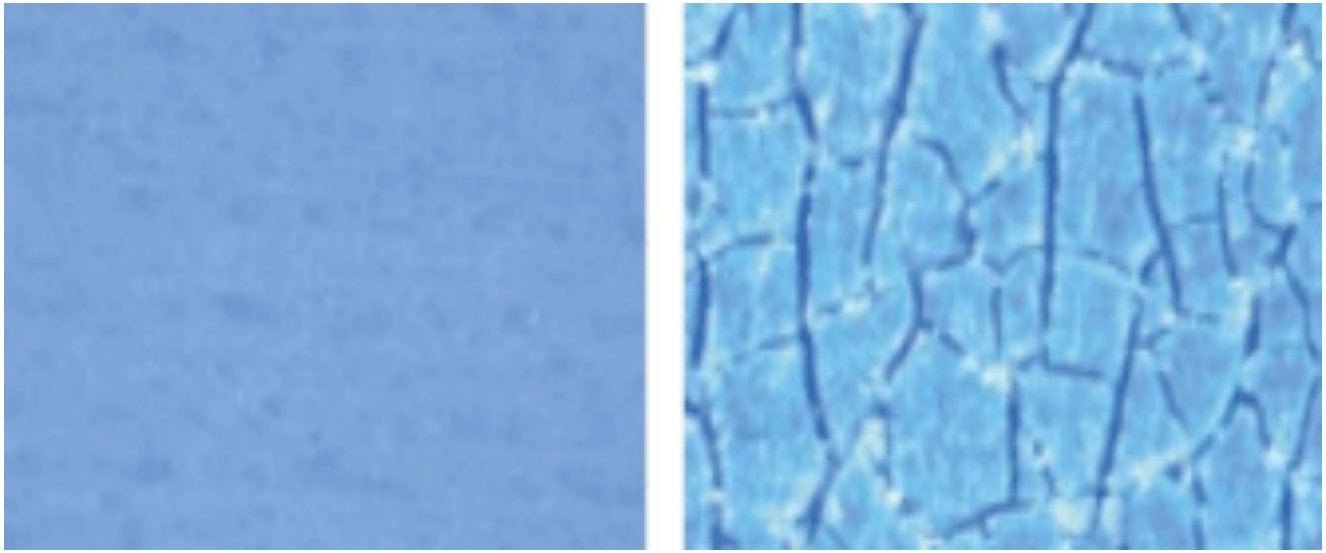
Property Deterioration In Polypropylene

Visible effects

- Chalky appearance
- Discolouration

Invisible effects

- Brittleness
- Loss of mechanical properties



Non degraded **Degraded**

Stabilization Process

- UV stabilizers in Plastics usually act by absorbing harmful UV radiation and dissipating the energy low level heat. Sometimes the chemicals used are similar to sunscreen protectors.

- Combination of various additives give best effect. Percent level of each additive and expected life is evaluated by actual exposure at different condition and “weatherometer” test.

Outdoor Exposure

Stabilizers

UV absorber Act as a shield by absorbing harmful UV radiation and converting the energy into heat. Effective range between 290 – 380 nm.

Quencher: Work as deactivator of excited states. Effective range between 300 – 400 nm

Light stabilizer: Scavenging the radical intermediates induced by light.

Metal deactivator: Inhibits degradation due to presence of residual metal from catalyst.

Combination of all the additive offer suitable stabilization

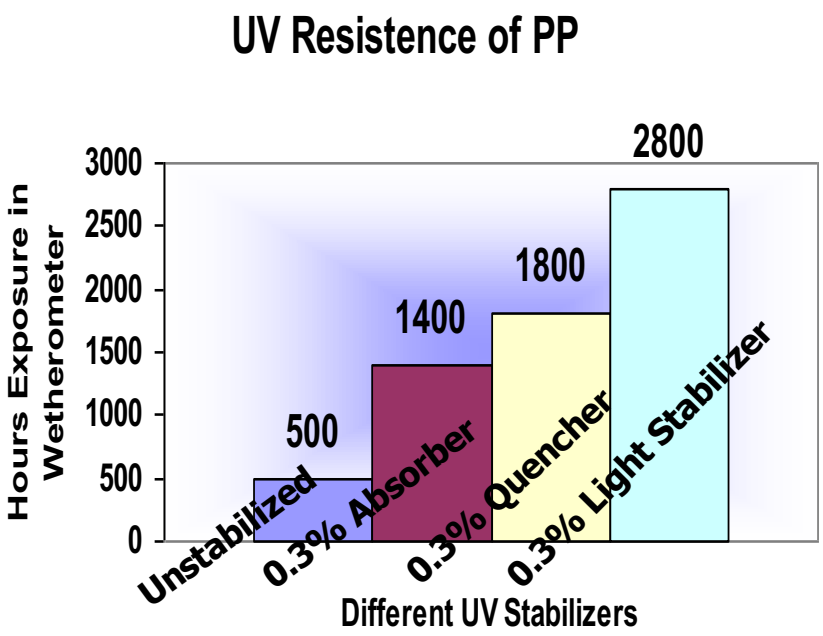
Commercial Stabilizers

- **UV absorbers:** Benzophenone, Benzotriazole and Triazine. Either one of these compounds or in combination.

- **Quencher:** Nickel base compounds work as energy transfer agent and "quench" the excited state of carbonyl group. Also these compounds work as metal deactivators.

- **Light stabilizer:** Hindered Amine Light Stabilizer (HALS) works as UV protectors by combining with oxygen when exposed to light. Also stops thermal degradation.

Exposure Study of Polypropylene

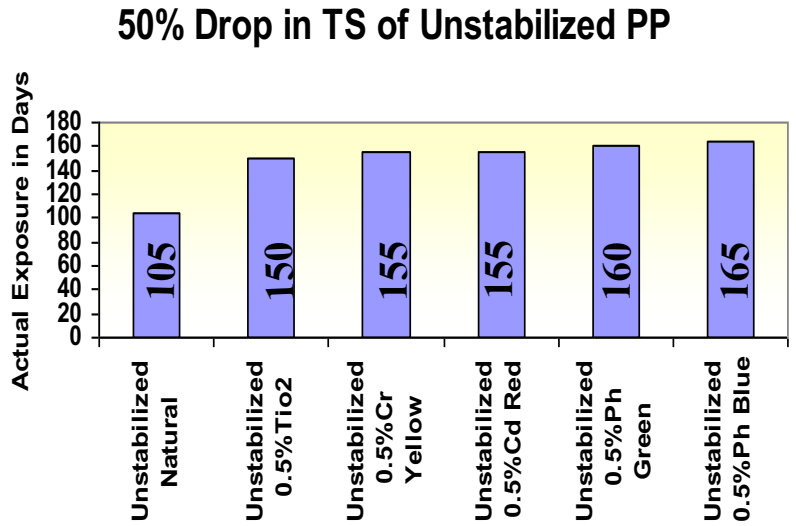


Sample: 2.5 mm IM dark gray pigmented plaque

Exposure temp. : 30 deg C

RH : 40%

Obs: Change in grayish scale from 5 to 3



Sample: 2.5 mm IM plaque

Exposure temp:

Day: 25 to 35 deg C

Night: 12 to 22 deg C

RH : 40 TO 65%

Quonset Style most common green-house

Chalking of Maruti 800 bumpers due to UV radiation

To Conclude….

- Photodegradation due to solar exposure on polymers depends on UV wavelength as well as weathering environment.

- Changes likely to be associated with global warming.

- 'UV radiation' causes photodegradation. But simultaneously thermal oxidation degradation also takes place due to heat generated by 'IR radiation'.

- Weathering performance of polymers can be significantly improved by correct combination of stabilizers.

Thank You