International Journal of Recent Development in Engineering and Technology
Website: www.ijrdet.com (ISSN 2347-6435(Online) Volume 14, Issue 12, December 2025)

Mechanisms and Applications of UV Stabilizers and Absorbers in Polyolefins: A Comprehensive Review

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Abstract-- **Polyolefins such as polyethylene (PE) and polypropylene (PP) are widely used in outdoor applications but are highly susceptible to photodegradation under UV radiation. This paper reviews the mechanisms of UV degradation, the role of UV absorbers and hindered amine light stabilizers (HALS), and recent advancements in stabilization technologies. The synergistic use of UV absorbers and HALS is highlighted as an effective strategy for long-term durability.**

Keywords-- **Polyolefins, UV Stabilizers, UV Absorbers, HALS, Photodegradation, Weatherability, Polymer Additives.**

I. Introduction

Polyolefins are extensively used in packaging, automotive, and agricultural applications due to their excellent mechanical properties and cost-effectiveness. However, they are highly vulnerable to UV-induced degradation, leading to chain scission, discoloration, and embrittlement. This necessitates the incorporation of UV stabilizers and absorbers to enhance their weatherability.

II. Mechanism Of UV Degradation In Polyolefins

UV radiation initiates photo-oxidation in polyolefins by generating free radicals. These radicals propagate through the polymer matrix, causing chain scission and crosslinking. The presence of chromophores such as catalyst residues accelerates this process.

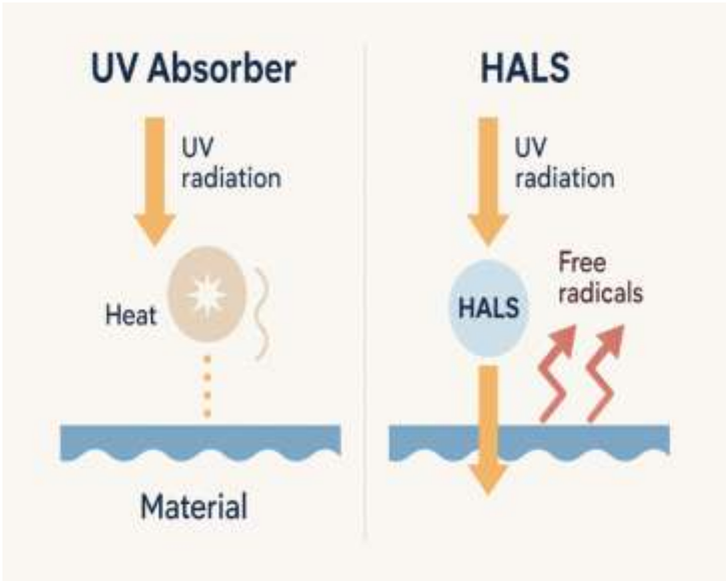

Figure 1: Mechanism of UV Absorbers and HALS

III. UV Stabilization Strategies

UV stabilization in polyolefins primarily involves two classes of additives: UV absorbers and hindered amine light stabilizers (HALS). UV absorbers prevent UV light from reaching polymer chains by converting it into heat, while HALS neutralize free radicals formed during photo-oxidation.

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Table 1:
Comparison of UV Absorbers and HALS

Aspect	UV Absorbers (UVA)	HALS
Primary Function	Absorb UV radiation and convert it into heat	Scavenge free radicals formed during photo-oxidation
Mechanism	Prevents UV light from reaching polymer chains	Interrupts degradation cycle by neutralizing radicals
Chemistry	Benzophenones, Benzotriazoles, Triazines	Sterically hindered cyclic amines
Effectiveness	Best for thin films and transparent products	Best for thick sections and long-term outdoor exposure
Synergy	Works well with HALS for combined protection	Works well with UVA for complete stabilization
Migration Risk	Moderate (depends on molecular weight)	Low (generally less migratory)
Thermal Stability	Good, but some UVAs degrade at high processing temps	Excellent thermal stability
Cost	Moderate to high	Moderate
Typical Loading	0.2–0.5%	0.1–0.5%
Applications	Films, fibers, packaging, transparent parts	Automotive, outdoor furniture, pipes, thick molded parts

UV Stabilizers and Absorbers used in Polyolefins, including types, common names, and key properties:

1. UV Absorbers (UVA)

Function: Absorb harmful UV radiation and convert it into heat, preventing polymer degradation.

Type	Common Names	Key Properties
Benzophenones	UV-531, UV-9	Good UV absorption (280–340 nm), moderate thermal stability, risk of migration
Benzotriazoles	Tinuvin 234, Tinuvin 326, Cyasorb UV-5411	Excellent UV absorption (300–400 nm), high thermal stability, low volatility
Triazines	Tinuvin 1577, Cyasorb UV-1164	High efficiency, low migration, suitable for high-temperature processing

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2. Hindered Amine Light Stabilizers (HALS)

Function: Do not absorb UV; instead, they scavenge free radicals formed during photo-oxidation.

Type	Common Names	Key Properties
Monomeric HALS	Tinuvin 770, Chimassorb 944	High efficiency, good compatibility, may migrate in thin films
Oligomeric HALS	Tinuvin 622, Chimassorb 119	Low volatility, excellent long-term stability, ideal for thick sections
NOR-HALS	Tinuvin NOR 371	Resistant to agrochemicals, superior performance in agricultural films

3. Synergistic Systems

- Combination of UVA + HALS is widely used for maximum protection.
- Often paired with antioxidants (e.g., phenolic or phosphite) for thermal stability during processing.

Key Additions:

Absorption Range (nm)

- Benzophenones: 280–340 nm
- Benzotriazoles: 300–400 nm
- Triazines: 290–350 nm

Applications in Plastics

1. *Polyethylene (PE) & Polypropylene (PP)*
   - *Agricultural Films:* Greenhouse covers, mulch films.
   - *Packaging Films:* Food packaging exposed to sunlight.
   - *Outdoor Furniture & Automotive Parts:* Bumpers, dashboards, trims.
   - *Pipes & Cables:* For outdoor installations.
2. *Engineering Plastics*
   - Transparent components requiring UV absorbers for clarity.
   - HALS for thick molded parts in automotive and construction.

Applications in Rubber

- *Outdoor Rubber Products:* Seals, gaskets, hoses exposed to sunlight.
- *Automotive Tires:* UV stabilizers prevent surface cracking and chalking.
- *Industrial Rubber Sheets:* Used in roofing and outdoor flooring.

Environmental Impact

Positive:

- Extends product life → reduces waste and resource consumption.
- Prevents premature failure → lowers replacement frequency.

Negative:

- *Additive Migration:* Some UV stabilizers can leach out, contaminating soil or water.
- *Microplastic Formation:* UV degradation without stabilizers accelerates fragmentation.
- *Persistence:* HALS and benzotriazoles are synthetic chemicals; some are not easily biodegradable.
- *Regulatory Concerns:* Certain UV absorbers (e.g., benzotriazoles) flagged for aquatic toxicity.

Mitigation Strategies:

- Use high molecular weight stabilizers to reduce migration.
- Develop polymer-bound UV absorbers (non-leaching).
- Explore bio-based stabilizers for sustainability.

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IV. CONCLUSION

UV absorbers and HALS remain the backbone of stabilization systems for polyolefins. Their synergistic use ensures comprehensive protection against UV-induced degradation. Future research should focus on environmentally friendly stabilizers, improved compatibility, and nanotechnology integration.

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