Coatings that stay looking good

Tinuvin®, Chimassorb®, Lignostab®, Irganox®, Irgafos®, Irgaguard®, Irgarol®, Tinopal®

BASF

The Chemical Company

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Meeting tomorrow's coatings challenges today

As world leader in the global chemicals industry, BASF offers an outstanding range of high-performance additives that support a wide spectrum of applications across many different industry sectors.

Global reach, global integration

One of BASF's most important characteristics from our customers' perspective is the sheer scale of our operations. With plants and service centers across the world, we can deliver the smallest or largest quantities of the high-quality additives they need. This is achieved through the strength and depth of our global supply chain processes and our expertise in logistics. We are also recognized world leaders in many of the products we supply, including light stabilizers, antioxidant technologies and other performance additives for coating protection. In addition to our expertise in coatings, we also supply specialty functional additives for the printing and packaging, adhesives and sealants and construction industries.

The power of applied expertise

At the heart of BASF are the scientists who develop and test the new solutions that will make business easier and more productive for our customers, today and tomorrow. Since the company's foundation in 1865, we have built up a level of technical and application expertise that makes us global market leader in polymers, resins, raw materials and additives for coatings, adhesives and sealants. Today, we have the world's most complete product portfolio in pigments, resins, formulation and functional additives, including unique and innovative products designed for specialist applications in the coatings industry. To ensure that we continue to develop the cutting-edge knowledge that our customers rely on, we maintain excellent links with scientific institutes and universities, as well as with raw materials suppliers and other partners in the whole value chain.

Protection and durability

The key to creating high-value, high-performance coatings is protection against a variety of degrading influences, including light, weather and chemicals. We understand the full technical possibilities of protecting polymers and resins against environmental and other adverse influences and can also work with you to meet the needs of any specific requirements in your industry or region. Whatever solutions we develop, we place paramount importance on achieving the consistent quality that our customers expect from us, along with long-term availability to ensure sustainable supply. BASF is constantly innovating to meet new trends or develop new solutions, and we have the expertise to work with you to ensure you get precisely the results you need.

If well-protected coatings come from well-developed minds, that's because at BASF, we create chemistry.

Introduction

Organic substrates such as coatings, inks, adhesives and sealants with aesthetical, protective and other functional properties are exposed to a variety of environmental and artificial factors such as solar radiation, humidity, temperature change, microbiological attack, air pollutants and many more.

BASF offers the most comprehensive portfolio of stabilizers and other performance additives: UV absorbers (UVA) and hindered amine light stabilizers (HALS) for effective stabilization against the detrimental effects of light and weathering, as well as phenolic and non-phenolic antioxidants against thermally induced degradation during production, processing and service life. The product range is completed with antimicrobials and optical brighteners.

Tinuvin® and Chimassorb® light stabilizers are suitable for water-based (WB), solvent-based (SB), UV-curable and powder coatings, as well as for inks, adhesives and sealants. The Tinuvin® range is represented by two types of light stabilizers: UVA and HALS, i.e., UVA-based on 2-(2-hydroxyphenyl)-benzotriazole (BTZ) or 2-hydroxyphenyl-s-triazine (HPT) chemistry as well as di- and oligo-functional HALS based on tetramethyl piperidine derivatives. Chimassorb® light stabilizers either belong to the UVA class of 2-hydroxy-benzophenones (BP) or to the group of oligo-functional HALS.

The Tinuvin® DW range is based on aqueous preparations (Novel Encapsulated Additive Technology: NEAT) of performance light stabilizers designed for water-based coatings, inks, adhesives and sealants applications.

Tinuvin® blends of the 5000 series are liquids based on synergistic combinations of UVA and HALS, thereby combining easy handling along with excellent compatibility and solubility in most organic solvents, resins and binder systems. Furthermore other solid HALS-based blends are being offered for the use in adhesives and sealants applications.

Tinuvin® Carboprotect® is a very red shifted UVA for the ultimate protection of carbon fiber reinforced epoxy matrices and can be used as design tool in, e.g., luxury and sports cars.

Lignostab® are lignin-stabilizing additives for wood pretreatment resulting in color retention and improved durability.

Irganox® and Irgafos® antioxidants (AO) protect coatings, plastics, fibers, adhesives and sealants against thermal degradation during processing, production and service life. Irganox® thereby represents a complete range of AOs based on sterically hindered phenols or thioethers, as well as blends of different AO classes. Irgafos® are so-called secondary AO process stabilizers based on phosphite chemistry.

Irgaguard® and Irgarol® antimicrobials are highly specific and effective growth inhibitors for gram-positive and gram-negative bacteria, mold and yeast on organic surfaces. They also effectively inhibit the photosynthesis of algae.

Tinopal® optical brighteners (fluorescent whitening agents) are designed to brighten coatings or adhesives and sealants or to mask yellowing. Tinopal® can also be used where fluorescence can provide means to detect film thicknesses or for registration and identification purposes.

Background of light and heat stabilization

How UV radiation and heat promotes degradation of organic substrates

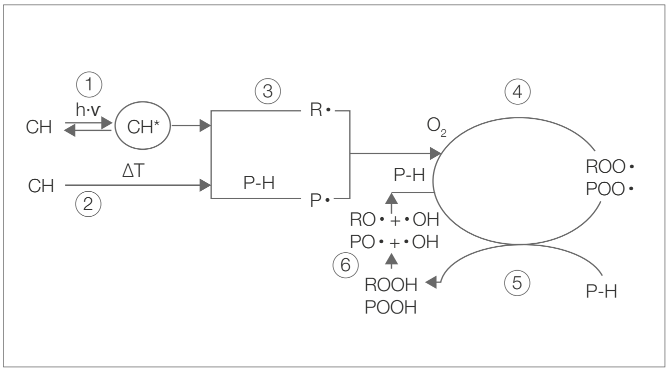
Light- or heat-induced oxidation of organic materials is a complex radical process characterized by initiation, propagation, chain branching, autocatalytic chain and termination reactions. Both initiation steps generate free radicals (R•) to enter this cyclic process.

The predominant initiation mechanism under normal service life conditions of polymers is the light-induced oxidation, the so-called photo oxidation (see fig.1). The initiation reaction is the photolysis ① where a chromophore CH (= UV-absorbing molecule or moiety) absorbs radiation energy (h·v). The absorbed energy leads to the formation of an excited state CH* (higher energy level). CH* molecules are highly reactive and can subsequently form free radicals (R•) by homolytic bond cleavage ③. Under high temperature conditions heat can accelerate the oxidation – the so-called thermal oxidation ② – by radical breakdown reactions and formation of free radicals R•. This heat-induced initiation step can occur during high-temperature processing, production and service life.

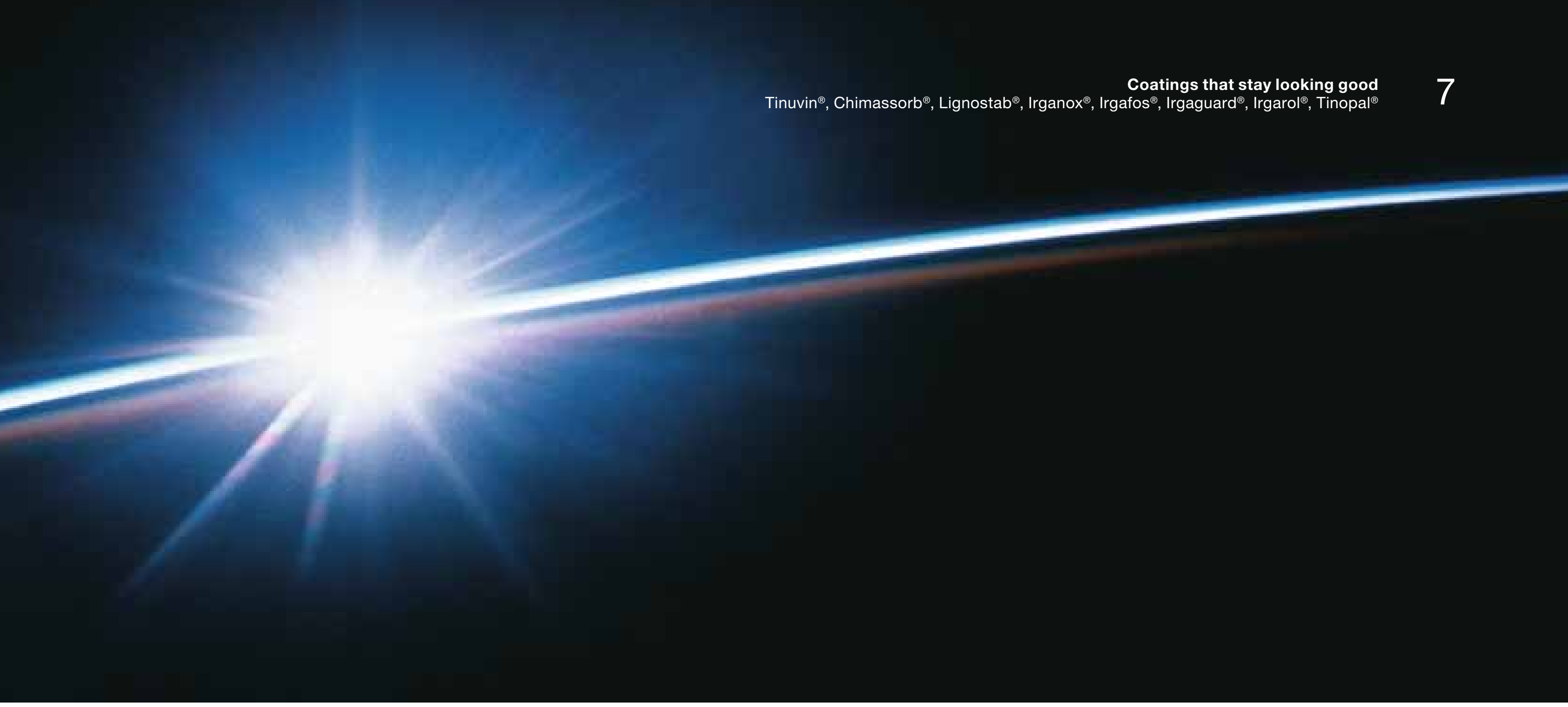
The free radicals R• generated during photo and thermal oxidation can subsequently react with oxygen (O_2) to form peroxy radicals (ROO•) ④, which can further attack the polymer (P-H) thereby forming unstable hydroperoxides (ROOH) ⑤. These hydroperoxides fragment due to UV radiation and/or heat and form additional free radicals ⑥. As the process continues, more and more molecular bonds break – a process which is autocatalytic in nature and is known as autoxidation.
Photo oxidation in the presence of light and O_2 is the predominant mechanism under interior and ambient conditions. As a result mainly discoloration (i.e., yellowing) of the substrate or fading of colorants (e.g., in wall paints or inks) are observed. Under exterior weathering conditions – water is the decisive factor – photo oxidation leads to photo-degradation resulting in additional surface defects of the coating such as loss of gloss, cracking, chalking etc. Heat exposure of organic substrates as encountered during processing steps such as synthesis, mixing, extrusion, curing or during high-temperature-baking cycles of coatings mainly cause yellowing, embrittlement or loss of other mechanical properties such as tensile strength.

In order to protect organic substrates against harmful UV-radiation and subsequent photo oxidation followed by photo degradation the use of appropriate light stabilizers such as UV absorbers (UVA) and free-radical scavengers such as hindered amine light stabilizers (HALS) is necessary. UV absorbers filter out the harmful UV light, thereby preventing color change of the resin, of the substrate underneath and of colorants in coatings, inks, adhesives and sealants. HALS trap free radicals once they are formed and are effective in preventing surface defects such as loss of gloss, cracking and chalking. While HALS are, technically speaking, a class of antioxidants or free-radical scavengers, the term “antioxidant” or “AO” generally refers to additives that are primarily used as heat stabilizers. Today the most commonly used AOs are based on sterically hindered phenol, thioether or phosphite technologies.

Fig. 1: Mechanism of light- and/or thermally-induced oxidation



CH = chromophore = UV absorbing molecule
R• = free radicals
P-H = polymer



Tab. 1: Overview of existing light and heat stabilizer technologies

		Radical scavengers	
	UV absorbers (UVA)	hindered amine light stabilizers (HALS)	antioxidants
mode of action	converts UV light into heat	deactivation of free radicals	deactivation of free radicals
usage area	interior/exterior	exterior	interior/exterior
prevents	photo oxidation and degradation	photo degradation	thermal oxidation
protect what?	deeper coating layers substrate underneath	coating surface pigments in coatings	coating
protects against	yellowing blistering loss of adhesion	surface defects loss of mechanical properties loss of water impermeability pigment fading	yellowing embrittlement loss of mechanical properties
chemical classes	2-hydroxyphenyl-benzophenones (BP) 2-(2-hydroxyphenyl)-benzotriazole (BTZ) 2-hydroxyphenyl-s-triazines (HPT)	tetramethyl piperidine derivatives	sterically hindered phenols phosphites thioethers

UV absorbers

Tinuvin® and Chimassorb® UV absorbers (UVA) prevent the degradation of both coatings and substrates by filtering out the harmful UV radiation during the photolysis cycle ① and before subsequent photo oxidation can take place.

UV absorbers

Today the most widely used UVA for coatings, inks, adhesives and sealants are 2-hydroxyphenyl-benzophenones (BP), 2-(2-hydroxyphenyl)-benzotriazoles (BTZ) and 2-hydroxyphenyl-s-triazines (HPT) (see fig. 2).
The mode of action of UVAs consists of a conversion of the absorbed light energy (h·ν) into heat (see fig. 3). First the UVA CH absorbs radiation energy (h·ν) leading to an energy-enriched excited state CH* resulting in an electronic rearrangement ②, e.g., a reversible intramolecular proton transfer. CH* is then deactivated by radiation less release of heat energy (ΔT) and reverts to the original form CH (ground state) ①.

Main selection criteria for UVA are their specific photo-physical (primary) and physical (secondary) properties. Photo-physical properties of UVA are the absorbance A (= measure of the filter effect of a UVA at a certain wavelength) and the extinction coefficient ε, which is a molecule-specific constant which indicates the efficiency of the filter effect by a chromophore. The absorbance A is a direct measure of the filter effect and is in inverse logarithmic relation to the transmittance T (= amount of light penetrating through a coating/plastic). The absorbance A and the transmittance T of UVA depend both on the chemical class and the molecular weight. The UV absorption spectra of the Tinuvin® UV absorbers and of blends thereof as well of the Chimassorb® UVA are shown on pages 30/31.

According to the Lambert Beer Law the absorbance A, i.e., the filter effect of a coating, is in linear relationship to the UVA concentration (c), the film thickness (= light path length d) and the extinction coefficient ε. Thus the Lambert-Beer´s Law allows to calculate/estimate the necessary amount of UVA needed for proper light protection at a given film thickness d. Increased c or d result in increased filter effect and therefore increased protection against harmful UV radiation. On the other hand it means that the filter effect is strongly influenced by the coating thickness; the thinner the coating thickness the more UVA is necessary (see tab. 2). Hence UVA, on their own, are inefficient to protect the very surface of a coating (where d approaches 0). In conclusion they cannot effectively prevent the formation of surface defects as a result of photo degradation under exterior conditions. For exterior conditions the combination of UVA and HALS imposes synergistic effects allowing excellent protection against surface defects and discoloration. For interior conditions the single use of UVA is mostly sufficient in order to prevent both fading of coatings or inks colorants as well as yellowing of resins.

The photo permanence (= physical/chemical loss of UVA during service life) and the heat stability (i.e., low volatility) are basic requirements for the performance of UVA in the final application.

BP UVA such as Chimassorb® 81 and Chimassorb® 90 are mainly used in applications where lower requirements on long-term stability are given.
BTZ UVA such as Tinuvin® 1130, Tinuvin® 384-2, Tinuvin® 928 or Tinuvin® 900 show broad spectral coverage and are used for various applications such as plastics, textiles, coatings, adhesives and sealants. In the coatings area the use of BTZ ranges from medium- (industrial/architectural) to high-end (automotive) applications.
In general HPT such as Tinuvin® 400, Tinuvin® 477 and Tinuvin® 479 exhibit superior photo permanence and heat stability compared to BTZ and BP. In addition HPT show excellent chemical resistance. Mono-resorcinyl-triazines such as Tinuvin® 400 or Tinuvin® 479 do not interact with certain metal ions (e.g., catalysts or production-related impurities) or strong alkali as opposed to BP and BTZ. HPT are the UVA class of choice for applications exposed to high baking temperatures and/or to extreme environmental conditions where highest demands on coating quality are required.

Tinuvin® Carboprotect® is a very red-shifted BTZ protecting light-sensitive substrates up to the Near Visible range. Examples include aromatic systems based on e.g., epoxies. It enables the use of clear coatings over e.g., CFRPs (Carbon Fiber Reinforced Plastics) designed as a structural element in automotive, sporting goods, renewable energy platforms and other decorative/fashion industries.

Tab. 2: The required concentration of UVA for effective protection depends on the dry-film thickness of the coating

dry film thickness	UVA concentration based on binder solids (% w/w)
10 - 20 µm	8 - 4
20 - 40 µm	4 - 2
40 - 80 µm	2 - 1

Fig. 2: General structures of 2-hydroxyphenyl-benzophenones (BP), 2-(2-hydroxyphenyl)-benzotriazole (BTZ) and 2-hydroxyphenyl-s-triazine (HPT) UV absorbers

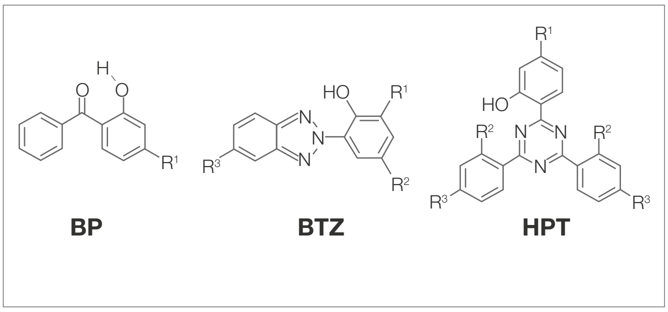
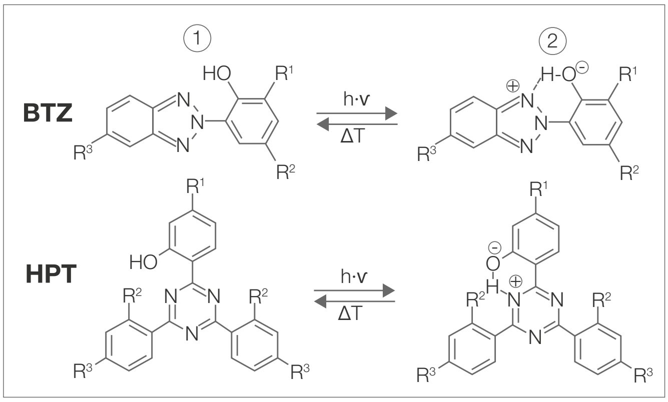


Fig. 3: Mode of action of 2-(2-hydroxyphenyl)-benzotriazole (BTZ) and 2-hydroxyphenyl-s-triazine (HPT) UV absorbers



Lambert-Beer Law

Transmittance T decreases exponentially, absorbance A increases direct proportionally to

- chromophore concentration c
- light path length or film thickness d
- extinction coefficient ε

$$A = \log_{10}\left(\frac{1}{T}\right) = \varepsilon \cdot c \cdot d$$

Product range of Tinuvin® and Chimassorb®

Product name	Chemistry	Physicochemical prameters				
		physical form	Mw (g/mol)	Mp (°C)	automotive and transportation	industrial
2-hydroxy-benzophenone UVA (BP)						
Chimassorb® 81	BP	solid	326	47 - 51		■
Chimassorb® 90	BP	solid	228	61 - 65		■
2-(2-hydroxyphenyl)-benzotriazole UVA (BTZ)						
Tinuvin® 1130	BTZ	liquid	mix	-	■	■
Tinuvin® 326	BTZ-Cl	solid	316	138 - 142		
Tinuvin® 384-2	BTZ	liquid 95 % in 1-methoxy-2-propyl acetate	452	-	■	■
Tinuvin® 99-2	BTZ	liquid 95 % in 1-methoxy-2-propyl acetate	452	-		■
Tinuvin® 900	BTZ	solid	448	138 - 142	■	■
Tinuvin® 928	BTZ	solid	442	109 - 113	■	■
Tinuvin® Carboprotect®	BTZ	solid	560	132 - 136	■	■
bis- and tris-resorcinyl-triazine UVA (HPT), high photo and thermal permanence						
Tinuvin® 460	HPT	solid	630	97 - 101		
Tinuvin® 477	HPT	liquid 80 % in 2-methoxy-1-propyl acetate	mix	-		■
2-hydroxyphenyl-s-triazine UVA (HPT), best photo and thermal permanence, no interaction with amine, strong alkali or any metal catalyst, pronounced absorbance in UV-B range						
Tinuvin® 1577 ED	HPT	solid	425	147 - 151		
Tinuvin® 400	HPT	liquid 85 % in 1-methoxypropan-2-ol	647	-	■	■
Tinuvin® 405	HPT	solid	584	73 - 77	■	■
Tinuvin® 479	HPT	solid	678	39 - 43 [1]	■	■

[1] Tg (°C)

Market segment					Application / remarks
furniture and flooring	printing and packaging	architectural	adhesives	sealants	
		■	■	■	mass stabilization of gel coats; UVA for moderate durability requirements
			■	■	mass stabilization of gel coats; UVA for moderate durability requirements
■	■	■	■	■	universal UVA for medium-performance solvent- and water-based coatings
			■	■	chlorinated red-shifted UVA, allows <1 % transmittance up to 370 nm; FDA approval for indirect food contact in polyolefines
	■		■	■	multipurpose UVA for medium- to high-durability requirements; minimum color impact in refinish clear coat applications
■		■	■	■	multipurpose UVA for medium-durability requirements
	■		■	■	UVA for medium- to high-durability requirements in powder and coil coating applications; limited solubility in liquid coatings
			■	■	UVA for medium- to high-durability requirements in powder and coil coating applications; excellent solubility in liquid coatings
			■	■	very red-shifted UVA for protection of aromatic epoxy systems; especially recommended for carbon- or glass-fiber-reinforced composites; allows < 1 % transmittance up to 420 nm
	■				red-shifted UVA with extremely high extinction coefficient; allows <1 % transmittance up to 370 nm; limited solubility in liquid coatings
■		■	■	■	red-shifted UVA with high extinction coefficient; for high-durability requirements; allows <1 % transmittance up to 370 nm
			■	■	UVA for high-durability requirements in adhesives and sealant applications; limited solubility in liquid coatings
■	■	■	■	■	UVA for high-durability requirements in clear coat applications inclusive UV-curing systems; excellent spectral coverage in combination with Tinuvin® 479
					UVA for high-durability requirements in powder clear coats or 100 % (UV)-curing systems; excellent spectral coverage in combination with Tinuvin® 479
	■	■	■	■	UVA with extremely high extinction coefficient; for highest durability requirements in clear coats, powder coatings or UV-curing systems; specifically suited for thin-film applications

Hindered amine light stabilizers (HALS)

Hindered amine light stabilizers (HALS) are mainly derivatives of 2,2,6,6-tetramethyl piperidine (TMP). They act as radical scavengers in the autoxidation cycle (see fig.1) and inhibit the photo-oxidative degradation of polymers in coatings, adhesives and sealants.

The mode of action of HALS is largely independent of the film thickness applied, which in turn means that they can also act at the coating surface where minor protection through the UVA is given (see Lambert-Beer Law). In clear coats they protect against surface defects such as loss of gloss or cracking, whereas in pigmented coatings chalking and discoloration can be prevented. Finally, these surface defects lead to increased water permeability, loss of physical and protective properties followed by substrate erosion. Today a large variety of different HALS representing mono-, di- or oligo-functional TMPs are available, which – due to their different physical and chemical properties – fulfil the requirements of the coatings and plastic industries (see fig. 4).

For coating applications, di-functional HALS such as Tinuvin® 292 or Tinuvin® 123 are the most widely used classes in the market. Mono-functional HALS such as Lignostab® 1198 are specifically designed as wood lignin stabilizers whereas oligo-functional HALS such as Chimassorb® 944 or Tinuvin® 622 SF are mainly used in powder or plastic applications. HALS with additional features or functionalities are Tinuvin® 144 (tribo activity for powder coatings) or Tinuvin® 152 (non-migrating HALS with reactable primary hydroxyl function for coatings over plastics).

According to the “Denisov cycle” the mode of action of HALS is a cyclic regenerative process (see fig. 5). The HALS compound ① is converted in the presence of oxygen (O_2) and UV radiation (h·v) into the corresponding nitroxyl radical NO• ② as active species, ② traps free RO• radicals under formation of an aminoether N-OR structure ③. N-OR interacts with ROO• forming intermediates which then decompose into harmless decomposition products, thereby reforming the active species NO• ②. The cyclic nature of the stabilization process along with the regeneration of the active species explains the high and long-term efficiency of HALS.

Besides solubility and compatibility the first selection criteria for HALS is their basicity (see fig. 6). The basicity of HALS is governed by the substitution pattern on the piperidine nitrogen: H or alkyl-substituted HALS are basic, whereas aminoether-(N-OR)-functionalized HALS are considered as non-basic.

Basic HALS (e.g., Tinuvin® 292, Tinuvin® 144) are highly efficient and long-term stable, however, they can undergo acid/base interactions with certain formulation components such as biocides, surfactants, catalysts or certain acid-treated pigments, which can result in limited formulation stability or the deactivation of HALS or of other additives.
Furthermore basic HALS can interfere with the curing process of acid-catalyzed or oxidatively curing systems. Non-basic N-OR HALS (e.g., Tinuvin® 123, Tinuvin® 5100, Tinuvin® 152) do not interact, which makes them the products of choice for all applications where traditional basic HALS fail.

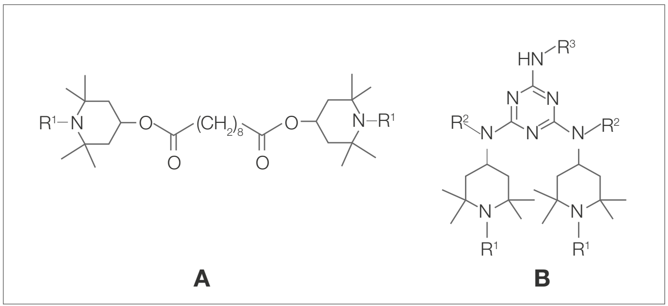
The use level of UVA and HALS strongly depends on the concentration of pigments (acting as UV screeners) and the final thickness of the coating. Clear coatings require higher amounts of UVA (and lower dose levels of HALS) whereas opaque pigmented coatings require higher amounts of HALS (and lower UVA dose levels). Typical use levels are listed in table 3.
The use of UVA in pigmented coatings depends on the pigments used. The light fastness or weather stability of some organic pigments can be improved by addition of UVA whereas for inorganic pigments the use of UVA can be neglected.

Tab. 3: Typical UVA and HALS use levels

Pigmentation	Active UVA (%) [1]	Active HALS (%) [2]
clear	1 - 2	1
semi-transparent	1 - 2	1 - 2
opaque	0 - 1	1 - 2

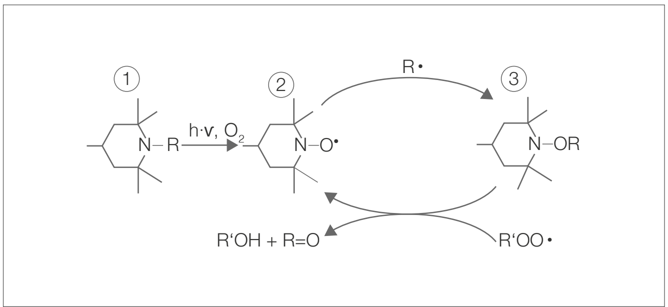
[1] % active UVA on binder solids (DFT ~ 40 µm)
[2] % active HALS on binder solids (does not depend on DFT)

Fig. 4: Typical HALS structures



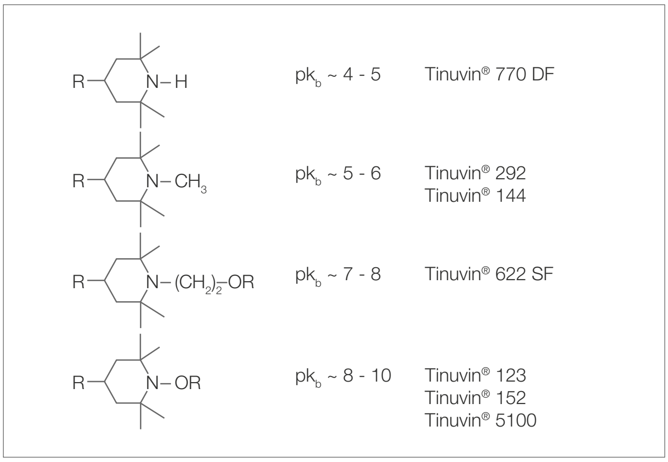
Typical structures of hindered amine light stabilizers (HALS).
A: linked by diester; B: linked by triazine ring

Fig. 5: Denisov cycle



Mode of action of hindered amine light stabilizers (HALS) according to the “Denisov cycle”

Fig. 6: Influence of HALS basicity vs. N-substituent



Product range of Lignostab®, Tinuvin®, Chimassorb®

Hindered amine light stabilizers

Product name	Chemistry	Physicochemical prameters				
		physical form	Mw (g/mol)	Mp (°C)	automotive and transportation	industrial
lignin stabilizer						
Lignostab® 1198	lignin stabilizer	solid	172	66 - 70		
Lignostab® 1198 L	lignin stabilizer solution	liquid 20 % in water	172	-		
HALS						
Tinuvin® 123	N-OR HALS	liquid	737	-	■	■
Tinuvin® 152	N-OR HALS	solid	757	72 - 76 [1]	■	■
Tinuvin® 5100	N-OR HALS	liquid	737	-		■
Tinuvin® 770 DF	N-H HALS	solid	480	81 - 85		■
Tinuvin® 144	N-alkyl HALS	solid	685	148 - 152	■	■
Tinuvin® 292	N-alkyl HALS	liquid	509 / 370	-	■	■
Tinuvin® 292 HP	N-alkyl HALS	liquid	509 / 370	-	■	
oligomeric HALS						
Tinuvin® 622 SF	oligomeric N-alkyl HALS	solid	3.100 - 4.000	57 - 61 [1]		■
Chimassorb® 2020 FDL	oligomeric N-H HALS	solid	2.600 - 3.400	92 - 96 [1]		
Chimassorb® 944 LD	oligomeric N-H HALS	solid	2.000 - 3.100	90 - 94 [1]		

[1] Tg (°C)

Market segment					Application / remarks
furniture and flooring	printing and packaging	architectural	adhesives	sealants	
■		■			lignin stabilizer for wood impregnation
■		■			lignin stabilizer solution for wood impregnation
■	■		■	■	non-basic HALS for acid-catalyzed coatings
			■	■	non-migrating, reactable low-basic HALS for polar solvent-based or plastic coatings (e.g., polycarbonate, ABS substrates)
■		■			non-basic HALS for oxidative curing coatings
			■	■	HALS with food-contact approval
			■	■	antioxidant-functionalized HALS with triboelectric charging activity for powder coatings
■	■	■	■	■	multipurpose HALS for various applications
					multipurpose HALS for color-sensitive applications such as refinish coatings
			■	■	low-basic HALS for powder coatings; limited solubility in liquid coatings
			■	■	oligomeric HALS with antioxidant properties; limited solubility in liquid coatings
			■	■	oligomeric HALS with antioxidant properties; limited solubility in liquid coatings

Tinuvin® DW

Tinuvin® DW are aqueous preparations of light stabilizers for all water-based applications. Based on Novel Encapsulated Additive Technology (NEAT), Tinuvin® DW is supplied as low-viscous, solvent-free, storage- and sedimentation-stable product form.

Tinuvin® DW represents a range of selected BTZ and HPT UVA as well as of N-OR HALS preparations. These light stabilizer preparations are based on a proprietary encapsulation technique where actives are essentially dissolved in an acrylic copolymer matrix. The NEAT-based preparations exhibit excellent long-term storage stability without any sedimentation or phase separation in their delivery form. The absence of Xi R43 labels and of co-solvents makes them the ideal choice for low- to zero-VOC applications. They are easy to incorporate and homogeneously disperse into water and/or water-based paints and allow the post addition at the end of the production process under normal stirring conditions without specific equipment and/or dispersing aids, e.g., emulsifiers or dispersants. After being incorporated into the liquid paint they do not impair paint properties and storage stability. The Tinuvin® DW range fully maintains dry-film properties such as inherent color, gloss and transparency. Other properties such as water permeability and blocking resistance, hardness and scratch resistance are not affected.

Properties of the NEAT family

- light stabilizer is “encapsulated” / dissolved in acrylic matrix
- particle size D_{50} < 150 nm
- active content of 20 % to 30 % (product-specific)
- total solids around 40 % to 50 % (product-specific)

The NEAT family

- **Tinuvin® 99-DW:** multipurpose BTZ for water-based architectural and industrial applications where traditional BTZ are already used
- **Tinuvin® 400-DW:** blue-shifted HPT for high-performance water-based architectural, industrial and automotive applications where BTZ fail or need to be upgraded
- **Tinuvin® 477-DW:** red-shifted HPT for water-based high-performance wood-coating applications
- **Tinuvin® 479-DW:** UVA with extremely high extinction coefficient for highest durability requirements, specially suited for thin film applications
- **Tinuvin® 123-DW:** non-basic N-OR HALS for all applications where basic HALS fail or can not be tolerated
- **Tinuvin® 5333-DW:** UVA/HALS light stabilizer blend with broad spectral coverage for high durability in joinery, GIP, glass and decorative coatings as well as for coatings over plastic

Key features of the NEAT family

- ideal for low- to zero-VOC applications
- no Xi R43 label
- low-viscous, solvent-free dispersions
- storage- and sedimentation-stable

Tinuvin® 5000 series

BASF Tinuvin® 5000 series and other Tinuvin® blends offer synergistic combinations against surface defects, as well as color and gloss retention in coatings, adhesives and sealants applications.

The Tinuvin® 5000 series is attractive in its ease of use and its broad and advantageous solubility and compatibility within most solvent-based coating systems. The Tinuvin® 5000 family matches all performance requirements for architectural, industrial and automotive applications.

The broad UV absorbance of BTZ-based blends makes them suitable for a wide range of coatings on wood, plastic and metal substrates.

HPT-based blends show a high thermal stability and superior photo permanence, which makes them particularly suitable for coatings exposed to high baking temperatures and/or to extreme environmental conditions. Furthermore they are not sensitive to high pH and certain metal ions, i.e., no formation of colored complexes. Blends containing N-OR HALS are especially suitable for oxidatively curing and acid-catalyzed systems. The non-basic character prevents potential interactions with acidic paint ingredients such as catalysts, biocides and pigments.

The 5000 family

- **Tinuvin® 5050:** blend based on BTZ UVA and basic HALS for exterior solvent-based industrial and decorative clear coats or low-pigmented coatings.
- **Tinuvin® 5060:** blend based on BTZ UVA and non-basic HALS for exterior solvent-based oxidatively curing or acid-catalyzed industrial and decorative clear coats or low-pigmented coatings.
- **Tinuvin® 5151:** blend based on BTZ UVA and basic HALS for exterior water-based and solvent-based industrial and decorative clear coats.
- **Tinuvin® 5460:** blend based on HPT UVA and a non-basic HALS for exterior solvent-based oxidatively curing or acid-catalyzed industrial and decorative coatings including UV- and electron-beam curable systems. Due to the chosen UVA to HALS ratio it is especially suitable for clear coats or low-pigmented coatings.
- **Tinuvin® 5248:** blend based on HPT UVA and a basic HALS for exterior solvent-based automotive and industrial coatings including UV- and electron-beam-curable systems. Due to the chosen UVA to HALS ratio it is especially suitable for clear coats or low-pigmented coatings.
- **Tinuvin® 5251:** blend based on HPT UVA and a basic HALS for exterior solvent-based automotive and industrial coatings including UV- and electron-beam-curable systems. Due to the chosen UVA to HALS ratio it is especially suitable for clear coats.
- **Tinuvin® 5272:** blend based on HPT UVA and a non-basic non-migrating HALS for exterior solvent-based automotive and industrial coatings including UV-curable systems. Furthermore the non-migrating properties of the HALS allow the use in coatings over plastics, especially polycarbonates.
- **Tinuvin® 5866:** blend based on UVA and HALS for transparent modified silicone sealants. Combines properties such as excellent initial color and long-term mechanical and light stability.

Key features of the Tinuvin® 5000 series

- synergistic combination of UVA and HALS
- high performance
- ease and simplicity of use

Product range of Tinuvin® DW, Tinuvin® 5000 and HALS blends

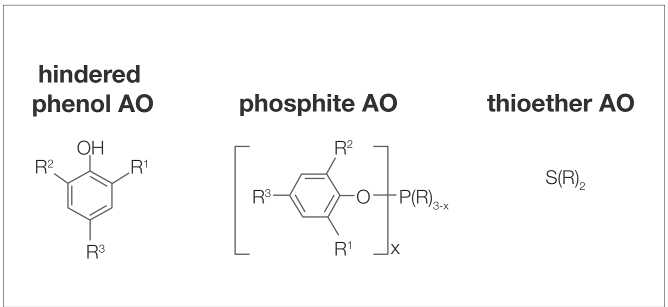
Product name	Chemistry	Physical form	Market segment			
			automotive and transportation	industrial	furniture and flooring	printing and packaging
blends						
Tinuvin® 5050	BTZ / N-alkyl HALS	liquid		■		
Tinuvin® 5060	BTZ / N-OR HALS	liquid		■	■	
Tinuvin® 5151	BTZ / N-alkyl HALS	liquid	■	■		
Tinuvin® 5248	HPT / N-alkyl HALS	liquid	■	■		
Tinuvin® 5251	HPT / N-alkyl HALS	liquid	■	■		
Tinuvin® 5272	HPT / N-OR HALS	liquid	■	■		
Tinuvin® 5460	HPT / N-OR HALS	liquid		■	■	
Tinuvin® 5866	AO / N-alkyl HALS / UVA	solid				
Tinuvin® 5941-R	BTZ / N-alkyl HALS	liquid	■			
Tinuvin® 111 FDL	N-alkyl / N-alkyl HALS blend	solid		■		
Tinuvin® 783 FDL	N-alkyl / N-H HALS blend	solid				
Tinuvin® B 75	AO / N-alkyl HALS / UVA	liquid				
Tinuvin® B 97	AO / N-alkyl HALS / UVA	liquid				
NEAT additive preparations for water-based applications						
Tinuvin® 123-DW	N-OR HALS	liquid 30 % active	■	■	■	■
Tinuvin® 99-DW	BTZ	liquid 24 % active		■	■	■
Tinuvin® 400-DW	HPT	liquid 20 % active	■	■	■	■
Tinuvin® 477-DW	HPT	liquid 20 % active		■	■	■
Tinuvin® 479-DW	HPT	liquid 20 % active	■	■		■
Tinuvin® 5333-DW	UVA HALS	liquid 40 % active		■	■	■

architectural	adhesives	sealants	Application / remarks
■	■	■	UVA/HALS blend for solvent-based applications
■	■	■	UVA/non-basic HALS blend for solvent-based oxidative curing coatings
■		■	universal UVA/HALS blend for water- and solvent-based applications
■			UVA/HALS blend for high-performance solvent-based applications
■			UVA/HALS blend for high-performance solvent-based applications
			UVA/non-migrating, reactable low-basic HALS blend for high-performance solvent-based plastic coatings
■			UVA/non-basic HALS blend designed for coil coating applications
	■	■	stabilizer blend for MS polymers, polyurethane and silicone sealants
			UVA/HALS blend for medium- to high-performance solvent-based coatings; minimum color impact in refinish clear coat applications
	■		HALS blend for powder coating application with triboelectric charging activity
	■	■	HALS blend for solvent-based applications; limited solubility
	■	■	AO/UVA/HALS blend for solvent-based applications
	■	■	AO/UVA/HALS blend for solvent-based applications
■	■	■	N-OR based HALS for all water-based applications
■	■	■	UVA for water-based medium-performance applications
■	■	■	blue-shifted UVA for water-based high-performance applications; excellent spectra coverage in combination with Tinuvin® 479-DW
■	■	■	red-shifted UVA for water-based high-performance wood coatings
■	■	■	UVA for water-based applications with extremely high extinction coefficient; for highest durability requirements, specifically suited for thin-film applications
■			high-performance UVA / non-reacting HALS light stabilizer blend with broad spectral coverage for high-durability requirements in joinery, GIP, plastic, glass and decorative applications

Antioxidants (AO)

AO prevent thermally induced oxidation of polymers in coatings, adhesives and sealants during heat exposure, processing and curing or baking at high temperatures as well as during their service life. Irganox® and Irgafos® represent different primary sterically hindered phenolic AO and secondary thioether or phosphite AO.

Fig. 7: AO structures



Primary AO such as the sterically hindered phenols (e.g., Irganox® 1010, Irganox® 1076) deactivate free radicals (RO•) formed during thermal oxidation and interrupt breakdown reactions via a kinetic mechanism. Primary AO work by donating hydrogen atoms to preferably oxygen-centered radicals (RO•, ROO•), thereby interrupting the autoxidation process. Phenolic AO are multipurpose products for a broad temperature range. They are mainly used to increase the long-term thermal stability of various coatings, plastics, adhesives and sealants.

Secondary AO decompose peroxides (ROOH) formed during the autoxidation process ⑤ and extend the performance of primary AO by synergistic effects.

Today hydrolytically stable phosphites and divalent sulfur compounds are the most widely used secondary AO. Applications include heat stabilization during synthesis, processing, mixing, extrusion and curing or coatings that are baked or cured at relatively high temperatures (e.g., coil coatings and powder coatings).

Irgafos® 126 and Irgafos® 168 are mainly used in powder coating applications.

The thioethers or thiosynergists Irganox® PS 800 or Irganox® PS 802 are especially suitable when “high temperature aging” is required (e.g., automotive cable applications).

Furthermore with the Irganox® B class a range of ready-to-use synergistic blends based on combinations of phenolic and secondary AO is available.

Unlike HALS, AO follow a non-regenerative mechanism, which in turn means that both primary and secondary AO are essentially consumed and rendered ineffective after reaction. Conversely, HALS are usually not effective in preventing thermal degradation. On the other hand, the regenerative nature of HALS allows them to function over much longer time scales. This makes them well suited as light stabilizers, although some oligo-functional HALS can be also effective heat stabilizers under long-term and moderately low heat exposure conditions (Tinuvin® 944 LD and Tinuvin® 622 SF).

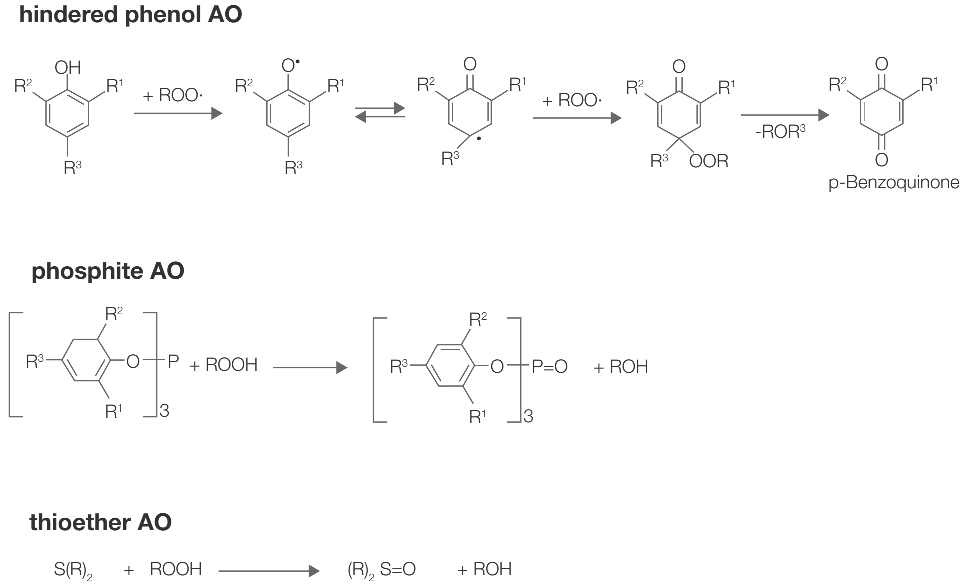
Hindered phenol AO

- activity over broad temperature range (RT to melt)
- improve long-term thermal stability
- non-regenerative mechanism, consumption during reaction

Thioether AO

- thiosynergists like it hot
- rate of ROOH decomposition increases with ΔT
- designed to protect against ”high temperature aging“

Fig. 8: Mechanism of AO



Phosphite AO

- phosphites are processing stabilizers
- stable against hydrolysis
- no colored reaction products

Oligomeric HALS

- HALS with AO properties
- work up to 120 °C
- stable to light, migration and extraction
- in contrast to AO regenerative mechanism

Product range of antioxidants

Product name	Chemistry	Physicochemical prameters				
		physical form	Mw (g/mol)	Mp (°C)	automotive and transportation	industrial
hindered phenolic (primary AO)						
Irganox® 1010	phenol	solid	1.178	110 - 125	■	■
Irganox® 1035	phenol	solid	643	63 - 78		■
Irganox® 1076	phenol	solid	531	50 - 55	■	■
Irganox® 1098	phenol	solid	637	156 - 161		
Irganox® 1135	phenol	liquid	39	-	■	■
Irganox® 1330	phenol	solid	775	240 - 245		
Irganox® 1425	calcium phosphonate	solid	695	> 260		
Irganox® 1520 L	phenol	liquid	425	13 - 14		
Irganox® 1726	phenol	liquid	537	27 - 29		
Irganox® 245	phenol	solid	587	76 - 79	■	■
Irganox® 245 DW	phenol	liquid	587	-		■
Irganox® 3114	phenol	solid	784	218 - 223		
Irganox® 565	phenol	solid	589	91 - 96		
Irganox® MD 1024	metal deactivator	solid	553	221 - 232		
thioether (secondary AO)						
Irganox® PS 800	thioether	solid	515	39 - 41		
Irganox® PS 802	thioether	solid	531	50 - 55		
phosphite (secondary AO)						
Irgafos® 126	phosphite	solid	604	160 - 175	■	■
Irgafos® 168	phosphite	solid	647	183 - 186	■	■

Market segment					Application / remarks
furniture and flooring	printing and packaging	architectural	adhesives	sealants	
			■	■	AO for hot-melt, tackifiers, solvent-based and powder coating applications; not to be used for direct fired gas ovens
			■	■	AO for hot-melt and solvent-based coating applications
			■	■	AO for hot-melt, tackifiers, solvent-based and powder coating applications
			■	■	AO for hot-melt polyurethane and polyamides
			■	■	AO for all solvent-based applications
			■	■	AO for hot-melt, tackifiers and solvent-based coating applications
			■	■	stabilizer for synthesis of polyester resins and adhesives
			■	■	AO for tackifiers and rubber vulcanisates
			■	■	AO for hot-melt and rubber applications
			■	■	AO for hot-melt, sealants, solvent-based and powder coating applications
			■	■	AO for water-based coating applications
			■	■	AO for hot-melt, tackifiers and solvent-based coating applications
			■	■	AO for styrene-isoprene-styrene, styrene-butadiene-styrene block copolymers
			■	■	AO with metal deactivating properties; recommended for polymers in contact with copper
			■	■	AO for hot-melt applications
			■	■	AO for hot-melt applications
			■	■	AO for hot-melts, solvent-based and powder coating applications; prevents yellowing in direct gas fired ovens
			■	■	AO for hot-melts, solvent-based and powder coating applications; prevents yellowing in direct gas fired ovens

Product range of antioxidant blends

Product name	Chemistry	Physicochemical prameters				
		physical form	Mp (°C)	automotive and transportation	industrial	furniture and flooring
AO blends						
Irganox® B 215	phenol / phospite	solid	116 - 179			
Irganox® B 225	phenol / phospite	solid	> 100		■	
Irganox® B 561	phenol / phospite	solid	> 60			
Irganox® B 612	phenol / phospite	solid	> 60			
Irganox® B 900	phenol / phospite	solid	59 - 61		■	

Market segment				
printing and packaging	architectural	adhesives	sealants	Application / remarks
		■	■	AO blend for adhesives and sealants applications
		■	■	AO blend for adhesives and sealants applications
		■	■	AO blend for adhesives and sealants applications
		■	■	AO blend for adhesives and sealants applications
				AO blend for powder coating applications

Biocides

Irgaguard® and Irgarol® are bioactive substances for control of microorganism (bacteria, fungi and algae) in order to prevent deleterious effects on organic substrates.

BASF offers organic and inorganic silver-based antimicrobials for use in coatings where sterile environments are required, as well as triazine-based algicides for marine and architectural applications.

The organic Irgaguard® B 1000 is a very active antimicrobial effective against a wide range of gram-positive and gram-negative bacteria. The combination of low migration rates versus high activity generally provides antimicrobial efficacy over the entire life cycle of the organic substrate.

The silver-based Irgaguard® H 6000 shows high efficacy with broad spectral activity against many target organisms such as bacteria, mold and yeast. In addition to its low eco toxicity, the good thermal stability and light stability combined with its low migration rates makes it suitable for use in hygienic coatings or adhesives and sealants for medical applications.

Irgarol® 1051 is a highly specific and effective inhibitor of the photo synthesis of algae thereby showing outstanding performance in their control. It has comparatively low biological activity towards marine organism and humans. Combined with its very low water solubility this makes it the ideal choice for use in antifouling coatings.

Irgaguard® D 1071 is a highly effective algicide designed for long-term bioprotection of architectural coatings. It prevents subsequent failures such as greenish appearance, increased dirt pick-up and/or water sensitivity and therefore helps to maintain the aesthetic and functional properties of the coating.

Optical brighteners

Tinopal® optical brighteners (OB) are designed to brighten or enhance the appearance of coatings, adhesives and sealants causing a perceived "whitening" effect or to mask yellowing.

Tinopal® can also be used where fluorescence can provide a means of detecting film thickness, registration and identification, e.g., in adhesives and sealants as fluorescent tracer in-line assurance inspections. OB are dyes working by a fluorescent mechanism. They absorb light in the ultraviolet region (usually 340 - 370 nm) of the electromagnetic spectrum, and emit light in the blue region (typically 420 - 470 nm).

The Tinopal® range is available in powder form soluble in solvents as well as in water and as solutions for direct use in various applications. Due to the limited photo stability of optical brighteners resulting in yellowish degradation products the use for exterior applications is not recommended.

Tinopal® NFW liquid is a biphenyl-stilbene derivative for water-based white and pastel-tone paints, clear coats and overprint varnishes to mask the yellowish inherent color and to intensify the brilliance of white and colored base coats.

Tinopal® SFP is a water-soluble triazine-stilbene derivative for use in photographic color developer baths to enhance the apparent whiteness of processed color prints or as fluorescent tracers.

Tinopal® OB CO is a benzoxazole derivative for applications such as solvent-based white and pastel-tone paints, clear coats and overprint varnishes primer and/or topcoats and many more applications, where enhancement of the appearance or masking of yellowing is desired. Furthermore it can be used a fluorescence tracer.

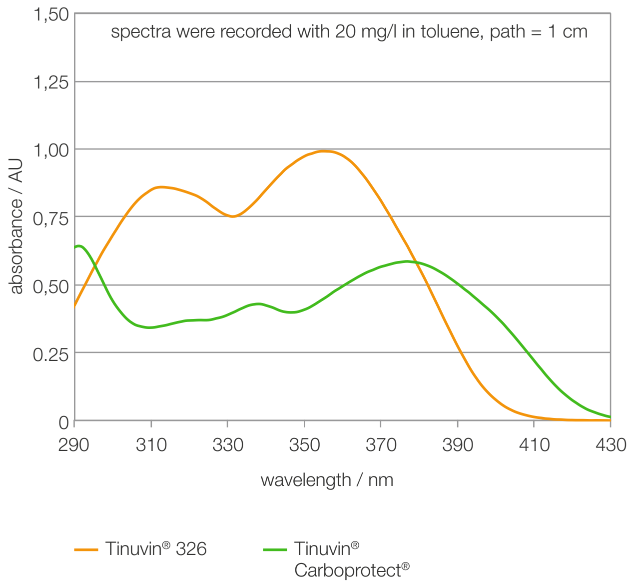
Product range of biocides and optical brighteners

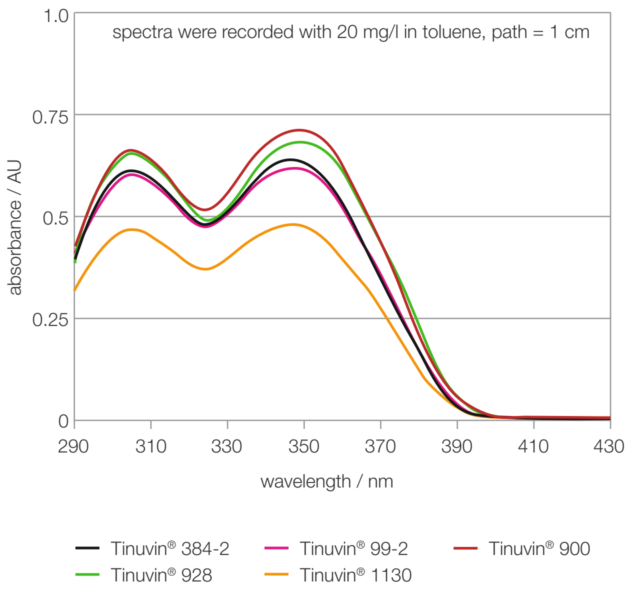
Product name	CAS	Chemistry	Physicochemical prameters				
			physical form	Mw (g/mol)	Mp (°C)	automotive and transportation	industrial
antimicrobials							
Irgaguard® B 1000	3380-34-5	organic antimicrobial	solid	290	56 - 58		
Irgaguard® H 6000	n.n.	silver-glass / zeolite	solid	-	~ 600		■
Irgaguard® D 1071	28159-98-0	organic algicide	solid	253	128 - 133		
Irgarol® 1051	28159-98-0	organic algicide	solid	253	129 - 133		■
optical brightener							
Tinopal® NFW LIQ	27344-41-8	biphenyl-stilbene	liquid	563	-		■
Tinopal® OB CO	7128-64-5	benzoxazole	solid	431	196 - 203		■
Tinopal® SFP	41098-56-0	triazine-stilbene	solid	1,305	-		■

Market segment					Application / remarks
furniture and flooring	printing and packaging	architectural	adhesives	sealants	
			■	■	organic antimicrobial for adhesives and sealants
■		■	■	■	silver-glass / zeolite-based antimicrobial for hygienic coatings
		■			triazine-based algicide for architectural and construction coatings
					triazine-based algicide for antifouling in marine and protective coatings
	■	■	■	■	liquid OB for water-based white and pastel-tone paints, clear coats, overprint varnishes, adhesives and sealants
	■	■	■	■	solid OB for water-based white and pastel-tone paints, clear coats, overprint varnishes, adhesives and sealants
	■	■	■	■	water-soluble OB for photographic color developer baths or as fluorescent tracers

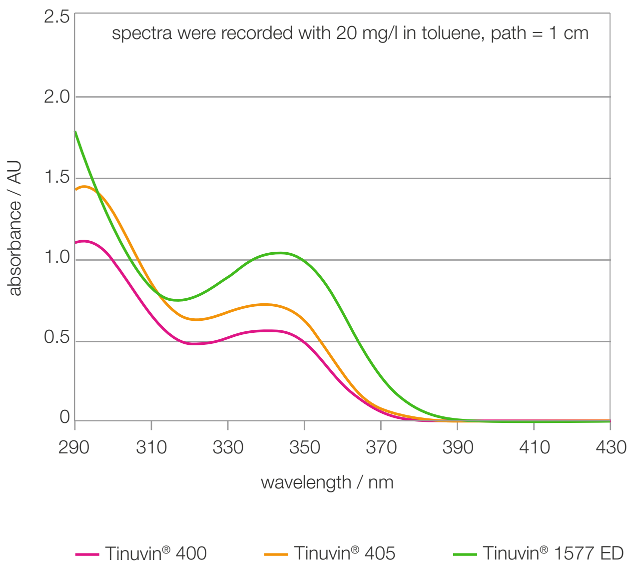
UV-VIS absorbance spectra of UV absorbers

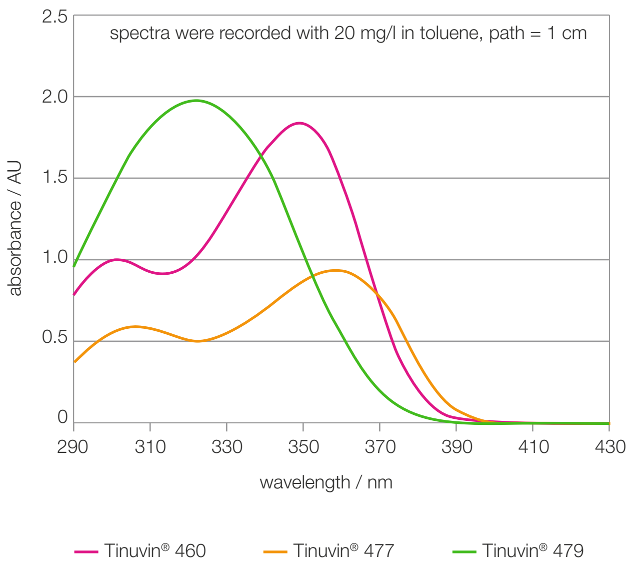
2-(2-hydroxyphenyl)-benzotriazole (BTZ)



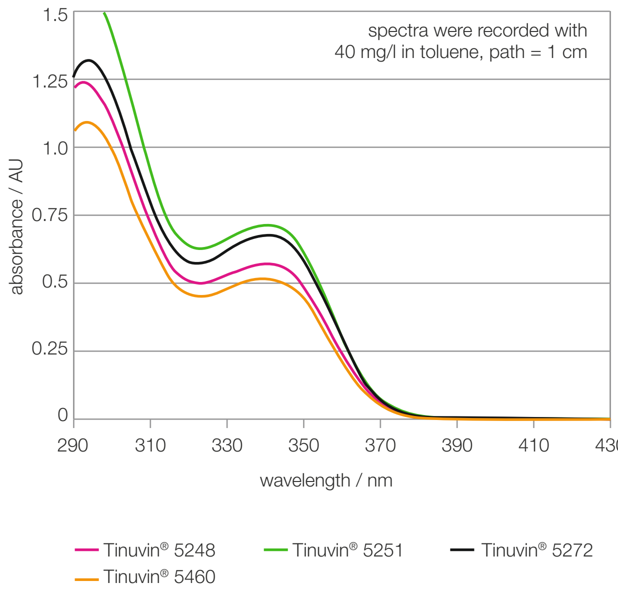


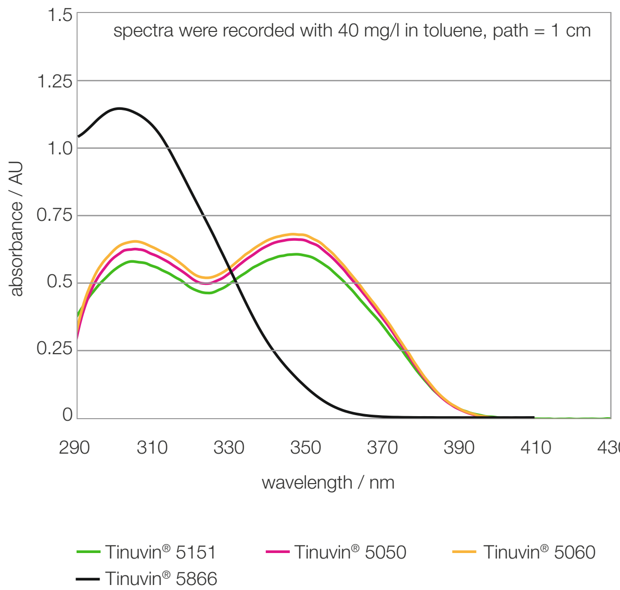
2-hydroxyphenyl-s-triazine (HPT)



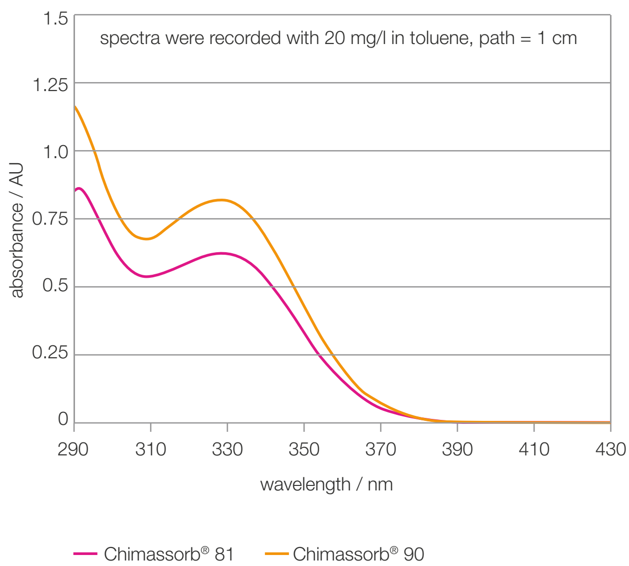


Tinuvin® 5000 series

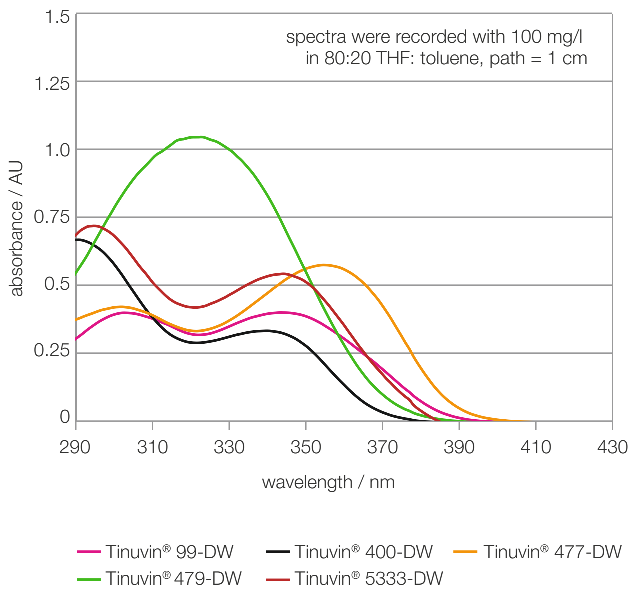




2-hydroxy-benzophenone (BP)



Tinuvin® DW series



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