Pigments & Additives Division Plastic Business



Exactly your chemistry.

The Coloration of Plastics and Rubber

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Foreword

The coloration of plastics is an area of technology in which everyone has an opinion, everyone else can do it better and cheaper and where the mistakes are highly visible and usually expensive.

This brochure sets out to provide the reader with a practical insight in to the polymers, processes and applications applying to the plastics industry and the coloring solutions available from the Clariant ranges of organic colorants.

Section 1 of this brochure is an introduction and guide to the coloration of plastics and includes chapters covering colorant classification, colorant selection criteria and an overview of the Clariant product ranges for plastics coloration. This is followed by a product by product guide to the main areas of application using the following key:

- suitable
- limited suitability (preliminary testing required)
- not suitable

Section 2 provides a concise guide; polymer by polymer to the coloring possibilities with Clariant organic colorants which includes polymer properties, processing and coloring techniques and details of the individual colorants, their suitability for an application and their application data in the selected polymer and process.

The coloring attributes, technical data and application values given are derived from Clariant laboratory testing under specific conditions which are detailed in **Section 3** of this brochure. These may differ according to actual working conditions, e.g. machine related data, applied concentrations, exposure to temperature and shear stress over prolonged periods of time, and/or the type and grade of polymer used. Users are therefore recommended to verify the suitability of a colorant for a particular use with preliminary trials under the relevant working conditions.

Additionally in **Section 3** a chapter concerns itself with Colour Index registrations, chemical designations, the physical attributes of the colorants and includes chemical resistance data.

A full index to the sections and chapters contained within this brochure can be found on the following page.

Note on the thermal stability of diarylide pigments

Pigments indicated with the symbol * throughout this brochure are collectively identified chemically as diarylide pigments. Due to the potential for thermal decomposition (refer to the relevant material safety data sheets) from these pigments, a heat stability of 200 °C is given, even when the coloring attributes of the pigment would remain stable at higher temperatures.

Further information can be found in ETAD INFORMATION NOTICE No. 2 "Thermal Decomposition of Diarylide Pigments" - September 1990.

Clariant shade cards and technical brochures

The Business; Marketing Plastics of Clariant strives to provide a high level of technical information regarding its products. Technical brochures and shade cards are continually being updated to include new products, cater for new applications and to provide customers with the relevant technical data in order to meet the demands of a fast changing industry. Please contact your local Clariant sales organisation or regional Technical Application Centre to ensure that the most up to date information is on hand and with any questions that may arise.

Addresses of the Regional Technical Centers can be found on page 85 of this brochure.

Clariant also provides a number of services, product data sheets and technical information on the Internet. For information specific to plastic applications click on to:

http://www.pa.clariant.com

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1.5 Optical Brightening Agents (OBA)

Introduction to OBA's Overview of the Hostalux and Leucopure range and areas of application Hostalux and Leucopure fastness properties

1 Introduction to the Coloration of Plastics and Product Overview

1.1 Introduction

Plastics are essential materials used in all aspects of daily life, their unique forming capabilities, thermal, tensile and electrical properties together with their resistance to chemicals and other harsh environments combine to make them the most flexible of engineering materials.

Plastics are synthetic, polymeric materials which can be formed under heat and pressure, upon cooling they regain their polymeric structure. Plastics are produced from polymers; chemical compounds composed of long chain molecules in small repeating units (monomers). Plastics are rarely processed alone; they can be modified with inorganic compounds to impart various physical characteristics, they are often stabilised with additives and processing aids to improve or modify performance properties and they can be co-polymerised or alloyed with other plastics to achieve distinctive physical and resistance properties.

The coloration of plastics is not only for decorative purposes, it is used for identification, safety, product branding, segmentation and environmental purposes. Coloration can be achieved using organic and inorganic pigments, solvent, disperse and other polymer soluble dyes. Effect pigments such as: aluminum and bronze powders, pearlescent and phosphorescent pigments can be added to enhance the optical properties of plastics. Pearlescent pigments can be used in certain instances to impart laser marking properties.

Pigment preparations made up of finely dispersed pigment particles in a polymeric or polymer compatible material are often used in dispersion critical applications. Pigments require a high level of dispersion to breakdown agglomerates which occur in the production process, transportation and storage of these colorants. The most common dispersion techniques are;

- Internal mixing (banbury type)
- > Twin screw extrusion
- Kneader mixing
- > Twin or triple roll milling
- > Compounding extrusion
- > Ball or bead milling

The physics of dispersion involve the breaking down of the internal forces that hold the primary pigment particles together in an agglomerated form. The aim of dispersion is to produce a homogeneous mixture of carrier and pigment which is compatible with the end polymer to be colored. Dispersion aids (wetting agents) such as; waxes, stearates, plasticisers, surfactants or liquid adhesives are incorporated to improve the dispersion process.

Colorants are classified as either pigments or dyes. Pigments can be inorganic or organic, colored, white or black. Pigments are practically insoluble in the medium in which they are incorporated.

Most inorganic pigments demonstrate good resistance to the influence of weathering, have hiding power and a high resistance to heat. Many however, lack color strength, are dull and a limited choice of shades (colors) is available. Certain groups of traditionally used inorganic pigments; cadmium, lead chromate and molybdate chemistries are legislated against in many countries and applications.

Organic pigments offer a comprehensive range of shades, color strengths and levels of brightness. A wide variety of chemistries provide for differing heat stability's and fastness properties. Organic pigment selection is critical to obtaining the desired properties at the most economical cost.

Unlike pigments which are practically insoluble in plastics; Polymer-, Solvent- and Disperse soluble dyes achieve their solubility during the processing phase of plastic materials and lose their crystal structure to go in total solution as a molecular distribution.

Soluble dyes are generally suitable for the coloration of amorphous polymers; U-PVC (unplasticised), PS, SAN, ABS, PMMA, PC, PEI and PSU etc. Many can also be used in the coloration of thermoplastic polyester and selected members of the polyamide family. They are not suitable for the coloration of plasticised polymers and polymer blends containing ethylene bonds due to their potential to migrate out of the polymer. In combination with butadiene modified polymers their resistance to migration should be initially tested.

A potential exists for organic colorant chemistries to react with polymer additives, processing stabilizers and impurities present in plastics. In addition, interactions or a reduction of properties in combination with lubricants and additives included during processing of these polymeric materials are possible. The effects of such interactions could lead to the formation of degradation products, to unstable shades, reduced thermal properties or migration problems. Processors are strongly advised to verify all data by testing each color formulation under the actual conditions of use.

1.2 Colorant selection criteria

The selection of colorants for a particular application is dependant on many factors. The most critical thereof are discussed below;

Values for the heat stability of a colorant are usually derived from a pre-determined concentration i.e. Standard Depth ¹/₃. The **limiting concentration** of a colorant determines its thermal stability profile in the stated polymer. The **limit concentration** determines the lowest dilution at which a colorant is thermally stable at a given temperature. The values obtained are valid for the stated grade and type of polymer; they are not automatically valid for other grades and for all polymers.

Particle size: In paste and liquid dispersions the particle size and hence the specific surface area of a pigment influence the rheology of the system. The larger the particle size, the lower the specific surface area of a pigment and consequently the viscosity is also lower. A pigment with a high specific surface area will require additional "wetting out" in order to obtain an optimum dispersion. In many instances, pigments manufactured from the same chemistry are offered in differing milled forms. A coarser milling produces larger particles; this in turn leads to a higher opacity and lower color strength in comparison with a finer milled product. Particle size distribution is also an important factor in obtaining an optimum dispersion in plastics applications. A narrow band distribution with a minimum of over- and undersized particles will more readily disperse in to a thermoplastic system, particularly when physical dispersion forces and pigment wetting are at a premium.

Dimensional stability: Many organic pigments have been shown to influence the crystalline behaviour of polyolefins by inducing a nucleating effect. The effect that the shrinkage in the direction of flow is no longer equal to that across the direction of flow is known as warpage or dimensional missbehavior, particular prevalent in the processing of HDPE.

Pigment dispersibility; in critical applications such as thin films, transparent packaging, fibers, monofilaments, thin wall articles and components with integral hinges, the optimum pigment dispersion is essential to provide the functionality in use. For these applications organic colorants that have been specifically manufactured for use in plastics e.g. controlled in the synthesis for crystallite growth and subsequently for particle size and distribution should be selected. These, having then been tested for ease of dispersion in a plastic medium according to industry standard tests such as European Standard EN 13900-5 "The determination of a filter pressure value in PP", LDPE thin-film testing or dispersion hardness in PVC provide the assurance of suitability for the given application.

The **light fastness** of a colorant is primarily determined by its chemistry. Particle size and distribution can also be influencing factors. The light fastness values are obtained by exposing a colorant dispersed in a polymer matrix to a UV light source together with a Blue wool scale. The results are assessed against the Blue wool scale whereby fastness to step 8 indicates very high light fastness and to step 1 indicates very low light fastness. A high level of dispersion is critical to obtaining the values quoted for a particular colorant.

The **weather fastness** properties of a colorant are a feature of molecular structure and particle size. Many factors, most importantly polymer stabilisation, pigment concentration and the strength of UV radiation can influence the result. Accelerated weathering in a weather-o-meter can provide a good indication of the performance of a given formulation however, a pre-test under the applied conditions of use is always recommended.

In plasticised polymers certain organic pigments can bleed out onto a contact substrate. This is a form of migration referred to as "bleeding". **Fastness to bleeding** is tested for in plasticised PVC and is measured against the ISO Grey scale whereby step 5 = no bleeding and 1 = excessive. In the presence of additives with a migratory nature i.e.; Anti-static agents, a pigment can migrate with the additive from the polymer matrix onto the surface.

Relative color (tinting) strength is the means of comparing the tinting strengths of two or more colorants. The DIN 53235 standard determines the test method for the assessment of colorants in reduced shade to International Standard Depth $1/_3$ (SD $1/_3$) against a standard reference. The SD $1/_3$ value obtained for a colorant is given in grams of colorant per kilogram of polymer assuming the addition of either 1 % or 5 % titanium dioxide. The lower the given value of a colorant the higher it's relative color strength.

Coloration costs refer to the total cost of coloring an end article and take into consideration the relative color strengths of the colorants as well as the kilo price of a given product.

The formulation to calculate the coloration costs is given as;

 $\frac{\text{Colorant price €/kg x SD }^{1}/_{3} \text{ in g/kg}}{100} = \text{Coloring cost in €/kg}$

1.3 The Clariant colorant ranges

Clariant offers specifically selected ranges of organic colorants under the PV Fast, Graphtol, DrizPearls, Hostasol, Solvaperm and Polysynthren names recommended for thecoloration of plastics. Under the names; Hostaprint, Hostasin and Hostacryl Clariant manufactures pigment preparations for the coloration of PVC, PMMA and Rubber. The Hostalux and Leucopure range from Clariant are optical brightening agents for enhancing the optical properties of plastics.

The **PV Fast®** range of pigment powders are high performance organic pigments with excellent heat resistance, high light fastness and very good bleed fastness properties. These pigments are designed for their ease of dispersion in thermoplastic materials and are specifically suitable for fibers, thin wall and dispersion critical technical applications.

The **Graphtol**[®] pigment powders are a range of classic and novel organic chemistries specifically selected for plastics applications. Graphtol pigments present a wide range of shades and technical properties which offer the user economical coloring solutions.

DrizPearls[®] pigments are selected PV Fast and Graphtol pigments in a dust free, free flowing form for applications in polyolefins. They offer many processing advantages and potential cost saving opportunities.

Solvaperm dyes are high-quality polymer soluble colorants that were developed for coloring polystyrene (PS) and its derivatives. They are in addition suitable for a wide range of other polymers including thermoplastic polyesters and polycarbonate.

Hostasol®* dyes are fluorescent colorants suitable for PS, SAN, ABS, PC, PMMA and U-PVC. Some Possibilities exist for the coloration of various grades of polyamide and in thermoplastic polyester applications.

The **Polysynthren®** range of polymer-soluble colorants have been especially developed for the coloration of thermoplastic polyester (with the exception of Polysynthren Yellow RL). They produce intensely colored, brilliant shades with outstanding fastness properties. The main applications are in PET fibers, filaments and bottles. Polysynthren's also find applications in other technical polymers, however pretesting is required. Polysynthren Yellow RL is a colorant that has been developed for the coloration of polyamide, there it exhibits excellent fastness properties.

The **Hostaprint®*** range of pigment preparations based on a vinyl chloride/acetate co-polymer provide for optimum pigment dispersion in a free-flowing, low dusting form. Hostaprint preparations are recommended for the mass coloration of plasticised (P) and unplasticised (U) PVC and suited for printing applications on PVC and Polyurethane. Hostaprint preparations are based on 50 % single pigment dispersions from our organic pigment range.

The **Hostasin**[®]* range of organic pigment dispersions are based on an oxidation resistant polyolefin copolymer carrier that is fully compatible with natural rubber and common synthetic rubbers. They are in a dust-free, free-flowing form and the optimised pigment dispersion ensures maximum color development and reproducibility.

The **HostacryITM** range of pigment preparations, based on an acrylic carrier, provide optimum pigment dispersion in a free-flowing, low dusting form. The Hostacryl pigment preparations are an excellent solution for coloring thin layered acrylics. Hostacryl's are based on 50 % single pigment dispersions with excellent fastness properties.

The **Hostalux**[®]* and **Leucopure**[®] ranges of **O**ptical **B**rightening **A**gents (OBA) offer a broad range of products with excellent fastness properties for enhancing the brightness and purity of plastics and synthetic fibers. They also produce whitening effect in natural polymers.

The above mentioned colorant ranges are specifically manufactured for and are tested in plastics applications. In addition, selected colorants under the trade names **Novoperm®**, **Hostaperm®***, **Permanent** and **Fat** can be used in the coloration of plastics. Usage is dependant upon the polymer being processed and the application technology. These products are however, not regularly test for in plastics and their specifications are determined in nonplastic test medium. For further information regarding potential use of these colorants, contact with your local Clariant sales organisation or regional Technical Application Center is advised.

1.4 Overview of the product ranges and main fields of application

PV Fast pigments																
Product name	Colour Index	РР	PE	PVC	PS/SAN	ABS	PC	POM	PA 6	PET	PBT	PMMA	Rubber/TPV	SBC	TPO	TPU
PV Fast																
Yellow H9G	Pigment Yellow 214						—		_	_						
Yellow H2G	Pigment Yellow 120										_	•				
Yellow HG 01	Pigment Yellow 180								—	—						
Yellow HG	Pigment Yellow 180								—	—						
Yellow H2GR	Pigment Yellow 191							٠	—	_						
Yellow HGR	Pigment Yellow 191								—	—						
Yellow HR 02*	Pigment Yellow 83	—	٠		—	—	—	—	—	—	—	—			•	
Yellow HR*	Pigment Yellow 83	—			_	—	_		—	—	—	—			•	
Yellow H3R	Pigment Yellow 181						—		—	—		٠				
Orange H4GL 01	Pigment Orange 72								—		—	•				
Orange H2GL	Pigment Orange 64						•	٠	—	_	٠	٠				٠
Orange GRL	Pigment Orange 43							—				•				
Orange 6RL	Pigment Orange 68									—		٠				
Scarlet 4RF	Pigment Red 242								—							
Red B	Pigment Red 149								٠							
Red D3G	Pigment Red 254								—			—				
Red HB	Pigment Red 247							—	—	—		٠				
Red 3B	Pigment Red 144								—	—						
Red BNP	Pigment Red 214								—	•						
Red HF4B	Pigment Red 187								—	—						
Red E3B	Pigment Violet 19							۲	•	٠	•	•				
Red E5B	Pigment Violet 19							•	•		•	•				
Pink E2G	Pigment Red 122							۲	٠		٠	٠				
Pink E	Pigment Red 122											•				
Pink E 01	Pigment Red 122							٠	٠	٠	٠	•				
Violet ER	Pigment Violet 19											•				
Violet BLP	Pigment Violet 23					—	—	—	٠	—	—	—				
Violet RL	Pigment Violet 23							_			_	_				
Blue A4R	Pigment Blue 15:1							۲	•	•	•					
Blue A2R	Pigment Blue 15:1								•		•					
Blue AV	Pigment Blue 15:1			—	—	—	—		_	—	_	—	—	—	—	—
Blue BG	Pigment Blue 15:3															
Green GNX	Pigment Green 7								٠	٠						
Brown HFR	Pigment Brown 25				_	_	_		_	_	_	٠		٠		
Brown RL	Pigment Brown 41					—	—		—	—	—	٠		٠		

Graphtol pigments														
Product name	Colour Index	РР	PE	PVC	PS/SAN	ABS	PC	POM	PA 6	PMMA	Rubber/TPV	SBC	TPO	TPU
Graphtol														
Yellow H10G*	Pigment Yellow 81	_			_	_	_	_	_				•	
Yellow GG*	Pigment Yellow 17	_	•			_	_		_				•	
Yellow 3GP	Pigment Yellow 155					_	_	•	_	•		٠	•	٠
Yellow GXS*	Pigment Yellow 14	_	•		_	_	_	_	_	_			•	
Yellow GR*	Pigment Yellow 13	—			_								•	
Yellow H2R	Pigment Yellow 139					_	_		_	—		•	•	•
Orange GPS*	Pigment Orange 13		•						_				—	—
Orange RL*	Pigment Orange 34	—	•			_			_	—			—	_
Red HFG	Pigment Orange 38					—	_		_	—			•	
Red LG	Pigment Red 53:1								_	•			•	
Red LC	Pigment Red 53:1							—	—	•			•	
Red BB*	Pigment Red 38	_	•			_			_				•	
Red F3RK 70	Pigment Red 170				—	—	—	—	—	_	—	—	•	—
Fire Red 3RLP	Pigment Red 48:3								_				•	
Red HF2B	Pigment Red 208				—	—	—	—	—	—			•	
Red F5RK	Pigment Red 170					_			_		_	_	•	_
Red 2BN	Pigment Red 262							_	—				•	
Red P2B	Pigment Red 48:2					—	_	—	—	—			•	
Carmine HF4C	Pigment Red 185					—	—	—	—	—			•	
Carmine HF3C	Pigment Red 176					—		—	—				•	
Rubine 6BP	Pigment Red 57:1				٠	—	—	—	—	—			٠	
Bordeaux HF3R	Pigment Violet 32	•	•		_	—	_	—	—	—				
Blue AN	Pigment Blue 15	—	—	•	—	—	—	—	—	—	•	•	•	•
DrizPearls														

Product name	Colour Index	РР	PE	PVC	PS/SAN	ABS	PC	POM	PA 6	PMMA	Rubber/TPV	SBC	TPO	TPU
DrizPearls														
Yellow 3GP	Pigment Yellow 155			_	_	_	_	_	_	_	_	_	•	_
Yellow HG	Pigment Yellow 180			_	_	_	_	_	_		_	_	•	_
Red F3RK 70	Pigment Red 170			_	_	_	_	_	—		_	—	•	
Red E5B	Pigment Violet 19			_	_	_	_	_	_		_	_	•	_
Pink E	Pigment Red 122			_	_	_	_	_	_		_	—	•	_
Violet RL	Pigment Violet 23			_	_						_	_	•	
Blue BG	Pigment Violet 15:3			—	—	_	_	_	—		_	—	•	
Green GNX	Pigment Green 7			_	_	_	_		_		_	_	•	

Solvaperm dyes													
Product name	Colour Index	Polymer											
		PS	SAN	ABS	PC	PETP/ PBTP	PMMA	PA	U-PVC				
Solvaperm													
Yellow G	Disperse Yellow 64							•					
Yellow 3G	Solvent Yellow 93			_		_		_					
Yellow 2G	Solvent Yellow 114							•					
Orange 3G	Solvent Orange 60							•					
Red 2G	Solvent Red 179												
Red G	Solvent Red 135							•					
Red PFS	Solvent Red 111							•					
Red BB	Solvent Red 195							_					
Red Violet R	Disperse Violet 26 /					•		•					
	Solvent Violet 59												
Violet FBL	Solvent Violet 37				—	•		—					
Violet RSB	Solvent Violet 13							—					
Blue 2B	Solvent Blue 104							•					
Green GSB	Solvent Green 3							—					
Green G	Solvent Green 28							—					

Polysynthren polymer so	oluble colorants											
Product name	Colour Index	Polymer										
		PS	SAN	ABS	PC	PETP/ PBTP	PMMA	PA				
Polysynthren												
Yellow GG	Solvent Yellow 133	_	_	_			•	_				
Yellow NG	Pigment Yellow 147	•	•	•			•	_				
Yellow GS	Solvent Yellow 163						•	_				
Yellow RL	Pigment Yellow 192	_	_	_	_	•	_					
Golden Yellow GR	Pigment Yellow 196	•	•	•			•	_				
Red GG	Solvent Red 212	_	_	_			_	_				
Red GFP	Solvent Red 135							•				
Violet G	Solvent Violet 49	•	•	•				_				
Blue R	Solvent Blue 122							_				
Blue RLS	Solvent Blue 45							_				
Blue RBL	Solvent Blue 104							_				
Brown 3RL	Pigment Orange 70	•	•	•			•	_				
Brown R	Solvent Brown 53							—				

Hostasol fluorescent dyes									
Product name	Colour Index								
		PS	SAN	ABS	PC	PETP/ PBTP	PMMA	PA	U-PVC
Hostasol									
Yellow 3G	Solvent Yellow 98							•	
Red GG	Solvent Orange 63							•	
Red 5B	Vat Red 41		•	•		٠		—	

Hostaprint pigment preparations

Product name	Colour Index	Product name	Colour Index
Hostaprint		Hostaprint	
Yellow GG 32*	Pigment Yellow 17	Carmine HF4C 32	Pigment Red 185
Yellow H4G 32	Pigment Yellow 151	Red E5B 32	Pigment Violet 19
Yellow 3GP 32	Pigment Yellow 155	Pink E 32	Pigment Red 122
Yellow HG 32	Pigment Yellow 180	Bordeaux HF3R 32	Pigment Violet 32
Yellow HR 32*	Pigment Yellow 83	Violet ER 32	Pigment Violet 19
Yellow HGR 32	Pigment Yellow 191	Violet RL 32	Pigment Violet 23
Yellow H2R 32	Pigment Yellow 139	Blue A4R 32	Pigment Blue 15:1
Orange H4GL 32	Pigment Orange 72	Blue A2R 32	Pigment Blue 15:1
Red HFG 32	Pigment Orange 38	Blue B2G 32	Pigment Blue 15:3
Red B 32	Pigment Red 149	Green GG 32	Pigment Green 7
Red BB 32*	Pigment Red 38	Brown RL 32	Pigment Brown 41
Red D3G 32	Pigment Red 254	Brown HFR 32	Pigment Brown 25
Red BNP 32	Pigment Red 214	Black L 32	Pigment Black 7
Red HF2B 32	Pigment Red 208		

Hostasin pigment preparations

Product name	Colour Index	Product name	Colour Index
Hostasin		Hostasin	
Yellow GR 30*	Pigment Yellow 13	Red B 30*	Pigment Red 38
Yellow HR 30*	Pigment Yellow 83	Red HF2B 30	Pigment Red 208
Orange G 30*	Pigment Orange 13	Blue A2R 30	Pigment Blue 15:1
Red LC 30	Pigment Red 53:1	Green GG 30	Pigment Green 7

Hostacryl pigment preparations

Product name	Colour Index	Product name	Colour Index
Hostacryl		Hostacryl	
Oxide Yellow BV	Pigment Yellow 184	Green GNX	Pigment Green 7
Pink E	Pigment Red 122	Brown HFR	Pigment Brown 25
Blue A4R	Pigment Blue 15:1		

1.5 Optical Brightening Agents (OBA)

Optical brightening agents, often referred to as Optical Brighteners or Fluorescent Whitening agents are extensively used in the coloration of plastics and synthetic fibers. The main fields of application in plastics are polyvinyl chloride, polyolefins, ethylene vinyl acetate copolymers, polystyrene, polyester and polyurethane. Optical brighteners produce a whitening effect in natural polymers. In shades of white and in pastel colors their addition results in cleaner (purer), more brilliant (higher chroma) and bluer tints. The addition of optical brighteners leads to a consumer perception of "new, uncontaminated and ecologically clean colors". Under ultraviolet light plastics containing optical brighteners fluoresce, this feature is often used for security marking, identification and quality control aspects of finished goods.

Optical brighteners absorb Ultra-violet (UV) light in the range 360 - 380 nanometers (nm) and re-emit this light in the visible spectrum in the range 420 - 460 nm. They are applied in a similar way to soluble colorants in plastics applications using conventional equipment. Behavior during processing is also similar to that of soluble dyes; the optical brighteners dissolve mono-molecularly in the polymer melt.

Optical brighteners are most effective when added in low concentrations and produce particularly good brightening and coloring effects when used in combination with solvent dyes. In combination with titanium dioxide and many types of filler, which also absorb light in the UV range, the excitation energy available to the optical brightener and therefore its effectiveness is reduced. The same scenario is applicable when an OBA is used in combination with UV Absorbers. However, when combined with a Hindered Amine Light Stabilizer (HALS) which do not absorb UV light, not only is an increase in the level of whiteness observed, the light fastness value of the OBA particularly in polypropylene and polystyrene can be improved.

Addition levels of optical brighteners vary according to the application and polymer, the following provides an indication;

For transparent polymers:	5 -	20	ppm	(0.0005	-	0.002	%)
For colored formulations:	20 -	100	ppm	(0.002	-	0.01	%)
For white formulations:	100 - 1	1000	ppm	(0.01	-	0.1	%)
For fiber applications:	150 -	200	ppm	(0.015	-	0.02	%)

For very low addition levels and to facilitate metering on the machine many OBA's are available in dilutions blended with calcium carbonate. In the production of OBA based concentrates, the concentration of optical brightener is typically in the range from 5 to 20 %. Solubility limits in the polymeric carrier at the melt processing temperature must be considered. In addition, the presence of plasticisers, particularly those used in PVC applications can promote migration or bleeding of the OBA. Selection of a suitable grade and the addition level are important considerations in these instances.

The selection of optical brightener for a given application is important. Although technical data sheets often refer to OBA's as being suitable in a wide range of polymers and applications, care should be taken. The thermal stability, light fastness and solubility vary according to the chemical type and the selected polymer. Other considerations include their use in the presence of plasticisers and other polymer additives such as antistatic agents which can lead to a migration of an OBA to the surface of the polymer. In grades of LDPE with a particularly low density and high melt flow the potential for blooming exists. Sublimation resistance is important in the coloration of polyester fibers and chemically aggressive polymer melts can reduce properties.

The following selection guide provides an overview of the Clariant range of Optical Brighteners and their suitability in a wide range of polymers.

For the brightening of polyester fibers and filaments optical brighteners can be added as: powder, as a dispersion in ethylene glycol or as concentrate based on a polymeric carrier. The property table found on the following page illustrates the fastness values determined in (DTY) polyester yarn with a titer of dtex 144 f 48 in a "bright" PET from the addition of 2 % masterbatch (corresponding to 200 ppm optical brightener). The fastness tests and assessments were carried out in a accordance with the current DIN and ISO specifications listed and are valid for the above mentioned conditions. Processors are strongly advised to confirm the results under actual conditions of use in the specified system.

Overview of the Hostalux and Leucopure ranges and areas of application Optical Brighteners for Plastics and Synthetic Fibers

Product name	PE / PP	PS / ABS	PBT / PET	PA	PVC		EVA
					flexible	rigid	
Hostalux							
КСВ							
KCB gran.							
KCU							—
KS					•		—
KSB					•		—
KSB 3					•		—
KSN					•		—
KS1	—				—	•	—
KS1 B	—				—	•	—
KS2					•		—
KVC	—	—	—	—	-		—
Leucopure							
EGM	•						_

Fastness Properties													
144 f 48 dtex PET (bright) DTY	48 dtex DIN 75 202 (bright) FAKRA		02	ISO 105 B02 ISO 105 CO4 Light (Washing 4 fastness 95 °C/203 °		04 4) °F	IS (I 210	0 105 P Dry hea) °C/41(30 s	01 t)) °F	ISO 105 PO2 (Steam pleating) 130 °C/266 °F 15 min			
Product name	1 x	3 x	5 x	Grey Scale	Gi	r <mark>ey Sc</mark> a	le	Gi	r <mark>ey Sc</mark> a	le	G	rey Sca	le
	Blue Scale	Grey Scale	Grey Scale	Method 2	Ν	PET	CO	Ν	PET	CO	N	PET	CO
Hostalux	ostalux												
KS 1	7	5	4-5	5	5	5	5	5	5	5	5	5	5
KS 1B	7	5	4-5	5	5	5	5	5	5	5	5	5	5
KSN	7	5	4-5	5	5	5	5	5	5	5	5	5	5
KS	7	5	4-5	5	5	5	5	5	5	5	5	5	5
KSB	7	5	4-5	5	5	5	5	5	5	5	5	5	5
KSB 3	7	5	4-5	5	5	5	5	5	5	5	5	5	5
Leucopure													
EGM	7	4-5	4	5	5	5	5	5	5	5	5	5	5

Polymer by Polymer guide

2 Polymer by Polymer guide

2.1 PVC and Plastisols

U-PVC P-PVC Hostaprint preparations PVC cable sheathing Plastisols Coloring recommendations and application data Weather fastness of pigments in PVC Cable sheathing formulations

2.2 Thermoplastic Elastomers and Rubber

Styrene Block Copolymers (SBC) Thermoplastic Polyurethane (TPU) Ethylene Vinyl Acetate (EVA) Thermoplastic Olefins (TPO) Rubber: Natural and Synthetic Colorants for Rubber and Elastomers Hostasin preparations

2.3 Polyolefins

Polyethylene (PE) Polypropylene (PP) Cyclic Olefin Copolymers (COC) Coloring recommendations and application data Influence of weathering Weather fastness data in HDPE

2.4 Styrenics

Polystyrene (PS) Acrylonitrile Butadiene Styrene (ABS) Styrene Acrylonitrile (SAN) Coloring recommendations and application data

2.5 Polymethyl methacrylate (PMMA)

Coloring recommendations and application data

2.6 Coloration of Synthetic Polymer Fibers Polypropylene fibers Polyester fibers Polyamide fibers Polyacrylonitrile fibers Coloring recommendations and application data

Textile fastness properties of colorants in PET fibers

2.7 Coloration of Engineering Polymers

Engineering polymers Polycarbonate (PC) Coloring recommendations and application data Polyacetale / Polyoxymethylene (POM) Thermoplastic Polyester (PET and PBT) Coloring recommendations and application data Polyamide (Nylon 6 and 6.6) Coloring recommendations and application data Polyetherimide (PEI) Polysulfone (PSU) Polyethersulfone (PES) Polyphenylene Sulphide (PPS)

2.8 Thermosetting resins

Thermoset Plastics Methacrylate Casting resin Unsaturated Polyester resin Epoxy Resins Thermosetting Polyurethane (PUR) Colorants for unsaturated Polyester (UP)

2.1 PVC and Plastisols

General information

Polyvinyl Chloride (PVC) continues to be one of the most important commercially produced plastics. More than 80 % of PVC produced is manufactured by the suspension polymerisation method, emulsion and bulk polymerisation make up the rest. PVC cannot be processed in its pure form, it is relatively unstable to heat, light and shear friction and requires a diversity of processing additives in order to bring it in to processable thermoplastic material.

Stabilisers such as lead, barium, tin, zinc and/or cadmium salts are added to overcome these problems. The processing additives and stabilisers have an influence on the base color and the transparency of the polymer. In addition, they also have a noticeable effect on the fastness properties of pigments and dyes used in the coloration of PVC. Stabilisers containing sulphur may cause a deepening of shade in the presence of lead-containing pigments due to the formation of lead sulphide. Barium-cadmium stabilisers and lubricants can lead to plate-out.

Unplasticised U-PVC (rigid grades) account for approximately 55 % of world production, the largest single use is in pipes: for water supply and distribution, agricultural irrigation, chemical processing, drainage, waste, guttering and vents, sewer systems and conduits for cables. The construction industry is the second largest consumer of U-PVC for window profiles, roofing sheets and interior moldings and trims. Other applications include interiors for household appliances and calendered films for packaging items.

Plasticised P-PVC (flexible grades) is produced by adding plasticisers: DOP, DIDP, DINP etc. or monomeric polymeric types to the blend via "Hot rolls" or internal mixers. The plasticiser content can vary greatly - typically around 30 %. Applications for plasticised (P-PVC) include flooring, footwear and wire and cable insulation. The presence of plasticiser can have a great influence of the migration behaviour of solvent dyes and many organic pigments. As a result many colorants recommended for use in U-PVC may have restrictions in plasticised grades. The same applies to PVC pastes (Plastisols) which contain up to 50 % plasticiser.

The processing temperatures for U- and P-PVC are generally between 130 and 220 °C. PVC can be processed by all methods commonly used to form thermoplastics; injection and blow molding, sheet and film extrusion and calendering. Organic colorant selection for PVC is a function of dispersibility, the limit concentration and coloration cost together with application dependant properties such as weather fastness and light stability.

Coloration of U-PVC

Organic pigments (PV Fast and Graphtol) and soluble dyes (Solvaperm, Fat and Hostasol) can be used for the coloration of U-PVC. Dyes are also suitable as a tinting medium to control the optical properties of the polymer. Pigment preparations (Hostaprint) are often used in critical dispersion applications e.g. calendered thin-films. In clear U-PVC highly transparent and intensive shades can be obtained using soluble dyes. The Hostasol range exhibit in low concentrations a pronounced edge fluorescence, in combination with titanium dioxide and other opaque pigments these fluorescent dyes produce brilliant shades. Soluble dyes demonstrate good fastness properties in U-PVC, however the light and weather fastness can be influenced by the PVC base stabilisation. The "Fat dyes" tend to contact bleed into fat, oils and solvents.

Coloration of P-PVC

Organic pigment selection is based on bleed-fastness, thermal properties, dispersion and price, the Graphtol and PV Fast pigments and the Hostaprint preparations are generally suitable for P-PVC coloration. The "bleed fastness" values for Graphtol and PV Fast pigments have been evaluated by placing the pigmented sample in contact with a white-pigmented plasticised PVC film at 140 °C for 2 hours. The assessment of bleeding was made against the ISO Grey Scale in accordance with EN 20105-A03. Step 5 on this scale denotes no bleeding onto the contact material. Soluble dyes will migrate in the presence of plasticiser and therefore are not suitable for P-PVC coloration.

Note: E-PVC (Emulsion PVC) contains emulsifiers and sodium carbonate which can react with certain organic pigment chemistries leading to unstable colors. A pre-test to establish suitability of a colorant in E-PVC is recommended.

Hostaprint preparations

The Hostaprint preparations are pre-dispersed single pigments based on a vinyl chloride/vinyl acetate copolymer. They provide for optimum pigment dispersion in a free-flowing, low dusting form and are recommended for the coloration of plasticised and unplasticised PVC (with the exception of PVC Plastisols). They are also particularly suited for the manufacture of inks for printing on PVC, PVDC, Cellophane, Polyurethane, Paper and Aluminum foils. The Hostaprint preparations are based on 50 % single pigment dispersions and their fastness properties equate to those of the powder pigments on which they are based. The Hostaprint pigment preparations are standardised in a plasticised PVC compound and in a printing application.

Hostaprint preparations can be treated similarly to powder pigments, they do however, offer clear advantages in their handling and dispersibility - factors that are of particular importance in the manufacture of colored films. They also permit accurate, economical dosing, leading to a reduction in waste and a uniform distribution of color. The need to control temperature and shear force to ensure full pigment dispersion is also negated.

Gravure / Screen printing

The copolymer carrier on which the Hostaprint preparations are based is readily soluble in esters, ketones, ester/ketone mixtures and dimethyl formamide. To prepare gravure or screen printing inks for printing film and coatings, the Hostaprint preparations are added to the binder solution in a high-speed mixer while stirring slowly, the speed of the mixer is then increased. The copolymer carrier dissolves and the pigment is liberated in a very finely dispersed form. It is important to ensure carefully controlled mixing to prevent the formation of lumps. If a dissolver mixer is used, a stirring time of 15 - 20 minutes is usually adequate after which the ink is ready for use. The preparation of a gravure ink in a binder solution is given as an example;

Binder solution 8 - 10 parts VC/VAc copolymer 50 parts methyl ethyl ketone 40 - 42 parts methyl isobutyl ketone

The following ketones are also suitable; Acetone Methyl butyl ketone Cyclohexane and Methyl cyclohexane

To accelerate drying times an ester; ethyl or butyl acetate can also be included, in which case, to achieve quick and thorough distribution in the binder system the ketone portion should be maintained at around 50 %.

The ester portion may also be partially replaced by an aromatic hydrocarbon e.g. toluene (content should not exceed 20 %). Alcohol's on the other hand act as precipitating agents and therefore are not suitable.

Printing ink

8 - 15 parts Hostaprint preparation 85 - 92 parts binder solution Viscosity is an important factor in the production of printing inks; the best results are generally obtained with a Hostaprint content of 12 - 15 %. If the viscosity is too high reduce the addition rate to around 10 %.

Coloration of PVC cable sheathing

PVC cable sheathing has to be colored with pigments which do not noticeably impair the electrical resistance of the insulation. The main factors to be taken into account are volume resistivity (important for all insulation) and dielectric loss (a measure of the loss incurred in the conversion of electrical energy into heat due to dipole oscillation in the insulating material). Dielectric loss does not occur with direct current, thus the loss increases as the frequency increases. In polyethylene, a non-polar material, oscillation cannot be induced even by alternate current, and so the issue of dielectric loss does not arise.

The dielectric loss factor is represented as ϵ tan δ , where ϵ is the dielectric constant and tan δ the loss angle. It thus follows that pigments to be used for coloring PVC cable sheathing must not have an adverse influence on the volume resistivity or the dielectric loss angle.

Clariant pigments recommended for cable sheathing which gave satisfactory results as regards tan δ values under testing on production batches containing 0.1 and 0.5 % pigment concentrations are indicated in the following tables. The dielectric properties of a PVC cable compound are not noticeably effected by the Hostaprint carrier and these pigment preparations (pigment type providing) are also suitable.

In addition, color formulations to reach RAL shades in accordance with DIN 47002 and British Standard (BS 6746) shades for the coloration of PVC cable sheathing are provided.

Coloration of Plastisols

In addition to spread coating, rotary casting of PVC is also colored from Plastisol pastes. They can also be used for coloring polyester and methacrylate casting resins (not suitable for epoxy casting resins). Plastisols are dispersions of fine particle sized PVC resin in a monomeric plasticiser liquid such as DIDP, DOP, DINP or polymeric plasticiser. Additives such as heat and light stabilisers, pigments, flame-retardants and processing aids are added to meet specific end product and processing requirements. Depending on requirements plastisols can be poured, pumped, sprayed, rotation molded or cast, they are liquids at room temperature and upon heating fuse and reach their optimum properties. Methods of processing plastisols include roller pastes, spread coating, coil and dip coating and foamed applications. End applications include tarpaulins and apparel, hollow and inflatable products, coatings for tool handles and handle grips, foamed coatings for steering wheels, toys and medical devices.

Suitable pigment dispersions are obtained in plasticiser pastes on a triple-roll mill, bead mill or in a dissolver these are then added to the plastisol preparation.

The Graphtol and PV Fast pigments are suitable for the coloration of plastisols. Selection is according to the fastness and thermal properties required. Bleed fastness of pigments and their limit concentrations must be taken in to consideration.

For a detailed list of properties refer to the Graphtol and PV Fast pigment recommendations for P-PVC.

Coloring recommendations and application data - Pigments for Polyvinyl Chloride (PVC)									
Product name			Light fa	stness					
	SD ¹ / ₃ [g/kg]	Hue angle [°]	Reduction (0.1 % + 0.5 TiO ₂)	Full shade (0.1 %)	Bleed fastness	Cable sheating	Limit conc. [%] P-PVC	Limit conc. [%] U-PVC	
PV Fast									
Yellow H9G	9.20	97.4	6-7	7	5	•	0.005	0.005	
Yellow H2G	10.40	90.0	8	8	5	—	0.005	0.005	
Yellow HG 01	4.50	90.4	6-7	7	5		0.005	0.005	
Yellow HG	5.50	88.7	6-7	6-7	5		0.005	0.005	
Yellow H2GR	9.50	84.0	6	6	5		0.005	0.005	
Yellow HGR	11.70	78.3	6	7	5		0.005	0.005	
Yellow HR 02*	2.20	81.3	7-8	7-8	5		0.005	0.005	
Yellow HR*	2.50	82.8	7-8	7-8	5		0.005	0.005	
Yellow H3R	13.10	65.3	8	8	5	•	0.005	0.005	
Orange H4GL 01	5.70	60.1	7-8	8	5	•	0.005	0.005	
Orange H2GL	6.90	46.7	8	8	5	•	0.005	0.005	
Orange GRL	6.10	42.3	7-8	8	4-5		0.005	0.005	
Urange 6RL	9.10	37.0	7-8	7-8	5	_	0.005	0.005	
Scarlet 4KF	8.80	27.3	7-8	8	5	_	0.005	0.005	
Ked B	5.20	21.0	/-8	8	5		0.005	0.005	
Red USG	0.40	17.2	ð C 7	ð C 7	5		0.005	0.005	
Red AB	9.40	12.9	0-7	0-7	5		0.005	0.005	
Red 3B	5.90	13.2	7-0	ð 7 0	5		0.005	0.005	
Red HE/B	5.70 7.70	6.2	7-0	7-0	5		0.005	0.005	
Rod F2B	12 10	250 1	7 Q	7 Q	5		0.01	0.005	
Red E5B	11 /0	256 1	g	8	5		0.005	0.005	
Pink F	7 70	330.1	8	8	5		0.005	0.005	
Pink E 01	8 10	339.4	8	8	5		0.005	0.005	
Violet FB	7.50	331.0	8	8	5	-	0.005	0.005	
Violet BLP	2.90	302.9	7-8	7-8	4		0.01	0.005	
Violet BL	2.50	302.7	7-8	7-8	4		0.01	0.005	
Blue A4R	3.60	249.6	8	8	4		0.005	0.005	
Blue A2R	3.30	249.3	8	8	5		0.005	0.005	
Blue BG	4.00	240.7	8	8	5		0.005	0.005	
Green GNX	8.90	180.4	8	8	5		0.005	0.005	
Brown HFR	7.50	25.9	8	8	4-5	_	0.005	0.005	
Brown RL	6.90	44.1	8	8	4	_	0.005	0.005	

Coloring recommendations and application data - Pigments for Polyvinyl Chloride (PVC)								
Product name			Light fa	stness				
	SD 1/ ₃ [g/kg]	Hue angle [°]	Reduction (0.1 % + 0.5 TiO ₂)	Full shade (0.1 %)	Bleed fastness	Cable sheating	Limit conc. [%] P-PVC	Limit conc. [%] U-PVC
Graphtol								
Yellow H10G* Yellow GG* Yellow 3GP Yellow 3GP Yellow GXS* Yellow GR* Yellow H2R Orange GPS* Orange RL* Red HFG Red LG Red LG Red LC Red BB* Red F3RK 70 Fire Red 3RLP Red F3RK 70 Fire Red 3RLP Red HF2B Red HF2B Red P2B Carmine HF4C Carmine HF3C	11.50 4.20 6.10 3.10 2.40 3.50 5.40 4.60 8.90 7.10 7.20 3.30 7.80 7.80 7.50 5.10 4.00 5.20 4.50 5.40	97.4 94.3 92.9 93.0 89.1 77.1 52.4 39.1 33.4 23.8 21.8 17.4 14.8 12.0 11.5 5.4 2.1 356.6 358.4	7 6-7 7-8 6 6-7 7 4-5 6 7 2 2 2 5-6 6-7 5-6 6-7 5-6 6-7 7-8 5-6 7 7-8 5-6 7 7-8 5-6 7 7-8 5-6 7 7 7-8 5-6 7 7 7 7 7 7 7 7 7 7 7 7 7	7 8 6-7 6-7 7 6 7-8 7 6 6 6 7-8 6-7 7-8 6-7 7 7-8 7-8 7 7-8 7 7-8 7 7-8 7 7-8 7 7-8 7 7 7-8 7 7 7 7 7 7 7 7 7 7 7 7 7	5 3 3-4 3 3 5 3 2-3 4 4-5 4-5 3 2 5 4-5 4 5 4 5 5 5		0.05 0.1 0.005 0.1 0.1 0.005 0.1 0.005 0.005 0.05 0.	0.005 0.025 0.025 0.025 0.025 0.025 0.025 0.025 0.005 0.005 0.005 0.01 0.1 0.1 0.01 0.1 0.01 0.0
Rubine 6BP Bordeaux HF3R Blue AN	4.70 3.60 3.40	353.7 336.5 251.3	3-4 7 8	6-7 7-8 8	5 5 4	•	0.01 0.005 0.005	0.01 0.005 0.005

Coloring recommendations and application data - Pigment Preparations for Polyvinyl Chloride (PVC)									
Product name		Light f	astness						
	SD ¹ / ₃ [g/kg]	Full shade (0.1 %)	Reduction (0.1 % + 0.5 % TiO ₂)	Bleed fastness	Cable sheating	Limit conc. [%] P-PVC	Limit conc. [%] U-PVC		
Hostaprint									
Yellow GG 32* Yellow H4G 32 Yellow 3GP 32 Yellow HG 32 Yellow HR 32* Yellow HGR 32 Yellow HGR 32 Yellow HGR 32 Yellow H3 Yellow H32* Yellow H32* Yellow H32 Yellow H32 Yellow H4G 32 Yellow H32 Red B 32* Red B32 Red B32 Red BAS2 Carmine H54C 32 Red E5B 32 Pink E 32 Bordeaux H53R 32 Violet ER Violet RL 32	8.40 22.00 12.20 11.00 4.40 23.00 7.00 11.40 17.80 10.40 6.60 12.40 11.40 10.20 9.00 22.80 15.40 7.20 15.00 5.80	7 8 8 6-7 7-8 6-7 7 8 7-8 8 6-7 8 8 6-7 8 8 8 7-8 8 8 7-8 8 8 8 7-8 8 8 8 7-8	6-7 7-8 7-8 6-7 6-7 7 7-8 7 7-8 7 7-8 5-6 8 7 8 7-8 6-7 7 7 8 6-7 7 7-8 6 7-8 6 7-8 6 7-8 7-8	3 5 3-4 5 5 5 5 5 4 5 3 3 5 5 5 5 5 5 5 5 5 5		0.20 0.01 0.10 0.01 0.01 0.01 0.05 0.01 0.01	0.01 0.01 0.01 0.01 0.01 0.02 0.01 0.01		
Blue A4R 32 Blue A2R 32 Blue B2G 32 Green GG 32 Brown RL 32 Brown HFR 32 Black L 32	7.20 6.60 8.00 17.80 13.80 15.00	8 8 8 8 8 8 8	8 8 8 8 8 8 8	4 5 5 4 4-5 5		0.01 0.01 0.01 0.01 0.01 0.01	0.01 0.01 0.01 0.01 0.01 0.01		

Coloring recommendations and application data - Soluble dyes for unplasticised Polyvinyl Chloride (U-PVC)									
Product name			Light fastness						
	SD ¹ / ₃ [g/kg]	Hue angle [%]	Reduction (0.1 % + 0.5 ПО ₂)	Full shade (0.1 %)					
Solvaperm									
Yellow G	0.18	93.8	7-8	7-8					
Yellow 3G	0.48	96.1	7-8	8					
Yellow 2G	0.17	96.7	7-8	8					
Orange 3G	0.51	65.4	7	8					
Red 2G	0.49	35.5	6	7					
Red G	0.72	28.5	7	8					
Red PFS	0.77	18.6	6	7					
Red BB	0.20	356.2	6	8					
Red Violet R	0.41	333.8	6	7-8					
Violet FBL	0.68	304.7	6	7					
Violet RSB	0.35	286.2	6	7-8					
Blue 2B	0.38	258.2	6	7-8					
Green GSB	0.42	201.8	5	7					
Green G	0.68	170.6	7-8	8					

Coloring recommendations and application data - Fluorescent dyes for unplasticised Polyvinyl Chloride (U-PVC)										
Product name			Light fa	stness						
	SD ¹ / ₃ [g/kg]	Hue angle [%]	Reduction (0.1 % + 0.5 TiO ₂)	Full shade (0.1 %)						
Hostasol										
Yellow 3G	-	-	5-6	7						
Red GG	-	-	5	6-7						
Red 5B	-	-	4-5	7						

Weather fastness of pigments in PVC

The following selection of PV Fast and Graphtol pigments were assessed for their fastness under accelerated weathering conditions from colored PVC films in a barium/ cadmium stabilized, plasticised PVC. The pigment test concentrations were; 0.1 and 1.0 % "full shade" and in reduction; 1.0 % pigment with 1.0 % titanium dioxide. The stabilized PVC compound was also assessed for weathering under the same conditions with and without the addition of 1.0 % titanium dioxide.

The PVC test films were produced on a twin-roll mill and then pressed to the required thickness of 1 mm. Thereafter they were exposed in a Atlas Xenotest 1200 W WOM using a cycle of 102 minutes dry and 18 minutes wet. The black panel temperature was set at 60 °C and the relative humidity at 60 %. The assessment to the Grey scale was carried out after 2.000, 4.000 and 6.000 hour's exposure.

The values given provide only an indication of the fastness to weathering from a single pigment in a specified PVC compound under the above described conditions. For further information on the subject of weathering in plastics refer to Chapter 3.4 in this brochure or contact your regional Clariant Technical Application Center.

Weather fastness data in PVC

Barium / Cadmium stab. - Xenotest^{®+} 1200 W WOM

	Grey	/ scale (ho	ours)		Grey	y scale (ho	urs)
	2000	4000	6000		2000	4000	6000
P-PVC Natural PVC compound Compound + 1 % TiO ₂	5 4-5	4-5 4-5	4-5 4	PV Fast Orange H4GL 01 0.1 % Pigment 1.0 % Pigment 1.0 % Pigment + 1 % TiO ₂	4-5 4-5 4	4 4-5 3	4 4-5 -
Graphtol Yellow 3GP 0.1% Pigment 1.0% Pigment 1.0% Pigment + 1 % TiO ₂	4 3 3	4 3 3	3-4 - -	PV Fast Orange H2GL 0.1 % Pigment 1.0 % Pigment 1.0 % Pigment + 1 % TiO ₂	3-4 4-5 3	3 3 -	- -
PV Fast Yellow H2G 0.1% Pigment 1.0% Pigment 1.0% Pigment + 1 % TiO ₂	4-5 4-5 4-5	4-5 4-5 4	4 4 3-4	PV Fast Orange GRL 0.1 % Pigment 1.0 % Pigment 1.0 % Pigment + 1 % TiO ₂	4 4-5 4	4 4 3-4	4 4 3
PV Fast Yellow HR 0.1% Pigment 1.0% Pigment 1.0% Pigment + 1 % TiO ₂	4-5 4-5 4	4-5 4 3-4	4 3 -	PV Fast Orange 6RL 0.1 % Pigment 1.0 % Pigment 1.0 % Pigment + 1 % TiO ₂	4-5 4-5 4	3-4 3 3	3-4 - -
PV Fast Yellow HR 02 0.1% Pigment 1.0% Pigment 1.0% Pigment + 1 % TiO ₂	4-5 4-5 4	4 3-4 3-4	4 3 -	PV Fast Red D3G 0.1 % Pigment 1.0 % Pigment 1.0 % Pigment + 1 % TiO ₂	4-5 5 5	4-5 4-5 4-5	4 4 3-4
PV Fast Yellow H3R 0.1% Pigment 1.0% Pigment 1.0% Pigment + 1 % TiO ₂	5 5 4	4-5 4 4	4 4 3	PV Fast Red BNP 0.1 % Pigment 1.0 % Pigment 1.0 % Pigment + 1 % TiO ₂	4 4 4	3-4 - -	- -

Weather fastness to ISO Grey scale: 5 = excellent, 1 = poor

Weather fastness data in PVC Barium / Cadmium stab. - Xenotest 1200 W WOM

	Grey	y scale (ho	ours)		Gre	y scale (ho	ale (hours)	
	2000	4000	6000		2000	4000	6000	
PV Fast Red 3B 0.1% Pigment 1.0% Pigment 1.0% Pigment + 1 % TiO ₂	4 4 4	4 4 -	- 3 -	PV Fast Violet RL 0.1 % Pigment 1.0 % Pigment 1.0 % Pigment + 1 % TiO ₂	5 5 5	5 5 5	4 4-5 4	
PV Fast Red HF4B 0.1% Pigment 1.0% Pigment 1.0% Pigment + 1 % TiO ₂	4 4 4	3-4 3-4 3	-	PV Fast Blue A4R 0.1 % Pigment 1.0 % Pigment 1.0 % Pigment + 1 % TiO ₂	5 5 5	5 5 5	5 5 5	
PV Fast Red E3B 0.1% Pigment 1.0% Pigment 1.0% Pigment + 1 % TiO ₂	5 5 4-5	4-5 4 4	3-4 3-4 3	PV Fast Blue BG 0.1 % Pigment 1.0 % Pigment 1.0 % Pigment + 1 % TiO ₂	5 5 5	5 5 5	5 5 5	
PV Fast Red E5B 0.1% Pigment 1.0% Pigment 1.0% Pigment + 1 % TiO ₂	4 5 4-5	3-4 3-4 3	- 3 -	Graphtol Blue AN 0.1 % Pigment 1.0 % Pigment 1.0 % Pigment + 1 % TiO ₂	5 5 5	5 5 5	4 5 5	
PV Fast Red B 0.1% Pigment 1.0% Pigment 1.0% Pigment + 1 % TiO ₂	4 4 3-4	4 4 3	4 3 -	PV Fast Blue A2R 0.1 % Pigment 1.0 % Pigment 1.0 % Pigment + 1 % TiO ₂	5 5 5	5 5 5	5 5 5	
PV Fast Pink E 0.1% Pigment 1.0% Pigment 1.0% Pigment + 1 % TiO ₂	5 5 4-5	4-5 4-5 4-5	4 4 4	PV Fast Green GNX 0.1 % Pigment 1.0 % Pigment 1.0 % Pigment + 1 % TiO ₂	5 5 5	5 5 5	4-5 4-5 4-5	
PV Fast Pink E 01 0.1% Pigment 1.0% Pigment 1.0% Pigment + 1 % TiO ₂	5 5 4-5	4-5 4-5 4-5	4 4 4	PV Fast Brown HFR 0.1 % Pigment 1.0 % Pigment 1.0 % Pigment + 1 % TiO ₂	5 5 5	4-5 4-5 4-5	4 4-5 4	
PV Fast Violet ER 0.1% Pigment 1.0% Pigment 1.0% Pigment + 1 % TiO ₂	4-5 4 4	4 4 3	3 3 -	PV Fast Brown RL 0.1 % Pigment 1.0 % Pigment 1.0 % Pigment + 1 % TiO ₂	5 5 5	5 5 5	4-5 4-5 4	
PV Fast Violet BLP 0.1% Pigment 1.0% Pigment 1.0% Pigment + 1 % TiO ₂	5 5 5	5 5 5	4-5 5 5					

Cable	able sheating formulations - Coloration of PVC cable sheathing (RAL shades in accordance with DIN 47002)										
RALS	Shade	Pigments	%	RAL Shade	Pigments	%					
1021	Rape Yellow	Graphtol Yellow GR* TiO ₂ Graphtol Yellow GR*	1.500 1.000	6016 Turquoise Green	PV Fast Green GNX Graphtol Yellow GR* Carbon Black TiO2	0.240 0.020 0.007 0.380					
		Graphtol Carmine HF3C Carbon Black TiO ₂	0.170 0.002 1.000	6018 Yellow Green	Graphtol Yellow GR* PV Fast Green GNX Carbon Black	0.130 0.060 0.003					
2003	Pastel Orange	Graphtol Yellow GR* Graphtol Red BB* TiO ₂	0.400 0.050 1.500	6027 Light Green	TiO ₂ PV Fast Green GNX	0.660					
3000	Flame Red	Graphtol Yellow GR*	0.760		Carbon Black TiO ₂	0.003 1.000					
		Graphtol Red BB* Carbon Black TiO ₂	0.400 0.003 1.000	7000 Squirrel Grey	Carbon Black PV Fast Blue A4R TiO ₂	0.012 0.005 0.660					
3017	Rose	Graphtol Carmine HF3C Graphtol Yellow GR* TiO ₂	0.110 0.030 1.000	7004 Signal Grey	Carbon Black TiO ₂	0.010 0.600					
3020	Traffic Red	Graphtol Red BB* Graphtol Yellow GR* TiO ₂	0.500 0.160 1.000	7015 Slate Grey	Carbon Black TiO ₂	0.050 0.500					
4001	Red Lilac	Graphtol Carmine HF3C PV Fast Blue A4R	0.032	7037 Dusty Grey	Carbon Black PV Fast Yellow H2G TiO ₂	0.015 0.005 0.600					
		TiO ₂	0.004	8004 Copper Brown	PV Fast Brown RL PV Fast Yellow H3R	0.200 0.050					
4002	Red Violet	Graphtol Red BB* PV Fast Blue A4R Ti02	0.100 0.006 0.500		Carbon Black TiO ₂	0.003 0.500					
4008	Signal Violet	Graphtol Carmine HF3C PV Fast Blue A4R TiO ₂	0.080 0.012 0.500	8015 Chestnut Brown	PV Fast Brown RL Carbon Black TiO ₂	0.400 0.020 0.500					
5015	Sky Blue	PV Fast Blue A4R Carbon Black	0.060	8016 Mahogany Brown	PV Fast Brown RL Carbon Black TiO ₂	0.400 0.035 0.500					
0010	0		0.500	9005 Jet Black	Carbon Black	0.250					
6010	urass üreen	Graphtol Yellow GR* PV Fast Green GNX Carbon Black TiO ₂	0.220 0.080 0.012 0.400								

British Standards shades (BS 6746) for	r PVC cable sheathing			
Shade	Pigments	%	Alternative Pigments	%
White	Ti0 ₂	0.5		
Cream	Hostaperm Yellow H4G TiO ₂	0.01 1.00		
Yellow	Graphtol Yellow GR* PV Fast Yellow HR 02*	0.05 0.15	PV Fast Yellow HGR	0.30
Orange	Graphtol Orange RL*	0.11		
Red	Graphtol Yellow GR* Graphtol Carmine HF3C	0.20 0.20		
Pink	Graphtol Carmine HF3C PV Fast Yellow HR 02* Carbon Black	0.010 0.005 0.001		
Violet	PV Fast Violet ER PV Fast Blue A2R	0.13 0.01		
Blue	PV Fast Blue A2R	0.05		
Turquoise	PV Fast Green GNX TiO ₂	0.01 0.30		
Green	Graphtol Yellow GG* PV Fast Green GNX	0.15 0.04	Novoperm Yellow F2G PV Fast Green GNX Carbon Black	0.150 0.035 0.005
Brown	Graphtol Orange RL* Carbon Black	0.100 0.022		
Grey	Carbon Black PV Fast Blue A2R TiO ₂	0.015 0.003 0.100		
Black	Carbon Black	0.30		
Brown Grey Black	Graphtol Orange RL* Carbon Black PV Fast Blue A2R TiO2 Carbon Black	0.100 0.022 0.015 0.003 0.100 0.30		

2.2 Thermoplastic Elastomers and Rubbers

The term Thermoplastic elastomer (TPE) is used to describe a wide variety of thermoplastic materials that have elastomeric (rubber-like) properties at ambient temperatures. The terms TPU (Thermoplastic polyurethane) and TPO (Thermoplastic oleofins) refer to sub-groups within the TPE family. Unlike conventional vulcanised rubber all TPE's can be processed and recycled as conventional thermoplastic materials. The largest group within the TPE family is a styrene block copolymer with butadiene or isoprene (SBC). The other 2 main groups are polyurethane based (TPU's) and blends of ethylene propylene copolymers (TPO's).

Styrene block copolymers (SBC's)

are thermoplastic elastomers possessing the mechanical properties of rubber and the processing characteristics of thermoplastic polymers. SBC's consist of a minimum of three blocks, two hard polystyrene end blocks and a soft, elastomeric (polybutadiene, polyisoprene) mid-block. These block copolymers find applications in such diverse fields as: thermo-forming, pressure sensitive adhesives, impact modifiers and in mixtures/compounds with offer polymers and fillers. Often referred to as "soft-touch" polymers SBC's are used in children's toys, automotive parts, personal hygiene and packaging applications. They can be injection molded, profile and film extruded and are suitable for food contact applications.

Coloration of SBC's is mainly from granular masterbatch or polymer compounds, all medium to high performance organic chemistries that have a heat resistance in polystyrene above the processing temperature can be used. Fastness to bleeding from organic pigments is not an issue however, the use of polymer soluble dyes must be treated with extreme caution. SBC's are broadly amorphous polymers but, the elastomeric component can lead to a degree of contact migration and should be tested for in the end application of the component to be produced.

Recommended is the PV Fast range of pigments and to a limited extend a number of the Graphtol pigments.

Thermoplastic polyurethane (TPU)

is a melt processable elastomer. TPU can be processed by all the methods normally employed for thermoplastic materials e.g. injection, blow and compression molding, extrusion and solution "spread" coating.

TPU is a linear segmented block copolymer composed of hard and soft segments. The hard segments can be either aromatic or aliphatic (based on isocyanates) which combined with short chain diols to form a hard block. The aromatic types have considerably better light fastness but are more expensive. The soft segments can be of either polyether or polyester depending on the application. TPU offers broad range of physical properties and high elasticity, it bridges the gap between rubber and plastics without the use of plasticisers. TPU is often compounded with glass or mineral fillers. It is also used extensively in polymer blends to enhance or modify properties. Applications for TPU's are numerous and include; - Wheels, Drive belts, Inflatables, Flexible tubing, In-liner skates, sporting goods, wire & cable and coated fabrics (laminating films) such as synthetic "artificial" leather. Many "Soft touch" effects are produced from thermoplastic polyurethane. For the solution spread coating of fabrics, two distinctive systems can be employed, the first a "one-component polyurethane" is thermoplastic and is discussed in this chapter, the second; "two-component polyurethane" is thermosetting and is discussed in chapter 2.8

Coloration of TPU is mainly from granular masterbatch, polymer compounds or liquid solutions (pastes). Pastes, used for solution spread coating of fabrics contain 20 - 50 % pigment and are either based on DMF or THF for aromatic type "onecomponent polyurethanes or isopropanol/toluene mixtures for aliphatic types. The coated layer, especially in the coloration of artificial leather is very thin (usually 50 - 80 µm), very high pigmentation levels are required and care must be taken to ensure that organic pigments have a high fastness to bleeding. Selected organic pigments must be insoluble in the solvent or solvent mixture. In aromatic types a high resistance to DMF is required. In pure dimethyl formamide, quinacridone pigments (P.R. 122, P.R. 202, P.R. 209 & P.V. 19) must be treated with care to avoid re-crystallisation even after prolonged periods of time. In other solvent mixtures this is not an issue. In addition to the Graphtol and PV Fast pigments, a number of Hansa, Hostaperm, Novoperm and Permanent pigments are also suitable for use in the production of pastes.

No special demands are made on the thermal stability of organic pigments used in polymer compounds and masterbatches for the coloration of TPU. The same organic pigments used to color PVC can be used however, due to the risk of migration soluble dyes are not suitable. The recommended Graphtol and PV Fast pigments are those found on pages 18 and 19 "Coloration of Plasticised PVC".

Ethylene vinyl acetate (EVA)

EVA is a random copolymer of vinyl acetate (VA) monomer and ethylene. The VA content can vary from 5 - 40 % by weight. Higher monomer contents improve the flexibility and impact strength of the polymer; lower monomer levels reduce the crystallinity and softening point. The MFI and wetting out capability improve as the molecular weight decreases. EVA is a flexible, transparent polymer with good low temperature stability and chemical resistance. In thermoplastic applications EVA can extruded, co-extruded, blow molded, injection molded and used as a polymer modifier for other grades of plastic. Applications for EVA include packaging film, heavy duty bags, wire and cable sheathing, flexible tube and pipes and shoe soles.

The processing temperatures vary greatly according to grade and process, the softening point of the polymer is around 75 °C and above 250 °C EVA starts to degrade.

The recommended Graphtol and PV Fast pigments for coloring EVA are included in the tables found on pages 33 and 34. The Hostasin pigment preparations are also suitable, further information to this range of pigment preparations is to be found on the following page.

Soluble dyes are not recommended for the coloration of EVA due to the potential for migration from the ethylene component of the polymer.

Thermoplastic olefins (TPO's)

Olefinic based elastomers (TPO's) are polypropylenes or blends of ethylene-propylene rubber which are combined with a co-monomer (elastomeric polymer) in a gas phase dual reactor. The combination adds flexibility to the polymer without the addition of a plasticiser. Flexibility is achieved through an internal plastification obtained internally during the production process. In this process, the co-monomers (elastomers) create an enlarged free volume that decreases the crystallinity of the ethylene-propylene rubber blends or polypropylene polymer. The advantage of TPO's lie in their low temperature impact resistance, high tensile strength and through no loss of plasticising agent after processing.

TPO's can be processed by injection and blow molding, sheet and profile extrusion or as films. The main applications are for automotive exterior and interior parts, films and other packaging materials and for roofing and other water resistant membranes.

Recommended are the Graphtol and PV Fast pigments to be found in the following tables. In addition, a number of Hostaperm, Novoperm and Permanent pigments are also suitable. No special demands are made on the thermal stability of organic pigments.

Rubber (Natural and synthetic)

Natural rubber is a high molecular weight polymer of isoprene. It is obtained from latex milk which is the sap of the Hevea (rubber) tree. The rubber tree grows throughout the tropics and is cultivated in plantations, primarily in Southeast Asia. The latex milk is coagulated and washed, then on exposure to air and mild heat gives natural rubber. To obtain a processable polymer the natural rubber undergoes a mastification process; a mechanical working under severe conditions to produce a soft gummy mass. Thereafter the material is vulcanized; a process usually in the presence of sulfur that introduces a network of crosslinking which transforms the "soft gummy mass" in to a strong, elastomeric, processable rubber.

Conventional synthetic rubbers are similar to natural rubber in that they are cross-linked thermoset polymers. They gained global importance during World War 2. World-wide today approximately 65 % of all rubber processed is synthetic. The most significant forms of synthetic rubber used are:

Synthetic Polyisoprene	IR	Tires
		(added to natural rubber)
Polyisobutadiene (Butyl) rubber	IBR	Inner tubes for tires
Styrene Butadiene rubber	SBR	Shoe soles, belts, flooring
Polychloroprene rubber	CR	Neoprene wetsuits
Nitrile rubber	NBR	Petrol hoses, Fuel tanks
Ethylene Propylene rubber	EPM/	Pond liners, Roofing
	EPDM	

A more recent development is the manufacture of synthetic thermoplastic rubber referred to as Melt Processable Rubber (MPR) and ThermoPlastic Vulcanate (TPV). These materials combine the processability of a thermoplastic polymer with the functional performance of rubber and are cheaper, recyclable and easier to color.

The pre-processing of thermoset rubber is usually via calendar-roll mills or internal mixers, during this phase colorants and fillers are added. In the forming phase these rubbers can be sheet or profile extruded and injection molded, conventional processing temperatures are from 60 to 150 °C. With MPR and TPV processing temperatures can rise up to 220 °C, they can be processed using conventional extrusion technology or in internal mixers before being formed.

For all types of rubber the requirements on colorants are generally not high, for cross-linked grades; bleed-fastness, resistance to prolonged temperature exposure and for natural rubber compatibility in the vulcanization process are the important factors. For the coloration of natural rubber, organic pigments in powder form have largely been replaced by pigment preparations which permit shorter mixing times and optimum pigment dispersion. In the coloration of thermoplastic rubber powder pigments are either compounded in or added in the form of pre-dispersed color concentrates (masterbatches). The selection of organic pigments is based on bleed-fastness and heat stability according to the grade used. Many applications for thermoset and thermoplastic rubber are to be found in hostile chemical environments and in outdoor use. In these instances, the appropriate selection of organic pigment is more critical.

Recommended for the coloration of thermoset and thermoplastic rubbers are the PV Fast and Graphtol powder pigments. The Hostasin range of pigment preparations which ensure excellent reproducibility through optimum pigment dispersion in a non-dusting form are compatible with natural rubber and most common synthetic grades.

Colorants for rubber and elastomers - Coloration of thermoplastic elastomer and rubber					
Product name	SBC	TPU	EVA	ТРО	Rubber / TPV
PV Fast					
Yellow H9G					
Yellow H2G					
Yellow HG 01					
Yellow HG					
Yellow H2GR					
Yellow HGR					
Yellow HR 02*					
Yellow HR*					
Yellow H3R					
Orange H4GL 01					
Orange H2GL		•			
Orange GRL					
Orange 6RL					
Scarlet 4RF					
Red B					
Red D3G					
Red HB					
Red 3B					
Red BNP					
Red HF4B					
Red E3B					
Red E5B					
Pink E					
Pink E 01					
Violet ER					
Violet BLP					
Violet RL					
Blue A4R					
Blue A2R					
Blue BG					
Green GNX					
Brown HFK	•				
Brown KL	•				

Colorants for rubber and elastomers - Coloration of thermoplastic elastomer and rubber					
Product name	SBC	TPU	EVA	ТРО	Rubber / TPV
Graphtol					
Yellow H10G*					
Yellow GG*					
Yellow 3GP	•	•			
Yellow GXS*					
Yellow GR*					
Yellow H2R	•	•			•
Orange GPS*		—		—	
Orange RL*		—		—	
Red HFG					
Red LG					
Red LC					
Red BB*					
Red F3RK 70	—	—			—
Fire Red 3RLP					
Red HF2B					
Red F5RK	—	—			—
Red 2BN					
Red P2B					
Carmine HF4C					
Carmine HF3C					
Rubine 6BP					
Bordeaux HF3K	•	•			•
Blue AN	•	•	•	•	

Hostasin preparations

The Hostasin pigment preparations are based on an oxidation resistant polyolefin copolymer that is compatible with natural rubber and most common synthetic rubbers. Since the pigments in the Hostasin preparations are already in a very finely dispersed form, relatively little mechanical effort and only a brief mixing time is required to obtain the full tinctorial strength of the pigment. A further advantage of the Hostasin preparations is their ease of handling, being in a granular form they are free-flowing, easy to meter and they do not smear or dust, thus they provide for clean, loss free processing. The pigment content of the Hostasin preparations is approximately 50 % and is controlled to provide for a consistent and reproducible color yield.

Coloration of natural and synthetic rubber							
Product name					_	Light fastness	Migration resistance
	SBC	TBU	EVA	TPO	Rubber / TP\	Reduction	Reduction
Hostasin							
Yellow GR 30*	—	—		—		6	5
Yellow HR 30*	_	_		_		6-7	5
Orange G 30*	—	—		—		4-5	5
Red LC 30	—	_		—		2-3	4
Red B 30*	—	—		—		4-5	5
Red HF2B 30	_			—		6-7	5
Blue A2R 30	—	—		—		8	5
Green GG 30	—	—		—		8	5

2.3 Polyolefins

Polyolefins can be sub-divided in to 3 main groups: Low density polyethylene (LDPE), high density polyethylene (HDPE) and polypropylene (PP). They are classified according to: density, melt-flow behaviour, chain branching and in particular, the melt processing temperatures:

LDPE	160 - 220 °C
HDPE	180 - 300 °C
PP	200 - 300 °C

Within each group there are many grades which can differ considerably with regard to their properties. The selection of grade is dependant upon the processing technique involved, polyolefins can be film-blown, bottle-blown, injection molded and extruded.

Three further groups of polyolefins exist: Linear low density polyethylene (LLDPE), medium density polyethylene (MDPE) and very low-density polyethylene (VLDPE). LLDPE has applications in films and as a carrier resin for masterbatches. The later two MDPE and VLDPE are not of commercial consideration in terms of coloration.

The coloration of polyolefins must be considered in terms of the group selected; LDPE is largely amorphous, relatively soft and has a melt flow index range from medium to very high. The higher the melt-flow and the lower the density of LDPE, the greater is the potential for pigment blooming to occur. The bleed-fastness figures quoted for P-PVC are a useful guide to suitability. In HDPE and PP, the thermal stability of organic pigments is the main criteria for selection. In injection molding applications it must be noted that many organic pigments have been shown to influence the crystalline behaviour of polyolefins (in particular HDPE) by inducing a nucleating effect. This in turn leads to dimensional instability of the molded part often referred to as warpage, distortion or dimensional miss-behaviour.

Soluble dyes are not recommended for the coloration of standard grade polyolefins due to their tendency to bloom or migrate out of the polymer matrix.

Polyethylene (PE)

Polyethylenes are thermoplastic polymers consisting mainly of ethylene monomer, which are divided according to their density, melting point and molecular structure (branching).

High density polyethylene (HDPE)

A highly crystalline polymer coming from a low pressure process based on Ti- or Cr-based catalysts, HDPE has a linear polymeric chain combined with a high density and melting point. New applications are opening for HDPE as well as other low pressure PE's by applying metallocene (single-site) catalysts, which allow the production of very narrow molar mass distributions and a more even arrangement of co-monomers. HDPE grades vary in their warpage behavior according to their method of manufacture, the selection of catalyst and their molar mass distribution. The narrower the molecular weight distribution of a grade, the lower its propensity to warp, in addition, due to the absence of the high and lower molar masses, the influence of organic pigments on the crystalline behavior is in many instances reduced.

Applications for HDPE include: large containers, fuel tanks, bottles and crates, wrapping film and pipes

Linear low density polyethylene (LLDPE)

Based on the same technology as HDPE, but the density is reduced through the incorporation of longer α -olefins as co-monomers. Single-site catalysts allow an expansion of the application range, mainly by allowing higher co-monomer contents with a more even distribution.

Applications for LLDPE include: film and packaging

Low density polyethylene (LDPE)

A product from a high-pressure polymerisation process, LDPE is characterised by its highly branched chain structure. As a result of this, density and crystallinity are reduced while the processability in a variety of conversion technologies is greatly improved.

Applications for LDPE include: packaging, bottles, cold water tanks, films

Polypropylene (PP)

is a semi-crystalline, linear hydrocarbon polyolefin and one of the most versatile polymers available, it is semi-rigid, translucent and tough, exhibiting good heat and chemical resistance. Compared to polyethylene, PP has a much higher softening point (163 °C), higher rigidity and hardness.

Applications for PP include: automotive, appliances, patio furniture, bottles, fibers and yarns, filament rope, tapes and webbing, films
Three differing grades of PP are commercially available:

Homo-polymers

General purpose PP suitable for a wide range of applications.

Block copolymers

Containing 5 - 15 % ethylene to improve resistance to low temperatures.

Random copolymers

Incorporating randomly arranged co-monomer units along the PP long chain molecule and often low levels of ethylene. These grades exhibit greater flexibility and improved clarity.

Polyethylene and Polypropylene (polyolefins) can be processed by all common thermoplastic forming processes; injection and blow molding, sheet, profile and film extrusion, rotational molding and melt-spun synthetic fibers.

The methods of polyolefin coloration are diverse: granular masterbatch, compounding, dry powder blends or liquid concentrates. Heat stability, dispersion quality for the end application and coloration costs are the main selection criteria together with application dependant properties such as weather fastness, light stability and warpage. Soluble dyes are not suitable for the coloration of these polymers due to the potential for contact migration.

For rotational molding applications in polyethylene, the processing temperatures are low; usually in the range 130 to 150 °C. However, the molding powder / pigment / additive blend can be exposed to these temperatures for extended periods dependant on the overall size of the molding, its complexity and wall thickness.

The recommended Graphtol, PV Fast and DrizPearls pigments for the coloration of polyolefins are to be found in the following tables. Information regarding standard depth ¹/₃ values, hue angle, heat resistance and light fastness values provided were assessed in HDPE. Suitability for use in low warpage applications is also provided; the results were assessed in Hostalen GC 7260 HDPE at 220 °C and 280 °C according to an internal test method for pigments with the required heat resistance at these temperatures. The results will vary according to the grade of HDPE and the processing parameters used. A pretest of the complete formulation under the prevailing processing conditions is required.

Cyclic Olefin Copolymers (COC)

Cyclic olefin copolymers are a new generation of technical olefinic polymers. They are manufactured by copolymeri-

sing the monomers ethylene and norbornene; a ring structured olefin derivative of cyclopentadiene and ethylene. This completely amorphous structure leads to a high strength, stiff olefinic polymer with excellent transparency and low shrinkage/warpage characteristics.

COC's find applications in medical equipment and devices, films, bottles and other forms of packaging. The melt processing range of cyclic olefin copolymers is from 200 -300 °C, typically from 260 - 300 °C for injection molding applications and these polymers can be processed using all conventional thermo-forming techniques. Coloration is from color concentrates or color compounding, only high performance organic pigments are suitable due to the high processing temperatures. In addition, due to the amorphous structure of COC polymer soluble dyes with sufficient heat resistance can also be used and are often preferred as they do not detract from the high clarity that COC's exhibit.

The following Solvaperm and Polysynthren dyes have been evaluated under laboratory conditions together with a selected range of PV Fast pigments that exhibit good transparency in the polymer.

Colorants for COC								
PV Fast	Polysynthren	Solvaperm						
Yellow H9G Yellow HG Yellow HG 01 Yellow HG 01 Yellow H2GR Yellow H3R Orange H4GL 01 Orange H2GL Scarlet 4RF Red D3G Red B Pink E Blue A4R Blue A4R Blue BG	Yellow NG Yellow GS Blue R Blue RBL Brown R	Orange 3G Red G Red BB Violet RSB Green G						
Brown RL								

Coloring recommendations and applications data - Pigments for Polyolefins (PU)										
Product name						e		astness	Warpage+	
	DPE				ω	stan	_	U	Suitability	
LDPE / LL	LDPE / LL	HDPE	ЪР	SD ¹ / ₃ [g/kg]	Hue angle [°]	Heat resi [°C]	Reduction	Full shade	220 °C	280 °C
PV Fast										
Yellow H9G				1.90	97.2	280	6-7	7		
Yellow H2G				3.80	89.0	260	8	8		_
Yellow HG 01				1.20	90.0	290	6-7	7-8		
Yellow HG				1.60	88.3	290	6-7	6-7		
Yellow H2GR				2.30	83.1	300	6-7	7-8		
Yellow HGR				3.40	79.6	300	6-7	7		
Yellow HR 02*		_	_	_	_	_	_	_	_	_
Yellow HR*		—	—	—	—	—	—	—	—	—
Yellow H3R				4.00	66.5	300	8	8		
Orange H4GL 01				2.40	56.7	290	8	8		
Orange H2GL				2.60	44.9	300	7-8	8	•	
Orange GRL				2.00	39.9	280	8	8	_	_
Orange 6RL				2.60	33.9	300	8	8		
Scarlet 4RF				2.30	27.2	300	7-8	8	_	_
Red B				1.50	23.9	300	8	8		_
Red D3G				1.30	17.4	300	8	8	_	_
Red HB				2.70	11.6	300	6	6-7		
Red 3B				1.80	11.9	300	7-8	7-8	_	_
Red BNP				1.60	11.6	300	7-8	8	_	_
Red HF4B				2.50	3.1	260	8	8		_
Red E3B				3.00	357.5	300	8	8		
Red E5B				2.70	354.8	300	8	8		
Pink E				2.20	338.8	300	8	8		
Pink E 01				2.30	338.1	300	8	8		
Violet ER				1.90	330.9	300	8	8	•	•
Violet BLP				0.60	301.1	270	7-8	7-8	—	—
Violet RL				0.70	300.7	280	7-8	7-8	—	—
Blue A4R				0.90	248.0	300	8	8	_	—
Blue A2R				0.80	248.2	300	8	8	_	_
Blue AV				2.70	234.2	300	8	8		
Blue BG				1.00	242.7	300	8	8	—	—
Green GNX				2.20	177.0	300	8	8	_	—
Brown HFR				2.20	25.7	290	8	8	•	•
Brown RL				2.00	38.5	300	8	8	_	—

Warpage+ Suitability for low warpage applications

✤ = diarylide

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Coloring recommendations and applications data - Pigments for Polyolefins (PO)										
Product name						e	Light fa	astness	Warpage+	
	DPE				Ð	istano	Ē	Ð	Suita	bility
	E/U	ш		[]]	angl	resi	uctio	shad	ပ္	ပ္
	LDP	НОР	РР	SD ¹ [g/kę	Hue [°]	Heat [°C]	Redu	Full	220 *	280
Graphtol										
Yellow H10G*		—	—	—	—	—	—	—	—	—
Yellow GG*		—	—	—	—	—	—	—	—	—
Yellow 3GP				1.80	93.0	260	7-8	8	-	—
Yellow GXS*		—	—	—	—	—	—	—	—	—
Yellow GR*		—	—	—	-	—	-	-	-	—
Yellow H2R				1.10	75.8	240	7	7	•	—
Orange GPS*		—	—	—	-	—	-	-	-	—
Orange RL*		—	—	—	—	—	—	—	—	—
Red HFG				3.50	31.0	280	7	7	—	•
Red LG				1.80	22.1	270	2-3	3		—
Red LC				2.20	21.3	250	2-3	3		—
Red BB*		—	—	—	—	—	—	—	—	—
Red F3RK 70				2.20	13.1	270	7-8	8	•	—
Fire Red 3RLP				2.20	10.5	240	6	6-7	•	—
Red HF2B				1.30	13.3	250	6-7	7	—	—
Red F5RK				2.10	8.4	250	7-8	8	•	—
Red 2BN				1.20	3.1	300	7	7-8	—	—
Red P2B				1.00	359.9	240	5-6	6-7		—
Carmine HF4C				2.00	359.8	250	5-6	6	—	—
Carmine HF3C				2.10	358.7	270	7	7		—
Rubine 6BP				0.90	351.5	260	4-5	6-7	—	—
Bordeaux HF3R				1.10	342.1	250	6-7	/	—	—
DrizPearls										
Yellow 3GP				2.10	91.4	240	7-8	8	_	
Yellow HG				1.90	88.4	290	6-7	6-7		
Red F3RK 70				2.80	16.6	280	7-8	8		—
Red E5B				3.00	356.8	300	8	8		
Pink E				2.75	340.2	300	8	8		
Violet RL				0.75	300.8	270	7-8	7-8	—	—
Blue BG				1.40	241.6	300	8	8	—	—
Green GNX				2.60	177.2	300	8	8	—	—

Warpage+ Suitability for low warpage applications

✤ = diarylide

Influence of weathering

Weathering: defined as the adverse response of a material or product to climate, is a critical dynamic in the formulation of plastics for outdoor applications. The factors that can influence weathering can be categorised according to geographical location: Solar radiation (light energy), temperature and water (moisture) and to include local climatic variations; sudden temperature change, humidity, airborne pollutants, acid rain, etc.

In discussing the selection of colorants for use in plastics that will spend some or all of their life cycle outdoors it is of paramount importance that the selected polymer is formulated to withstand its application environment and anticipated life cycle. For polyolefins such as HDPE and PP additional stabilisation against thermal oxidation and the damaging effects of UV radiation is usually required. The selection of polymer stabilisers; primary and secondary antioxidants, UV absorbers and hindered amine light stabilisers (HALS) is too specialised for discussion in this brochure. However, Clariant does offer an extensive range of polymer additives for stabilising and polymer enhancing applications in a wide range of plastics. For details of these products, technical information and sampling contact your local Clariant sales organisation or regional Technical Application Centre.

It is however, a point to note that certain polymer additives used in the stabilisation of Polyolefins have been found to influence the performance of organic pigments;

- Certain groups of primary antioxidants can induce polymer yellowing during exposure influencing the overall color of an article
- Phosphonite process stabilisers (secondary antioxidants) improve the melt characteristics and thermal stability of HDPE. Several organic pigments benefit from this interaction to demonstrate higher thermal stabilities.
- HALS chemistries containing triazine can cause a strong yellowing of the polymer during heat aging. A shift in the shade of the stabilised polymer will alter the overall optical properties of the end article.

The resistance of colorants to the primary influences of weathering in plastics application can best be assessed by conducting out extensive outdoor trials under the conditions of use. A commonly used alternative which provides guideline data under a specific "limited" set of conditions is to expose a sample from the end article to accelerated weathering in a weather-o-meter (WOM). Accelerated weathering is a useful tool for fast assessment of performance under service life conditions.

The evaluation of the effects of weathering on a colored article is carried out by assessing color change. Although no absolute pass and fail system exists, evaluation is often carried out against the ISO 105-A02 1993 Grey scale for assessing color change. The scale is numbered 1-5 whereby the step 5 indicates no visible color change and the step 1 is a major shift in shade whereby the original unexposed color is no longer recognizable. The scale is graduated in half steps and the plastic industry generally recognises that when step 3 has been reached, the color change is no longer acceptable. Step 3-4 is considered the limit for a pass.

The color change can also be measured using CIE L.a.b. colorimetry. The Delta E value as a measure of total color difference is in the assessment of weathering not particularly useful however, the individual deltas are a useful method of producing comparative data and defining limits.

The assessment of fastness to weathering of the PV Fast and Graphtol pigments has been conducted in HDPE employing two differing polymer stabilisation systems. Injection molded plates were exposed in a Atlas Xenotest 1200 W WOM using a cycle of 102 minutes dry and 18 minutes wet. The black panel temperature was set at 60 °C and the relative humidity at 60 %.

The two differing polymer stabilisation systems employed were;

Stabilisation 1:	0.05 % Hostanox [®] * 010
	0.10 % Hotavin [®] * ARO 8
	0.15 % Hostavin N 321

Stabilisation 2: 0.10 % Hostanox M 102 0.10 % Benzotriazole UV Absorber 0.20 % Hostavin N 30

The following results were obtained using pigment concentrations of 0.2 % "Full shade" and 0.2 % plus 0.5 % titanium dioxide in "Reduction". The assessment to the Grey scale was carried out at 500 hours intervals, the data recorded in the results table presents the step reached after 3.000 and 5.000 hours exposure.

Weather fastness data in HDPE - Assessment to Grey scale after 3000 and 5000 Hours exposure

Stabilisation 1

Product name	After 300	00 Hours	After 5000 Hours				
	Full shade	Reduction	Full shade	Reduction			
PV Fast							
Yellow H2G	4-5	4	4	-			
Yellow H3R	4-5	4	3-4	-			
Orange H4GL 01	4-5	-	3-4	-			
Orange H2GL	4-5	-	-	-			
Orange GRL	5	3-4	4-5	-			
Orange 6RL	3-4	3-4	-	-			
Red B	4	-	-	-			
Red D3G	5	4	3-4	3			
Red 3B	3-4	-	-	-			
Red E3B	5	4-5	5	4			
Red E5B	4-5	4	4	-			
Pink E	5	4-5	5	4			
Pink E 01	5	4-5	5	4			
Violet ER	3-4	-	-	-			
Violet BLP	4-5	4	4	3-4			
Violet RL	4-5	4	4	3-4			
Blue A4R	5	5	5	5			
Blue A2R	5	5	5	5			
Blue AV	5	5	5	5			
Blue BG	5	5	5	5			
Green GNX	5	5	5	5			
Brown HFR	5	4	5	3			
Brown RL	4-5	4-5	4-5	4-5			

Stabilisation 2

Product name	After 300	00 Hours	After 5000 Hours							
	Full shade	Reduction	Full shade	Reduction						
PV Fast										
Yellow H2G	5	4-5	4-5	3-4						
Yellow H3R	5	4-5	4	-						
Orange H4GL 01	5	-	3-4	-						
Orange H2GL	4-5	-	-	-						
Red D3G	5	4	4-5	3						
Red E3B	5	4-5	5	4-5						
Red E5B	4-5	4-5	4	3-4						
Pink E	5	4-5	4-5	4						
Pink E 01	5	5	4-5	4-5						
Blue A4R	5	5	5	5						
Blue A2R	5	5	5	5						
Blue AV	5	5	5	5						
Blue BG	5	5	5	5						
Green GNX	5	5	5	5						

2.4 Styrenics

Styrene, a by-product of petroleum is the key component in the manufacture of a variety of thermoplastic materials. Polystyrene being the most recognisable, others include acrylo-nitrile-butadiene styrene (ABS), styrene-acrylonitrile (SAN), unsaturated polyester resins (covered in a later chapter) and expanded polystyrene foam (EPS).

Polystyrene (PS) is a crystal clear transparent thermoplastic processable from 190 - 280 °C, it is hard and brittle and often referred to as "General purpose polystyrene" (GPPS). Below its glass transition temperature, around 100 °C it is a glass like, transparent and amorphous polymer.

Polystyrene can be modified with butadiene rubber to improve its impact properties either by copolymerising styrene monomer with butadiene monomer (referred to as butadiene/ styrene) or by blending finely dispersed particles of butadiene rubber in to the polystyrene providing opacity and impact modification to the polymer. These materials are referred to as medium (MIPS) or high impact (HIPS) polystyrene dependant on the level of dispersed rubber.

A third modification of polystyrene is expanded polystyrene foam (EPS), a lightweight, rigid plastic foam produced from solid beads of polystyrene. Expansion is achieved via small amounts of pentane gas which have been dissolved in the polystyrene in the cooling phase after polymerisation. The gas then expands by exposure to steam to form a series of non-interconnecting cells. These are then molded to form blocks, boards or customised products such as drinking cups or food containers. During the molding phase the remaining pentane gas and steam fuse to form a homogeneous product.

The coloration of polystyrene (PS, MIPS & HIPS) is mainly from masterbatch granules, color compounding or concentrated liquid pastes. As the polymer is abrasive, liquid dispersants or waxes are added to protect organic pigments to improve pigment wetting and to increase pigmentation levels.

To maintain a high degree of transparency in GPPS soluble dyes provide the best coloring solution. Due its almost completely amorphous state, blooming or re-crystallisation of soluble dyes from GPPS is not possible. Soluble dyes are also the preferred method of tinting opaque shades in GPPS for the reason that many organic pigments either possess a degree of solubility, which can lead to unstable colors, or due to their limit concentration lack thermal stability at the required processing temperature. Although not a usual occurrence, when formulating with soluble dyes in impact modified grades of polystyrene, a potential for blooming due to the presence of the butadiene rubber does exist and should be checked for in the end application. In opaque and semi translucent shades the PV Fast pigments are recommended, selected Graphtol grades are also suitable. The main consideration is heat stability followed by light fastness requirements. Solvaperm, Hostasol and a number of Fat dyes are recommended for transparent colors and for increasing the brightness and intensity of shade in opaque colorations. The fastness properties and thermal stability of the recommended colorants can be found in the following tables.

The listed Solvaperm, Hostasol and Fat soluble dyes can be used in the coloration of EPS. Initially the soluble dyes are either dissolved in solvent mixtures (e.g.: ethanol/methylene Chloride) or tumble blended directly on to the beads with the aid of a neutral solvent. Coloration is achieved in the mold during the foaming process at 120 °C in the presence of steam.

Deep-drawn EPS film is produced at around 220 °C by extruding GPPS in the presence of blowing agents. Structural EPS foam is formed by injection molding impact modified or GPPS grades of polystyrene together with chemical blowing agents in the presence of a wetting medium. No special demands are placed on the thermal stability of colorants in these processes and the selected pigments and soluble dyes recommended for polystyrene are suitable. Coloration in both processes is greatly influenced by the foam structure which adds a strong whitening effect and high concentrations of colorants are required even to reach pale shades.

Acrylonitrile-butadiene styrene (ABS) is a terpolymer traditionally manufactured by polymerising styrene and acrylonitrile in the presence of polybutadiene. Some manufacturers today have moved away from this copolymerisation to a special grafting process whereby in the first stage butadiene is polymerised and then cyanide and phenyl groups are grafted on through a chemical reaction. This grafting process optimises the polymers properties and eliminates the well recorded problems of smell and polymer yellowing.

ABS has an amorphous structure; its base color can vary from white (similar to impact modified polystyrene) to a dull beige. The presence of a high proportion of butadiene rubber in certain grades can present a potential for migration from solvent dyes. Many grades offered contain anti-statics or other active ingredients, these also have the potential to promote migration. The coloration of ABS is mainly from masterbatch granules or color compounding and is strongly influenced by the polymers opacity. Only high-performance organic pigments are suitable; heat stability and light fastness are the major considerations and the thermal stability of a pigment can vary from grade to grade of ABS. Pigment concentration is also critical in obtaining the required heat stability and light fastness. Many PV Fast pigments are suitable for ABS coloration but a pre-test to determine maintenance of fastness properties is recommended. To obtain bright shades and also for use as shading (tinting) components polymer soluble dyes are often used.

The recommended PV Fast organic pigments, together with the Solvaperm and Hostasol soluble dyes for coloring ABS can be found in the following table. They have all been evaluated in DOW Chemicals Magnum 3391. Their fastness and thermal properties will vary from manufacturer to manufacturer and according to the grade used.

Styrene-acrylonitrile (SAN) is a copolymer of styrene and acrylonitrile with an amorphous structure. The acrylonitrile elements improve the temperature resistance, impact strength, stiffness and optical properties in comparison with polystyrene. SAN is often used in polymer blends with PVC and ABS to alter flow characteristics and in masterbatch production as a carrier for colorants and polymer additives.

SAN can be injection molded, extruded and blow molded. It is resistant to grease, food staining, stress cracking, crazing, boiling water and a wide range of chemicals. It is ideally suited for use in kitchen, bathroom and office environments. Common applications include kitchen articles and tableware, cosmetics and personal care packaging, bathroom fittings and toothbrushes.

The coloration of SAN including the selection of colorants together with their fastness properties are broadly similar to the recommendations provided for coloring polystyrene. Processing temperatures are 210 - 290 °C.

Coloring recommendations and application data - Pigments for Polystyrene (PS) and Styrene-acrylonitrile (SAN)							
Product name		Light fastness					
	SD 1/ ₃ [g/kg]	Hue angle [°]	Reduction	Full shade	Heat resistance [°C]		
PV Fast							
Yellow H9G	2.30	99.8	6	7	280		
Yellow H2G	3.00	88.7	8	8	260		
Yellow HG 01	1.40	90.5	6	7-8	300		
Yellow HG	1.50	87.6	6-7	6-7	300		
Yellow H2GR	2.70	83.4	6-7	7	300		
Yellow HGR	3.10	78.5	7	7	300		
Yellow H3R	4.40	65.1	8	8	300		
Orange H4GL 01	2.30	56.1	8	8	300		
Orange H2GL	2.70	42.9	7	7-8	300		
Orange GRL	1.80	43.6	7-8	8	300		
Orange 6RL	2.40	34.6	7	7	300		
Scarlet 4RF	2.40	27.6	7	7-8	300		
Red B	1.50	19.2	8	8	300		
Red D3G	1.70	17.4	8	8	300		
Red HB	2.00	11.1	6	6-7	300		
Red 3B	1.90	14.7	8	8	300		
Red BNP	1.50	13.2	6-7	6-7	300		
Red HF4B	1.80	5.7	8	8	300		
Red E3B	2.30	348.3	8	8	300		
	2.10	355.0	/-8	7-8	300		
PINK E	2.20	340.1	8	8	300		
PINK E UI	2.00	330.1	8	8	300		
Violet ER	1.80	333.1	8	8	300		
Violet BLP	0.70	301.5	0-7	7-8	200		
	1.20	233.0	0-7	/-0 0	270		
Plue A2P	0.90	240.1	0	0	200		
Blue BG	1 10	240.0	8	8	300		
Green GNX	2.00	177.0	8	8	300		
Brown BI	1.90	38.6	8	8	300		
brownine	1.00	50.0	Ū	0	500		

Coloring recommendations and application data - Pigments for Polystyrene (PS) and Styrene-acrylonitrile (SAN)							
Product name	Light fastness		astness				
	SD ^{1/} 3 [g/kg]	Hue angle [°]	Reduction	Full shade	Heat resistance [°C]		
Graphtol							
Yellow 3GP	2.00	91.5	7-8	8	260		
Red LG	1.70	22.0	3-4	4	300		
Red LC	1.70	25.6	3-4	4	300		
Fire Red 3RLP	2.30	10.6	4-5	6	250		
Red 2BN	1.20	4.5	5-6	6	300		
Red P2B	1.30	358.1	5	5-6	240		
Carmine HF4C	1.20	1.9	6-7	7	270		
Carmine HF3C	1.30	358.3	7	7	300		
Rubine 6BP	1.50	352.0	3-4	6	260		

Coloring recommendations and application data - Soluble dyes for Polystyrene (PS) and Styrene-acrylonitrile (SAN)						
Product name			Light fa	astness		
	SD ¹ / ₃ [g/kg]	Hue angle [°]	Reduction	Full shade	Heat resistance [°C]	
Solvaperm						
Yellow G	0.54	93.2	7-8	7-8	300	
Yellow 3G	1.20	94.5	7-8	8	300	
Yellow 2G	0.52	95.5	7-8	8	300	
Orange 3G	1.50	63.0	6	8	300	
Red 2G	1.60	28.0	6	7	300	
Red G	2.10	23.9	7	8	300	
Red PFS	2.60	24.5	5-6	7	300	
Red BB	0.56	353.5	6	8	300	
Red Violet R	0.93	329.0	6	7-8	300	
Violet FBL	1.70	305.5	5-6	7	300	
Violet RSB	0.85	289.0	6	7-8	300	
Blue 2B	1.00	268.5	6	7-8	300	
Green GSB	0.98	218.0	4-5	7	300	
Green G	1.60	183.5	7-8	8	300	

Coloring recommendations and application data - Soluble colorants for Polystyrene (PS) and Styrene-acrylonitrile (SAN)										
Product name			Light fa							
	SD ¹ / ₃ [g/kg]	Hue angle [°]	Reduction	Full shade	Heat resistance [°C]					
Polysynthren	Polysynthren									
Golden Yellow GR	1.80	73.5	5	7	300					
Red GFP	2.30	24.0	7	8	300					
Blue R	0.90	283.0	6-7	7	300					
Blue RLS	1.80	279.5	6-7	7-8	300					
Blue RBL	0.97	268.5	6	7-8	300					
Brown 3RL	1.90	35.5	7	8	300					
Brown R	1.20	16.0	7	8	300					
Fat										
Red 5B 02	0.54	358.4	3	4-5	270					
Blue B 01	0.96	266.6	6-7	7	300					

Coloring recommendations and application data - Fluorescent dyes for Polystyrene (PS) and Styrene-acrylonitrile (SAN)							
Product name			Light fa				
	SD ^{1/} 3 [g/kg]	Hue angle [°]	Reduction	Full shade	Heat resistance [°C]		
Hostasol							
Yellow 3G	-	-	4-5 ¹⁾	72)	300		
Red GG	-	-	41)	72)	300		
Red 5B	-	-	31)	42)	300		

¹⁾ 0.2 % dye + 1 % TiO₂ ²⁾ 0.05 % dye

Coloring recommendations and application data - Pigments for Acrylonitrile butadiene styrene (ABS)							
Product name			Light fa				
	SD 1/ ₃ [g/kg]	Hue angle [°]	Reduction	Full shade	Heat resistance [°C]		
PV Fast							
Yellow H9G	2.80	97.4	6	6-7	260		
Yellow H2G	4.60	90.5	8	8	250		
Yellow HG 01	1.30	89.9	6	7-8	300		
Yellow HG	1.50	88.9	6-7	6-7	290		
Yellow H2GR	3.00	82.9	6-7	7	300		
Yellow HGR	3.20	80.1	7	7	300		
Yellow H3R	5.00	64.7	8	8	280		
Orange H4GL 01	2.40	56.5	8	8	290		
Orange H2GL	2.90	44.4	7	6-7	270		
Orange GRL	2.20	38.8	7-8	8	290		
Orange 6RL	2.60	34.9	6-7	6-7	300		
Scarlet 4RF	2.50	27.9	7	7	300		
Red B	1.70	19.3	8	8	280		
Red D3G	2.00	17.8	7-8	7-8	270		
Red HB	2.50	13.4	5-6	6	300		
Red 3B	1.90	15.1	8	8	300		
Red BNP	1.70	13.1	6	7	300		
Red HF4B	1.80	4.6	7-8	8	290		
Red E3B	3.40	359.7	8	8	300		
Red E5B	3.10	357.0	7-8	7-8	300		
Pink E	2.70	341.2	7-8	8	300		
Pink E 01	2.00	337.0	7-8	8	300		
Violet ER	2.20	334.6	8	8	270		
Blue A4R	1.10	249.0	6-7	6-7	280		
Blue A2R	0.80	246.5	8	8	300		
Blue BG	1.20	241.8	8	8	300		
Green GNX	2.20	179.4	8	8	290		

Graphtol					
Red LG	1.80	22.9	2-3	3	260
Red LC	1.90	22.0	3-4	3	260
Red 2BN	1.20	4.4	6	6	290

Coloring recommendations and application data - Soluble dyes for Acrylonitrile butadiene styrene (ABS)									
Product name			Light fa	istness					
	SD ¹ / ₃ [g/kg]	Hue angle [°]	Reduction	Full shade	Heat resistance [°C]				
Solvaperm									
Yellow G	0.64	92.2	7	7	250				
Yellow 2G	0.61	93.5	6-7	7-8	300				
Orange 3G	1.80	62.5	5-6	7-8	300				
Red 2G	1.80	31.0	5	7	300				
Red G	2.40	24.7	7	7	300				
Red PFS	2.30	13.0	3-4	5	300				
Red BB	0.58	350.0	5-6	6-7	280				
Red Violet R	1.00	324.5	5	6	300				
Violet FBL	1.80	304.0	4	6	300				
Violet RSB	0.97	287.5	5	6	290				
Blue 2B	1.10	267.0	4	5	300				
Green GSB	1.20	213.5	4	6	300				
Green G	1.70	181.0	5	6	300				

Polysynthren					
Golden Yellow GR	2.00	73.0	6-7	7	250
Red GFP	2.70	25.0	7	7	290
Violet G	0.90	343.0	6-7	6-7	240
Blue R	0.97	279.5	5	6	300
Blue RLS	1.90	277.0	5-6	5-6	300
Blue RBL	1.10	266.0	4	6	300
Brown 3RL	2.30	43.0	7-8	8	300
Brown R	1.30	16.0	7	8	300

Coloring recommendations and application data - Fluorescent dyes for Acrylonitrile butadiene styrene (ABS)										
Product name				Light fastness						
	SD ^{1/} 3 [g/kg]	Hue angle [°]	Reduction	Full shade	Heat resistance [°C]					
Hostasol										
Yellow 3G	-	-	31)	5-6 ²⁾	300					
Red GG	-	-	41)	6-7 ²⁾	300					
Red 5B	-	-	3-4 ¹⁾	6 ²⁾	250					

 $^{1)}$ 0.2 % dye + 1 % TiO_2 $^{2)}$ 0.05 % dye

2.5 Introduction to Polymethyl methacrylate (PMMA)

Polymethyl methacrylate (PMMA) or "Acrylic" as it is commonly known is manufactured by bulk, solution, suspension and emulsion polymerization of methyl methacrylate (MMA) monomer. PMMA is a fully amorphous polymer and exhibits excellent transparency: optical properties are better than those of glass at about half the density. It retains a good gloss while maintaining high surface hardness and weather resistance.

PMMA can be processed via film and sheet extrusion and can be easily vacuum formed by heating to 100 °C. Melt processing temperatures are from 190 to 260 °C and it can be readily injection molded. One of the main applications of PMMA is as a glass replacement in windows, light fittings, fish tanks and transparent protection screens. It is used to produce laserdiscs, automotive and electronic parts, point of sale displays and Liquid Crystal Display (LCD) plates. PMMA exhibits a good compatibility to human tissue and is used in the production of contact lenses, in dentistry and cosmetic surgery.

The coloration of Polymethyl methacrylate is in the main from color compounding or from PMMA based masterbatches. Of utmost importance is the retention of optical properties in the polymer which limits the addition of additives, fillers and processing aids.

The Solvaperm and Hostasol dyes are favoured in coloring PMMA due to their high transparency, high saturation in transmission and complete solubility in the polymer. These recommendations together with applicable Graphtol and PV Fast pigments and a number of suitable Polysynthren dyes are to be found in the following tables.

Coloring recommendations and application data - Colorants for Polymethyl methacrylate (PMMA)

Product name	Heat resis	stance [°C]	Light f	astness
	Reduction (0.1 % + 1.0 TiO ₂)	Full shade (0.1 %)	Reduction (0.1 % + 1.0 TiO ₂)	Full shade (0.1 %)
PV Fast				
Yellow HG 01	280	280	4	6
Yellow HG	280	280	3-4	5-6
Yellow H2GR	280	280	4	5
Yellow HGR	280	280	3-4	4-5
Yellow H3R	280	280	7-8	8
Orange H4GL 01	280	280	6-7	7-8
Orange H2GL	280	280	in test	in test
Orange GRL	240	280	7	8
Orange 6RL	280	280	7-8	8
Scarlet 4RF	280	280	7	7-8
Red B	280	280	6-7	8
Red 3B	280	280	7-8	8
Red BNP	260	280	7	7-8
Red HF4B	280	280	5	7
Red E3B	280	250	8	8
Red E5B	280	250	8	8
Pink E	280	260	8	8
Pink E 01	280	260	8	8
Violet ER	260	250	8	7-8
Blue A4R	280	280	7	8
Blue A2R	280	280	8	8
Blue BG	280	280	8	8
Green GNX	260	280	8	8

Coloring recommendations and application data - Colorants for Polymethyl methacrylate (PMMA)							
Product name	Heat resis	tance [°C]	Light fa	Light fastness			
	Reduction (0.1 % + 1.0 TiO ₂)	Full shade (0.1 %)	Reduction (0.1 % + 1.0 TiO ₂)	Full shade (0.1 %)			
Graphtol							
Red 2BN	280	280	6	8			
Carmine HF3C	260	280	4	7			
Hesteand							
nostadryi							
Yellow Oxide BV	280	280	8	8			
Pink E	300	300	8	7-8			
Blue A4R	300	300	8	8			
Green GNX	300	300	8	8			
Brown HFR	280	280	8	8			
Solvaperm							
Yellow G	280	280	7-8	8			
Yellow 3G	280	280	6-7	7			
Yellow 2G	280	280	7-8	8			
Orange 3G	280	280	6	7-8			
Red 2G	280	280	6	7			
Red G	280	280	6-7	7-8			
Red PFS	280	280	4-5	7			
Red BB	280	280	6	8			
Red Violet R	260	280	6	7-8			
Violet FBL	280	280	5-6	7			
Violet RSB	280	280	6	7-8			
Blue 2B	280	280	6	7-8			
Green GSB	280	280	4-5	7			
Green G	280	280	6-7	7-8			
Polysynthren							
Vollow NG	200	200	0	0			
Vollow GS	200	200	0	0			
Pod CEP	200	200	6.7	0			
Blue B	280	200	6	7-0			
Blue BLS	200	200	6-7	7-0			
Blue BBI	200	200	6	7-8			
Brown 3Bl	200	200	7	8			
Brown B	280	280	8	8			
brownin	200	200	0	0			
Hostasol							
Yellow 3G	280	280	5-6	7			
Red GG	280	280	4	7-8			
Red 5B	280	280	3	4			

2.6 Coloration of Synthetic Polymer fibers

The most commonly colored melt-spun synthetic fibers: Polypropylene, Polyester and Polyamide, together with Polyacrylic are discussed in this section. The melt-spinning extrusion process pumps the polymer melt through the small holes of a spinneret to form continuous filaments. The meltspun fibers can be extruded from the spinneret in different cross-sectional forms (round, trilobal, pentagonal, octagonal etc.). Dependant on the number of holes in the spinneret, monofilament (one hole) or multifilament (several holes) fibers are produced.

After leaving the spinneret the melt-spun fibers are "drawn" as they cool to impart strength.

Drawing is the process of stretching and orientating fibers which pulls the molecular chains of the polymer together and orientates them along the fiber axis, thus creating a considerably stronger yarn. Texturing is a procedure used to increase the volume and the elasticity of a filament yarn. The most common texturing processes are; False-twist texturing, Stuffer-box and Air-jet texturing.

Polypropylene fibers are abrasion resistant, colorfast, and resistant to chemicals, mildew, perspiration, rot and weather. They are light-weight, stain and soil resistant and provide good bulk and cover. Major uses include clothing and apparel, automotive interior trims, shelf coverings and seats, home furnishings such as carpets, upholstery, wall-coverings, and bedding and Industrial products; disposable clothing, non-woven fabrics, ropes and geo-textiles for the building and construction industries.

The coloration of polypropylene fibers is from single pigment concentrates (SPC's) which are then blended in a second stage extrusion process to produce bespoke (tailormade) colors. The processing temperatures for the meltspinning of PP fibers range from 230 °C up to 280 °C. Pigment selection is based on heat stability, dispersion characteristics and the required fastness properties such as resistance to light, heat and rubbing. Ease of dispersion is crucial to the selection of pigments for the production of highly concentrated SPC's that contain up to 40 % organic pigment (up to 70 % for inorganic pigments). The dispersion characteristics of an organic pigment can be controlled by the pigment manufacturer in the synthesis and finishing steps. Inorganic pigments are controlled by surface treatments and/or in the grinding process.

The production of SPC's is from dry pigments, pigment flushes or pigment preparations via a twin-screw extruder or kneader/flushing mixer. The level of dispersion is controlled by measuring pressure change using a filter pressure test extruder. Poor pigment dispersion gives rise to expensive processing difficulties at the melt-spinning stage such as filament breakages and a high number of screen changes.

Recommended are the PV Fast and Graphtol powder pigments and the DrizPearls range of pre-wetted, dust-free and free-flowing pigments found in the following tables. Those listed as suitable under "Type EN 13900-5" are tested batch for batch in accordance with European Standard EN 13900-5, "Determination of a filter pressure value".

Polyester fibers are strong, resistant to stretching, shrinking and to most chemicals. They are easily washed, quick drying and resistant to wrinkling, mildew and abrasion. Major uses are; Apparel: all forms of clothing, Home furnishings: Carpets, curtains, draperies, sheets and pillow cases, wallcoverings and upholstery, Others: hoses, belts, ropes, netting, threads, automotive seats, sails and fiberfill for pillows, cushions and furniture.

Coloration can be introduced during the manufacture of PET in the polycondensation (polymerisation) phase. In this method the colorant is pre-dispersed in ethylene glycol to produce a slurry. This is introduced into the reactor where it is distributed by stirring to become a homogeneous solution in the polymer melt. Colorants introduced in this form must be able to withstand temperatures of 240 - 285 °C for 5 - 6 hours duration.

The more flexible method of coloring melt spun polyester is from color concentrates. Colorants selected require a thermal stability of at least 285 °C for 15 minutes.

A range of organic pigments and polymer soluble colorants are suitable for the melt spinning coloration of polyester fibers. In addition to the above mentioned requirements; resistance to sublimation and textile fastness properties (color fastness to light, rubbing, steam pleating, dry heat etc.) are essential but demands vary according to the final application.

The recommended PV Fast, Solvaperm, Hostasol and Polysynthren colorants for inclusion in the polycondensation process and for the manufacture of concentrates are listed in the following tables followed by their textile fastness properties.

Polyamide fibers are exceptionally strong, elastic and resistant to oil and most chemicals. They are easy to wash, low in moisture absorbency and produce smooth, soft, lightweight and long lasting fibers. Major uses are; Apparel: Blouses, dresses, hosiery, ski-wear, windbreakers, swim-

wear and cycle wear, Home furnishings: Bedspreads, carpets, curtains and upholstery, Industrial and others: hoses, belts, parachutes, racket strings, ropes and netting, sleeping bags, tents, threads, fishing-line and dental floss.

Polyamide's (Nylon) PA 6 and PA 66 grades are used in the melt spinning of polyamide fibers. The melt phases of these grades of Nylon are chemically highly corrosive and have a reducing effect on many organic colorants. This and the processing temperature requirements reduce severely the available coloring options. The processing range for PA 6 is from 260 to 280 °C and for PA 66 from 280 to 340 °C. In addi-

Coloring recommendations and explication data Diaments for Swithstic fibers

tion, the requirements for fastness properties such as light, heat, perspiration and washing fastness are application dependant.

Melt spun polyamide fibers are usually colored from predispersed concentrates. The following table contains PV Fast pigments, Solvaperm, Hostasol and Polysynthren dyes which have been tested in selected PA 6 and PA 66 grades can therefore be considered for selection. It is important to note that due to the chemical variations in differing grades of polyamide available on the market, pre-testing of colorant and polymer is essential to determine suitability of use.

Coloring recommendations and approaction data - Figments for Synthetic fibers							
Product name	PP 1	fiber	PET	fiber	PA 1	iber	
	Suitability	Type EN 13900-5	Color concen- trates	Polycon- densation coloration	PA 6 fiber	PA 66 fiber	
PV Fast							
Yellow H9G			_	—	_	_	
Yellow H2G	•	_	_	_	_	_	
Yellow HG 01		_	_	_	_	_	
Yellow HG			_	_	_	_	
Yellow H2GR			—	—	—	—	
Yellow HGR			—	—	—	—	
Yellow H3R			—	—	—	—	
Orange H4GL 01			—	—	_	—	
Orange H2GL			—	—	—	—	
Orange GRL			—		_	—	
Orange 6RL	•	—	—	—	•	•	
Scarlet 4RF				—	_	—	
Red B						—	
Red D3G		—	—	—	—	—	
Red HB			—	—	—	—	
Red 3B			—	—	—	—	
Red BNP				—	—	—	
Red HF4B		—	—	—	—	—	
Red E3B		—	٠	٠	—	—	
Red E5B			•	٠	—	—	
Pink E2G		—		٠	•	—	
Pink E				٠	•	—	
Pink E 01		—	٠	٠	•	—	
Violet ER			•	—	—	—	
Violet BLP			_	—		—	
Violet RL			—	—		—	
Blue A4R				٠	—	—	
Blue A2R					•	•	
Blue BG				٠	-	•	
Green GNX				•	•	•	
Brown HFR			_	_	_	_	
Brown RL			_	_	_		

Coloring recommendations and application data - Pigments for Synthetic fibers								
Product name	PP f	iber	PET	fiber	PA 1	PA fiber		
	Suitability	Type EN 13900-5	Color concen- trates	Polycon- densation coloration	PA 6 fiber	PA 66 fiber		
Graphtol								
Yellow 3GP		_	_	_	—	_		
Yellow H2R						_		
Red HFG	•							
Red LG			_	_	_	_		
Red F3RK 70			—	—	—	—		
Fire Red 3RLP			—	—	—	—		
Red 2BN	•	—	—	—	—	—		
Red P2B			—	—	—	—		
Carmine HF3C			—	—	—	—		
Rubine 6BP			—	—	—	—		

-		-			
-	r17	μ	0:	a ri	le
-	112	۰.	6		10

Yellow 3GP	_	_	_	_	_
Yellow HG	_	_	_	_	_
Red F3RK 70	_	_	_	_	_
Red E5B	_	_	_	_	_
Pink E	_	_	_	_	_
Violet RL	_	_	_	_	_
Blue BG	_	_	_	_	_
Green GNX	_	_	_	_	_

Solvaperm						
Yellow G	_	_		_	_	_
Yellow 2G	_	_	•	_	_	_
Orange 3G	_	_	_	_	•	_
Red 2G	_	_	•	•		_
Red G	_	_		-	_	_
Red BB	_	_		•	_	_
Violet RSB	_	_	•	_	_	_
Blue 2B	_	_			•	_
Green GSB	_	_	•	•	_	_
Green G	_	_		•	_	_

Coloring recommendations and application data - Pigments for Synthetic fibers								
Product name	PP	fiber	PET	fiber	PA f	PA fiber		
	Suitability	Type EN 13900-5	Color concen- trates	Polycon- densation coloration	PA 6 fiber	PA 66 fiber		
Polysynthren								
Yellow GG		_		•	_	_		
Yellow GS	_	_		•	_	_		
Yellow NG		_		•				
Yellow RL		—	—	—		•		
Golden Yellow GR	—	_		•	—	—		
Red GG					—	—		
Red GFP	—	—			—	—		
Violet G	—	—			—	—		
Blue R	_				—	—		
Blue RLS	—	—			—	—		
Blue RBL	—	—			•	—		
Brown 3RL		_		•	_	_		
Brown R	_	_			_	_		

Hostasol				
Yellow 3G	_	_	•	•
Red GG	_	_	•	•

Textile fastness properties of colorants in PET fibers

The textile fastness properties were determined in a semidull grade of polyethylene terephthalate (PET) from FDY with a titer of dtex 144 f 48 (round cross section). Coloration was from polyester based single color concentrates, the dosing rate given refers to the percentage of colorant incorporated in to the yarn.

		ISO 1	05 B (90	SO 105 B 02	ISO	105 C	04	ISO	105 P	10	ISO 10	5 X 12	ISO	105 P	02	ISO 10	5 X 1:
Dosing rate (%)	144 F 48 DTEX PET SD DTY	1 x Blue G Scale S	3 x irey (cale S	5 x Grey Scale	(Light fastness) Blue Scale	(Wa 95 ° Gre	Ishing C/203 Iy Sca	e °F 1	(D) 210 °C, Gre	ry hea ∕410 °F ÿ Sca	t) : 30 s le	(Rubb Aft ISO F Grey S	iing) er o 01 Scale	(Strea 127 °C/ Ge	m plea 266 °F 2 y Scal	iting) 0 min. e	(Rub Af ISO Grey	bing) ter P 02 Scale
					Method 2	z	PET	CO	z	PET	CO	Dry	Wet	z	PET	CO	Dry	Wei
0.84	Solvaperm Yellow G	9	2	1-2	9	4-5	3-4	4	4-5	1-2	ო	4-5	4-5	4-5	3-4	4	4-5	4-5
0.80	Polysynthren Yellow NG	2	4-5	4	7	4-5	4-5	4-5	4-5	4-5	4-5	4-5	4-5	4-5	2	5	4-5	4-5
0.80	Polysynthren Yellow GG	5	2	1-2	4	2	5	2	5	4-5	2	2	4-5	2	4-5	5	4-5	4-5
0.80	Polysynthren Yellow GS	7	4-5	4-5	7	4-5	4-5	4-5	4-5	4	4	4-5	4-5	4-5	4-5	4-5	4-5	4-5
0.54	Polysynthren Golden Yellow GR	9	4	4	5-6	2	5	2	5	4-5	2	2	2	2	2	5	4-5	2
0.50	Polysynthren Brown 3RL	2	4-5	4-5	œ	£	2	2	2	4-5	2	2	£	£	£	2	4	വ
0.64	Polysynthren Brown R	7	5	4-5	8	2	5	5	4	3-4	5	4	4-5	2	4	9	1-2	2-3
0.80	Polysynthren Red GG	2	3-4	2	7	2	4-5	4-5	4-5	4-5	4-5	4-5	4-5	4-5	4-5	4-5	4-5	4-5
1.00	PV Fast Red BNP	7	4-5	4-5	7	2	4-5	4-5	4-5	4-5	4-5	2	2	4-5	4-5	4-5	2	വ
1.00	PV Fast Scarlet 4RF	> 7	2	പ	œ	£	പ	2	2	2	പ	പ	£	£	£	2	4-5	വ
0.80	Polysynthren Red GFP	7	4	ŝ	9	D	2	2	2	2-3	£	£	2	3-4	4-5	2	e	3-4
1.20	PV Fast Red B	> 7	2	4-5	6-7	Ð	2	2	2	£	2	£	£	£	£	2	4-5	വ
1.00	Solvaperm Red BB	5-6	ę	2	2	2	2	2	5	1-2	2-3	4	2-3	2	ę	4	4	3-4
1.00	PV Fast Pink E	> 7	4-5	4-5	7	2	4-5	4-5	4-5	4-5	4-5	ъ	2	4-5	4-5	4-5	2	വ
0.60	Polysynthren Violet G	2	4-5	4-5	6-7	വ	2	2	2-3	2	2	4-5	4-5	4	2	2	2	4
0.80	Polysynthren Blue R	5-6	2-3	2	4-5	£	പ	2	2	3-4	പ	4-5	4-5	£	3-4	4-5	2	വ
0.60	Polysynthren Blue RLS	4	1-2		4	4-5	പ	5	2	2	2	4-5	4-5	2	വ	5	4-5	4-5
0.80	Polysynthren Blue RBL	4	1-2	-	4	£	2	2	2	3-4	4-5	4-5	4-5	£	4-5	2	4	4-5
0.60	PV Fast Blue A4R	> 7	5	2	80	£	2	2	2	2	ъ	ъ	2	2	2	5	4-5	2
0.60	PV Fast Blue BG	> 7	2	2	œ	£	പ	2	2	£	2	2	വ	£	വ	2	2	വ
0.80	Solvaperm Green G	2	2	-	4-5	വ	2	2	2	3-4	4-5	4	ო	2	4	4-5	ო	က
0.60	PV Fast Green GNX	> 7	5	2	œ	വ	2	2	5	2	2	2	വ	£	വ	2	5	വ
0.50	Hostasol Yellow 3G	7	4	3-4	œ	D	2	2	2	3-4	£	4-5	4	2	4	2	4	4
0.60	Hostasol Red GG	< 4	-		4-5	£	4	2	4-5	2-3	4	പ	4-5	5	3-4	4-5	4-5	4-5

Textile fastness properties of colorants in PA fibers

The textile fastness properties were determined in a polyamide 6 filament yarn with a titer of dtex 48 f 8. Coloration was from polyamide 6 based single-color concentrates, the dosing rate given refers to the percentage of colorant incorporated in to the yarn.

		` 0	3 X	3-4	3-4	11)	4	3-4	3-4	2	£					
	ture	3.0 %	2 x	6-7	6-7	-	6-7	6-7	6-7	7-8	7-8					
	nperat kposu 75 202		1 ×	7	2	-	7-8	7	2	7-8	7-8					
	gh ten ight ex DIN 7		3 X	2-3	3-4	ı.	3-4	-	-	2	2					
	Ξ	0.2 %	2 x	9	6-7	ı.	5-6	-	-	7-8	7-8					
			1 x	٢	9	ı.	9	-	-	7-8	7-8					
	s to ing		0M	2	4-5	4-5	2	2	2	2	2					
	stness ampoo		PA	2	4	4-5	2	2	2	2	2					
	Fa		ш.	2	2	4-5	2	2	2	2	2					
			0M	2	£	2	£	£	5	5	£					
	ration 04	acid	PA	2	4-5	5	2	2	5	5	5					
	persi 105-E		ш.	2	5	4-5	£	2	5	5	5					
	ess to	Ð	0M	5	2	2	വ	2	5	5	5					
	Fastno	lkalin	PA	5	4-5	2	2	2	5	2	5					
		IJ	ш.	5	5	4-5	2	2	5	5	5					
	to 0 °C C 03		WO	5	4-5	5	2	2	5	5	5					
	ttness hing 6 0 105-	Fastness washing 6 EN 20 105-		3-4	3-4	с	2	2	5	5	5					
ers	Fas wasl EN 2			4-5	4-5	4	2	5	5	5	5					
ımide fib	stness otest 105-B 2	stness test 105-B		6-7	7-8	11)	6-7	7	7	8	∞					
for Polya	Light fé Xenc EN ISO 00		0.2 %	2 2	7	ı	ę	4-5	4-5	7-8	7-8					
olorants	Dosing rate		%	25	10	10	25	20	20	25	25					
Fastness properties of co	Colorant Name			Polysynthren Yellow RL	Solvaperm Orange 3G	Hostasol Red GG	PV Fast Red B	PV Fast Violet RL	PV Fast Violet BLP	PV Fast Blue BG	PV Fast Green GNX					

Polyacrylonitrile (PAN) fibers exhibit outstanding wickability and are quick drying. They are easily washable and retain their shape, they have superior resistance to UV degradation and are resistance to oils, chemicals and moths. Major uses include: Apparel: Sweaters, socks, sports and children's wear, Home furnishings: Blankets, rugs, upholstery, luggage, awnings and outdoor furniture, Industrial and others: Sail cloth, cleaning wipes, and reinforcement for concrete and stucco.

Acrylic fibers (PAN) are produced by solution polymerizing acrylonitrile. The acrylonitrile is difficult to dye and is usually combined with a comonomer to improve the ability of the resulting fiber to absorb colorant. Solvent is then used to dissolve the polymer prior to fiber extrusion. PAN fibers can be dry or wet spun, they are used in staple or tow form. PAN has a high crystalline melting point of 317 °C and is soluble only in a limited range of solvents: Di-methyl Acetamide (DMAc), DMF and DMSO.

Unlike the coloration of Polyester, Polypropylene and Polyamide melt-spun fibers which are colored from color concentrate dispersions based on a polymeric material, colorants for PAN fiber extrusion are prepared as a solvent paste. The pigments must be totally insoluble in the solvent while retaining a pumpable viscosity. The range of suitable colorants for PAN fibers is therefore restricted, recommended Graphtol and PV Fast pigments can be found in the following table.

Pigments for PAN fibers

Product name

PV Fast	
Yellow H9G	
Yellow H2G	
Yellow HG 01	
Yellow HG	
Yellow H2GR	•
Yellow HGR	•
Yellow HR 02*	
Yellow HR*	•
Yellow H3R	
Orange H4GL 01	
Orange H2GL	
Orange GRL	
Scarlet 4RF	
Red B	
Red D3G	
Red 3B	
Red BNP	
Red HF4B	
Violet BLP	
Violet RL	
Blue A4R	
Blue A2R	
Blue BG	
Green GNX	
Brown HFR	
Brown RL	

Product name

Graphtol	
Yellow H10G*	•
Yellow GG*	
Yellow GR*	•
Yellow H2R	•
Orange GPS*	
Orange RL*	•
Red BB*	
Red F3RK 70	
Fire Red 3RLP	•
Red HF2B	
Red F5RK	
Red P2B	•
Carmine HF4C	•
Carmine HF3C	
Bordeaux HF3R	•

Permanent	
Red FGR	

Hostaperm	
Red Violet 3RL	
Violet RL-NF	

= diarylide

2.7 Coloration of engineering polymers

Engineering polymers are a group of thermoplastic materials which offer high strength, stiffness, toughness and resistance to wear, chemical attack and heat. Engineering polymers can be reinforced, filled or modified with a wide range of materials forming blends and alloys. Due to this diversity, any recommendations for their coloration can only be provided as a guideline. In all instances initial testing involving the final colorant formulation including additives and processing aids in the intended carrier system require evaluation under actual conditions of use in the final polymer system.

The heat stability and light fastness values of organic colorants can be in some instances lower than those reached in polyolefins. Selected organic pigments can promote nucleation in semi-crystalline engineering polymers reducing properties and processability. Many of these polymers are hydroscopic, the presence of moisture will lead to a reduction in properties upon processing.

The chemistries of engineering polymers are varied and although often referred to as a group, the various chemical families must be treated separately. Colorant selection is of particular importance, not only with regard to heat stability, light- and weather fastness etc., but in some instances the chemical aggressiveness in the melt phase of some of these polymers can act as a reducing agent, breaking down the chemical bonds of many organic pigments and dyes. Melt processing temperatures, gating considerations, hot runner systems and tooling designs are all critical factors in the selection of the right colorant combination.

A number of solvent soluble dyestuff chemistries demonstrate a poor resistance to sublimation when processed at elevated temperatures. Sublimation is defined as the change of phase of a substance direct from a solid to a vapour; by-passing a liquid phase. It is a form of degradation which leads to processing problems, blooming, contact bleeding and staining on tooling and other metal surfaces.

The following solvent dyestuff chemistries exhibit a slight or poor resistance to sublimation according to Clariant testing methods;

Slight:Solvent Yellow 98, Solvent Yellow 114,
Solvent Orange 60Poor:Solvent Yellow 93, Solvent Orange 63,
Solvent Red 111, Vat Red 41

Processing temperatures for engineering polymers vary considerably and place exacting demands on organic pigments and soluble dyes. In this chapter the coloration of the following polymers is discussed with colorant recommendations. In other engineering polymers contact to one of the regional Clariant Technical Application centres is advised.

Polymer	Processing temperature range °C
Polyoxymethylene (POM)	190 - 220
Polyester (PET)	270 - 310
Polyester (PBT)	240 - 280
Polycarbonate (PC)	280 - 340
Polyamide (PA 6)	230 - 280
Polyamide (PA 66)	280 - 320
Polyethermide (PEI)	340 - 420
Polysulfone (PSU / PES)	350 - 380
Polyphenylene sulphide (PPS)	300 - 360

Polycarbonate (PC)

Polycarbonate is a highly transparent (light transmission up to 92 % that of glass), amorphous light weight polymer. It combines high strength, toughness and heat resistance with excellent dimensional and color stability. The monomer "Bisphenol A" is reacted with sodium hydroxide, the resulting sodium salt of Bisphenol A is reacted in an interfacial polymerisation with phosgene to produce polycarbonate.

Polycarbonate can be injection molded, sheet and film extruded, and gas blow molded to form non-carbonated drink bottles. Other major applications include optical lenses, lighting elements, sheeting and panels for glazing and construction, compact discs, electrical and medical devices. Structural foam grades of polycarbonate are also available however, these are usually painted to provide a high quality surface finish. Care must be taken when processing polycarbonate as minute traces of moisture can lead to a degradation of physical properties.

Due to a high melt viscosity, the processing temperatures of polycarbonate are high: 280 - 340 °C, coloration is limited to selected organic and inorganic pigments and polymer soluble dyes. Masterbatch and color compounds are the common techniques for coloring polycarbonate, again when processing masterbatches care must be taken not to introduce moisture in to the system.

The major considerations when selecting organic colorants for polycarbonate are thermal stability and light fastness. The following tables of PV Fast and Graphtol pigments, Solvaperm and Hostasol fluorescent dyes together with the Polysynthren polymer soluble colorants have been positively tested and find regular applications in polycarbonate. Their heat stability and light fastness values obtained in the polymer are also provided.

Coloring recommendations and appli	cation data - Pig	gments for Polyca	arbonate (PC)		
Product name			Light fa	astness	
	SD 1/ ₃ [g/kg]	Hue angle [°]	Reduction	Full shade	Heat resistance [°C]
PV Fast					
Yellow HG 01	1.40	91.3	6-7	7-8	300
Yellow HG	1.60	89.9	5-6	5-6	300
Yellow H2GR	2.50	84.5	6	6-7	340
Yellow HGR	3.50	82.0	4-5	6	330
Orange GRL	1.70	43.3	7-8	8	290
Orange H2GL	2.70	45.3	7-8	7	300
Orange 6RL	1.80	36.6	7	8	300
Scarlet 4RF	2.50	28.2	7-8	7-8	300
Red B	1.60	25.5	8	8	310
Red HB	2.80	13.5	4-5	5	310
Red 3B	1.90	15.8	8	8	300
Red BNP	1.70	14.2	7	7-8	300
Red HF4B	2.70	7.3	8	8	300
Red E3B	3.20	350.6	7	8	300
Red E5B	3.80	358.7	6-7	7	290
Pink E	2.30	341.1	8	8	310
Pink E 01	3.00	336.0	8	8	310
Violet ER	2.20	339.9	8	8	320
Blue BG	1.00	239.5	8	8	320
Green GNX	2.20	178.0	8	8	340

Graphtol					
Red LG	1.70	21.5	2-3	3	310
Red LC	1.60	23.0	2-3	3	310
Red 2BN	1.30	9.8	7	7-8	300
Carmine HF3C	2.00	3.1	6-7	7	300

Coloring recommendations and appli	cation data - So	luble colorants fo	or Polycarbonate	(PC)	
Product name			Light fa	astness	
	SD 1/ ₃ [g/kg]	Hue angle [°]	Reduction	Full shade	Heat resistance [°C]
Solvaperm					
Yellow G	0.57	93.2	7-8	8	340
Yellow 3G	1.35	94.8	7-8	8	330
Yellow 2G	0.53	94.5	7-8	8	330
Orange 3G	1.57	62.1	7	8	340
Red 2G	1.55	30.6	5-6	8	340
Red G	2.03	23.3	7-8	8	340
Red PFS	2.12	15.9	5-6	7	340
Red BB	0.59	352.1	7	8	330
Red Violet R	0.94	326.5	6-7	8	330
Violet RSB	0.85	286.5	7-8	8	310
Blue 2B	0.96	266.3	6	7-8	340
Green GSB	1.02	214.3	6	7-8	340
Green G	1.63	183.9	7-8	8	310

Polysynthren					
Yellow GG	0.36	98.6	3	5	330
Yellow GS	1.90	76.3	8	8	320
Yellow NG	1.33	91.6	8	8	300
Golden Yellow GR	1.74	74.2	7	7-8	340
Red GG	0.98	39.0	7	8	320
Red GFP	2.29	23.4	7-8	8	340
Violet G	0.64	339.7	7-8	8	300
Blue R	0.88	280.9	7-8	8	300
Blue RLS	1.57	275.0	6	7	330
Blue RBL	0.95	266.1	6	7-8	340
Brown 3RL	1.97	40.6	8	8	340
Brown R	1.09	13.0	8	8	340

Hostasol					
Yellow 3G	-	-	6 ¹⁾	7-8 ²⁾	340
Red GG	-	-	6 ¹⁾	72)	320
Red 5B	-	-	5-6 ¹⁾	6-7 ²⁾	320

¹⁾ 0.2 % dye + 1.0 % TiO₂

²⁾ 0.05 % dye

Polyacetale / Polyoxymethylene (POM)

Polyacetales are hard, tough polymers with excellent dimen-sional stability and good impact resistance maintained across a wide temperature range. Copolymers of polyacetale have better thermal stability and processability than homo-polymers due to the presence of random ethylene oxide units in the molecular chain. These also open the processing window slightly. Both grades are highly crystalline and the natural polymer exhibits a translucent white color. Although polyacetale is not to a high degree hygroscopic, the presence of moisture will lead to processing problems and pre-drying is recommended.

Exceeding the thermal degradation temperature of POM will lead to rapid decomposition and to the formation of formaldehyde gas. This degradation process can be significantly accelerated by the poor selection of colorants. Since chemically identical pigments from differing manufacturers can vary in their behaviour and purity, only products specifically recommended for the coloration of polyacetale should be considered. Polyacetale displays very high shrinkage rates upon cooling and post-molding shrinkage can occur for up to 48 hours after processing.

Polyacetale is suitable for injection molding of thin-wall and complex parts and for extrusion; mainly to produce semi finished parts. Applications include pump housings, impellers, gears, cams, cogs, automotive parts, hose connectors and garden sprinklers.

Coloration is from granular masterbatch, liquid concentrates and color compounds. Selection of organic pigments is critical as mentioned previously, certain chemistries breakdown in the aggressive melt phase of the polymer, others that for example contain high levels of volatiles or water in the molecule will induce polymer degradation. Many classes of organic pigments have a tendency in very low concentrations to become partially soluble leading to unstable shades. Solvent soluble dyes are not recommended for coloring polyacetale due to their potential to bloom from the polymer matrix. Dimensional stability is also an issue and certain groups of organic pigments can induce a nucleating effect leading to warpage in an injection molded part.

The following Clariant PV Fast and Graphtol pigments have been found to be thermally and chemically stable in POM;

Product name	Light fastness Reduction	Limit concentration (%)
PV Fast		
Yellow H9G	6-7	0.1
Yellow HG 01	6-7	0.1
Yellow HG	6-7	0.1
Yellow H2GR	7	0.1
Yellow HGR	7	0.1
Yellow H3R	4-5	0.1
Orange H4GL 01	7-8	0.1
Orange H2GL	7-8	0.1
Orange 6RL	7-8	0.01
Scarlet 4RF	7	0.01
Red B	7-8	0.01
Red D3G	8	0.01
Red HB	6	0.01
Red 3B	7-8	0.01
Red BNP	7	0.01
Red HF4B	7	0.01
Red E3B	8	0.1
Red E5B	7-8	0.1
Pink E	8	0.1
Pink E 01	8	0.1
Violet ER	8	0.1
Blue A4R	8	0.1
Blue A2R	8	0.01
Blue BG	8	0.01
Green GNX	8	0.01
Brown HFR	7	0.01
Brown RL	8	0.01

Thermoplastic Polyester (PET and PBT)

Thermoplastic polyesters are divided into two main groups; Polyethylene Terephthalate (PET) and Polybutylene Terephthalate (PBT). Thermoplastic Polyester is a longchain polymer with a hydrocarbon backbone structure containing ester linkages, hence the name.

PET - Polyethylene terephthalate is an amorphous polyester formed in a transesterification reaction. Dimethyl terephthalate (DMT) is reacted with ethylene glycol, the reaction is heated to around 210 °C to boil of the methane and then the temperature is further increased to 270 °C at which point polymerisation takes place.

In recent years PET has not only replaced glass and other traditional materials, it has also replaced PVC, PE and PP in a number of applications due to its excellent design flexibility, high transparency, impact resistance and barrier properties. Main applications are in fibers (previously discussed), bottles, jars and containers and in packaging applications to produce films and tapes.

Most PET bottles are produced in two stages; initially a "preform" is injection molded, in the second stage the preform is heated to just above the glass transition temperature (Tg = 82 °C) and is placed in a bottle forming mold. Gas or air is then injected in to the preform and it is stretch-blown to fill the cavity. In stretch-blowing the amorphous preform, the long-chains in the polymer molecule harden and a strain induced crystallisation takes place giving the bottle its exceptional clarity, resistance to internal pressure and toughness.

PBT - Polybutylene terephthalate is a modified polyester formed also in a transesterification reaction. DMT is reacted with butylene glycol to produce a highly crystalline polyester. PBT has good mechanical strength and is resistant to chemicals, solvents and other tough and aggressive environments. It is widely used in the electronic, electric, fiber optic and automotive industries. It can be processed by injection molding, by extrusion in to sheets, films and profiles and can be melt-spun to produce fibers.

An extensive range of high-performance organic pigments and polymer soluble colorants can be used for the coloration of thermoplastic polyester*. The selection of inorganic pigments is often more critical due to their abrasiveness particularly when incorporated into filled grades of PBT. Colorant selection is based on heat stability and the required fastness properties for the end application. When selecting polymer soluble colorants it is important to note that solubility in the polymer melt is concentration dependant, particularly in filled grades. Polymer soluble colorants are recommended for tinting and full shade applications.

Quinacridone pigment classes (Pigment Red 122, Pigment Red 202 and Pigment Violet 19) have a tendency to become unstable at low concentrations in PBT.

The recommended PV Fast, Hostasol, Solvaperm and Polysynthren colorants for the coloration of PET and PBT sub-divided by application can be found in the following tables.

* The coloration of PET bottles produced by the "stretch-blow molding" process must be treated separately. Organic pigments that are not soluble in the polymer melt induce a nucleating effect on the PET influencing crystallite growth and thus, preventing stretch-blow molding of the preform.

Coloring recommendations and application data - Colorants for PBT and PET						
Product name	PI	ВТ	PET			
	unmodified	20 % glass filled	Stretch blow molding	Injection / Extrusion		
PV Fast						
Yellow HG 01			—			
Yellow HG			—			
Yellow H2GR			_			
Yellow HGR			—			
Yellow H3R			-			
Orange H4GL 01	•	•	—	—		
Urange H2GL	•	•	—	—		
			_	—		
Urange onL			_	_		
Rod R			—	-		
Red HB			_			
Red 3B			_	-		
Bed BNP			_			
Red HF4B			_	_		
Red E3B	•	•	_	•		
Red E5B	•	•	_	•		
Pink E	•	•	_			
Pink E 01	•	•	_			
Violet ER	•	•	_			
Blue A2R			•			
Blue A4R	•	•	_	•		
Blue BG			•			
Green GNX			—	•		
Brown HFR			—	•		

Coloration recommendations and application data - Soluble colorants for PET and PBT

Product name	PET						PBT	
		Light fa	astness					
	SD ¹ / ₃ [g/kg]	Reduction [SD 1/ ₃]	Full shade [SD ¹ / ₂₅]	Heat resistance [°C]	Stretch blow molding	Injection / Extrusion	Unmodified	20 % Glass filled
Solvaperm								
Yellow G	0.40	8	8	320				_
Yellow 2G	0.34	7-8	8	300			•	•
Orange 3G	1.20	7-8	8	320	•			
Red 2G	1.10	3-4	6-7	320	•			
Red G	1.50	7-8	8	320				
Red PFS	1.50	6-7	7	300	•			•
Red BB	0.40	7	8	300		•		
Red Violet R	0.84	6	7	280	_			
Violet RSB	0.65	7-8	8	300	•			
Blue 2B	0.67	5-6	7	320	•			
Green GSB	0.84	5-6	7	300				
Green G	1.20	7	7-8	300				

Polysynthren							
Yellow GG	0.32	5	6	300			
Yellow GS	1.35	8	8	320			•
Yellow NG	0.95	8	8	300		•	•
Yellow RL	0.90	7-8	8	320	•	—	—
Golden Yellow GR	1.20	6	7	320			
Red GG	1.05	8	8	320			
Red GFP	1.70	7-8	8	320			
Violet G	0.51	7-8	8	320			
Blue R	0.63	7	8	290			
Blue RLS	1.20	6	7	310			
Blue RBL	0.69	5-6	7	320			
Brown 3RL	1.50	8	8	320			
Brown R	0.82	8	8	320			

Hostasol							
Yellow 3G	-	71)	72)	300		•	
Red GG	-	41)	72)	300		•	

¹⁾ 0.2 % pigment

²⁾ 0.2 % pigment + 1.0 % TiO₂

Polyamide (Nylon)

Polyamides are a family of engineering resins having outstanding toughness and wear resistance, a low coefficient of friction, excellent electrical properties and chemical resistance. The family consists of several different types. Nylon 66, Nylon 6, Nylon 610, Nylon 612, Nylon 11, Nylon 12, Nylon 6-66 copolymer and Nylon 46 are the most common. Of these, Nylon 66 (PA 66) and Nylon 6 (PA 6) dominate the market. Polyamide is defined as a polymer containing repeating amide groups, the nomenclatures refer to the number of methyl (-CH₂-) units that occur on each side of the amide (CONH) groups.

Polyamides are hygroscopic polymers, they take up moisture readily. It's presence during processing particularly in higher temperature grades (PA 6 and PA 66) can severely degrade the mechanical properties of the final article. Polyamides can also absorb moisture after processing; this not only influences the dimensional stability of an article it can also lead to a color shift over time. These changes can occur for up to 150 days after processing until equilibrium has been reached. The process is reversible and the rate of absorption / desorption is dependant upon the grade, the ambient temperature and the relative humidity.

Polyamides 6 and 66 are slightly alkaline in their melt phases creating a chemically aggressive environment which has a "reducing" effect on many organic compounds including colorants. As a general rule colorants based on "azo, "-N=N-", (nitrogen double bond) chemistry should be avoided. (This guideline applies to all polyamide grades containing a "6" in the nomenclature). Although a limited number of polymer soluble colorants are recommended for the coloration of PA 6 and PA 66 they do display solubility limits which when exceeded can lead to migration and plate-out.

Polyamides 11 and 12 exhibit properties between those of polyolefins and Nylon 6, their melting points are lower and crystallinity is higher than in PA 6. Nylon 11 is manufactured from caster bean oil and Nylon 12 from butadiene; they are highly flexible polyamides with lower moisture absorption and superior resistance to hydrocarbons. Polymer soluble colorants are not recommended for the coloration of these grades. However, a number of high-performance organic pigments based on "azo" chemistry are suitable dependant on concentration, processing parameters and grade. Preliminary trials should be carried out to determine compatibility.

Nylon 6 is manufactured by a "ring opening polymerisation" of the monomer caprolactam. In this process the monomer rings are opened up to form a polymer chain. The melt processing range is from 230 - 280 °C, it is easier to process

than Nylon 66 and has a lower mold shrinkage. Nylon 6 can be modified with glass fibers to improve stiffness. Main applications in injection molding and extrusion processing are in the automotive sector, in home appliances, for power tool housings and to produce bearings, cogs, electrical connectors and kitchen utensils.

Nylon 66 is manufactured in an "acid catalysed condensation polymerisation" by reacting the monomers adipic acid with hexamethylene diamine. The melt processing range for injection molding and extrusion grades is from 280 - 300 °C. Nylon 66 is relatively difficult to process due to a very low melt viscosity, a narrow processing window and high post mold shrinkage. Applications include under the bonnet automotive parts such as engine covers, fan blades and grilles. Industrial machine casings, wheels, castors, cams, bolts and rivets.

The coloration of injection molding and extrusion grades of Polyamides 6 and 66 is from colored compounds and predispersed color concentrates. The following tables list a number of Hostasol and Solvaperm dyes together with selected PV Fast high-performance organic pigments which have been positively tested in grades of Nylon 6 and Nylon 66 under laboratory conditions. It is essential for the processor to carry out preliminary trials in the desired application with the appropriate polymer grades to ensure suitability for the intended use.

Coloration recommendations and application data	- Colorants for Polyamides (PA) for Injection Molding Applications
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Coloration recommendations and application data - Colorants for Polyannues (PA) for injection moluting Applications							
Product name			PA 6			PA	66
		Heat resis	tance [°C]	Light fa	istness		
		uo	de	uo	de		e
	/3]]	ucti	sha	ucti	sha	/3]]	t stan
	g/kg	Redi	lin lin	Sedi	Ē	sD ¹ g/kg	lea: esi: °C]
	0,	LL L	LL.	LL.	LL.	0,	
PV Fast							
Orange 6RL	1.7	300	300	7-8	8	1.9	300
Red B	1.8	280	280	6-7	6-7	-	-
Red E3B	4.0	280	270	7-8	7-8	-	-
Red E5B	4.5	280	270	6-7	7	-	-
Pink E	2.6	280	280	6-7	7	-	-
Pink E 01	2.7	280	280	6-7	7	-	-
Violet ER	2.6	300	270	6	6-7	-	-
Violet BLP	0.7	< 260	260	7-8	7-8	-	-
Violet RL	0.7	< 260	260	7-8	7-8	-	-
Blue A2R	0.7	280	280	8	8	0.8	280
Blue BG	0.9	300	300	8	8	1.0	300
Green GNX	1.7	280	280	8	8	1.9	280
Polysynthren							
Vellow BI	12	300	300	7-8	7-8	13	300
	1.2	500	500	70	70	1.0	500
Solvaperm							
Orange 3G	1.3	300	300	3-4	7-8	-	-
Red 2G	1.3	300	300	5-6	7-8	1.4	300
Red G	1.4	280	280	3-4	7-8	1.4	280
Red PFS	1.7	280	280	3-4	3-4	-	-
Blue 2B	0.8	280	280	4-5	5-6	0.9	280
Hostasol							
Yellow 3G	-	300	300	2-3	3-4	-	300
Red GG	-	280	300	1-2	2-3	-	290
Savinyl							
Yellow RLSW	0.9	290	290	7	8	-	-
Orange RLS	1.6	290	290	7	8	-	-
Red 2BLSE	0.7	280	280	< 6	7	-	-

Polyetherimide (PEI), Polysulfone (PSU) and Polyethersulfone (PES)

These three polymers belong in the same chemical family, they are inherently flame resistant amorphous polymers. Polyetherimide (PEI), Polysulfone (PSU), and Polyethersulfone (PES) exhibit excellent thermal properties, high strength and broad chemical resistance. In addition they can be repeatedly exposed to hot water and steam sterilisation. They are naturally transparent polymers with varying degrees of an amber tint.

Polyetherimide is processed from 340 - 420 °C, Polysulfone and Polyethersulfone from 350 - 380 °C. All three have a very high melt viscosity. To lower this by increasing the processing temperatures can lead to darkening of the moldings. Predrying is essential as these polymers readily take up moisture. Coloration is usually from color compounds, if granular masterbatches are used it is important that they do not introduce moisture into the polymer.

Due to the extremely high processing temperatures coloration from organic pigments and dyes is limited. The following table of Polysynthren, Hostasol and Solvaperm dyes together with selected PV Fast pigments where found suitable under laboratory conditions in the polymer grades specified. **Polyphenylene Sulphide (PPS)**

Linear polyphenylene sulphide is a thermoplastic polycondensate, it is a semi-crystalline polymer with high temperature performance and excellent chemical resistance. To overcome its inherent brittleness PPS must be filled with reinforcement fibers and fillers. These improve the strength, the surface and electrical properties and the dimensional stability of the polymer. Polyphenylene sulphide is inherently flame retardant and the main applications are in the production of high performance electrical components.

Linear PPS polymer can be extruded, blow molded or compression molded into blocks, rods and other stock shapes that are often used for prototyping. Unfilled linear polymer can also be melt spun and melt blow to produce fibers and fabrics that are used for conveyor belts, flame resistant clothing and filtration media.

The base color of the polymer is beige and after a short exposure to UV radiation turns brown. The melt processing temperature range is 300 - 360 °C (typically 320 °C for injection molding applications). Polyphenylene sulphide is usually color compounded.

Colorants for PSU and PES		Colorants for PPS				
Product name		Product name				
PV Fast	Polysynthren	PV Fast	Solvaperm			
Blue A2R	Violet G	Yellow HG 01	Orange 3G			
Blue BG	Blue R	Yellow HG	Red G			
Green GNX		Yellow H3R	Red Violet R			
		Orange GRL	Blue 2B			
Hostasol	Solvaperm	Red HB				
Yellow 3G	Orange 3G	Red B				
Red GG	Red G	Red E3B				
Red 5B	Violet RSB	Red E5B				
	Green G	Pink E				
		Blue A2R				
Colorants for PEI		Blue BG				
Product name		Green GNX				
Solvaperm	Polysynthren	Polysynthren	Hostasol			
Yellow 2G	Violet G	Violet G	Yellow 3G*			
Red PFS	Blue R	Blue R	Red GG*			
Red 2B		Brown R				
Red Violet R						
Blue 2B						
Green G						
PSU iniection molded 370 °C - 0.1 % fu	ll shade	PPS injection molded 320 °C - 0.1 % fu	ull shade / 0.5 % + 1.0 % TiO ₂ reduction			

PSU injection molded 370 °C - 0.1 % full shade

PES injection molded 360 °C - 0.2 % full shade

PEI injection molded 360 °C - 0.2 % full shade / 0.2 % + 1.0 % TiO $_2$ reduction

* 0.1 % full shade / 0.1 % + 1.0 % TiO₂ reduction

2.8 Introduction to Thermosetting resins

Thermoset Plastics

Thermoset plastics (often referred to as resins) react during processing to form crosslinked structures. In their uncured state they are liquid monomers or partially polymerized powders which can be formed (cast) or applied as a coating to create a finished article or film layer. Curing is a process of polymerisation which with the addition of chemical curing agents i.e. catalysts, and or heat creates the crosslinked structure which thereafter can no longer be melted or reprocessed. The most common thermosets in use today are based on unsaturated polyester, methyl methacrylate, epoxy resins and polyurethane.

The polyester and epoxy types are also extensively used in the production of thermoset composites. Composites are thermoset resins reinforced with orientated, continuous fibers of carbon or a carbon and glass fiber combination built up into layers to form very strong, rigid structures.

In the production of thermoset composites, gelcoats are usually applied, either by spraying or brushing on to the mold surface prior to the application of the composite material. Gelcoats are usually based on unsaturated polyesters and provide thermoset composites with a high quality surface finish and a protective coating against water and weather. Gelcoats are manufactured in a high shear mixing of polyester resin with a thixotrope monomer, colorants and fillers to meet individual specifications.

Unsaturated Polyester resin (UP resin)

Unsaturated polyester is a polycondensation product of dicarboxylic acid with dihydric alcohol dissolved in an unsaturated styrene monomer solution. This solution is subsequently cured using catalysts (predominantly organic peroxides) which affect a polymerisation. Curing induces a crosslinking to produce a thermoset polyester resin.

There are two methods of curing UP resin: "hot" or high temperature curing and "cold" or room temperature curing. In "hot curing", a peroxide catalyst is added to the UP resin and the mixture is then heated to between 70 and 80 °C. In "cold curing", an accelerator, e.g. cobalt naphthenate is used. It is added with the catalyst to the UP resin and the reaction starts at room temperature. The curing reaction is exothermic and the generated heat can raise temperatures to around 140 °C. Unsaturated polyester resins in their uncured state are liquids; they can be cast (casting resin), coated on to a substrate and sprayed or brushed (Gelcoats). After curing they become crystal clear and brittle, to improve mechanical properties fillers are often added. Pigments should preferably be added in a pre-dispersed form to the uncured UP resin, e.g. as pastes. These can be based on the uncured UP resin, a plasticiser (the curing process and properties of the cured resin are not noticeably influenced by low levels of plasticiser), or other compatible intermediaries.

Most dyes are fully soluble in the unsaturated polyester resin (uncured) and can be added directly. They can also be added pre-dissolved in dimethyl formamide, ethanol, butyl acetate or methylene chloride.

In coloring UP resins a number of points need to be taken in to consideration. Colorants must be resistant to peroxides, they should also not accelerate or retard the curing process to any significant extent. Pigments will react differently depending on the type of catalyst and the amount being used. Their light fastness can also influenced considerably by the selection of catalyst. Although reaction temperatures of 140 °C are not that demanding for pigments, in thick coatings and castings the rate of cooling is slow, this places an additional demands on the thermal stability of colorants.

The following table of recommendations including their influence on curing rates is based on evaluations under laboratory conditions in a "cold" curing application.

Epoxy resins are low molecular weight, tacky liquids that are cured with hardeners to present a tough and hard crosslinked structure. As the hardeners (curing agents) become part of the final structure of the epoxy resin (unlike the catalysts and accelerators used in polyester resins) they can be formulated to offer a wide range of properties. Epoxy resins are excellent adhesives; they offer good chemical resistance, thermal stability and electrical properties. They can be processed by all standard thermoset techniques and are used in the production of fiber reinforced composites (laminates) and as binders for thermoset molding compounds. Epoxy resins have excellent hardness and wear resistance. They find applications in the aerospace industry, in the sport and leisure industries and in other areas where hard protective coatings are required.

The resin is transparent with a natural yellow/brown tint. For this reason pale shades and bright colors are difficult to achieve. Coloration is from powder pigments either predispersed in epoxy resin or in fillers and extenders also to be included in the system. There are no special selection requirements for pigments, they do not noticeably affect the curing process. However, the curing process is highly moisture sensitive, all additives and fillers must be pre-dried before use.

Thermosetting Polyurethane (PUR)

PUR is formed by reacting a polyol (an alcohol with more than two reactive hydroxyl groups) with a dissocyanate or a polymeric isocyanate in the presence of a catalyst. PUR is a thermoset polymer often referred to as "two-component" polyurethane, it is used to produce rigid foams as insulation materials, flexible foams for carpet backing, upholstered furniture and mattresses and in spread-coating applications for the coloration of artificial leather.

Polyol is the collective term for polyester-, polyether- and aliphatic Polyols. They are reacted with isocyanate to form a pre-polymer of polyurethane (PU). The market is dominated by polyether polyols which are manufactured from propylene oxide and ethylene oxide. Polyester polyols are usually a condensation reaction of ethylene glycol with a dicarboxylic acid. They tend to be more expensive than the polyether types and are more difficult to handle. However, they develop PU's with superior tensile, abrasion, flexing and oil resistant properties.

The coloring component of a polyurethane formulation is introduced in paste form in to the Polyol before it is reacted with an isocyanate. These pastes are dispersions of pigment either in a polyol or a plasticiser which are produced in a dissolver, on a triple-roll mill or in a bead mill. Organic pigments are preferred for the coloration of PUR due to their high color strength and lack of abrasiveness. The long-term thermal stability of organic pigments should be considered in foam applications due to the heat build-up formed in the curing process which is an exothermic reaction that can generate temperatures up to 180 °C for prolonged periods of time. Light fastness is often a factor, depending on the end application. Both organic and inorganic pigments are used to improve the light fastness of the PUR. Strong solvents are used in the spread-coating process and organic pigments must exhibit good solvent resistance in addition to migration fastness and rub resistance.

In addition to the Graphtol and PV Fast pigments presented in the following tables a number of Hostaperm, Novoperm and Hansa grades are suitable for the coloration of thermoset polyurethane. The most commonly used are mentioned in the following table, further information is available via your local Clariant sales organisation or regional Technical Application Center.

Colorants for PUR

Product name

Graphtol

Yellow H10 G*
Yellow GG*
Yellow 3GP
Yellow GXS*
Yellow GR*
Yellow H2R
Red HFG
Red BB*
Fire Red 3RLP

Red HF2B Red 2BN Red P2B Carmine HF3C Carmine HF4C Rubine 6BP Bordeaux HF3R**

Blue AN**

PV Fast

PV Fast		
Yellow H9G	Red 3B	
Yellow H2G	Red BNP	
Yellow HG 01	Red HF4B	
Yellow HG	Red E3B	
Yellow H2GR	Red E5B	
Yellow HGR	Pink E	
Yellow HR 02*	Pink E 01	
Yellow H3R	Violet ER	
Orange H4GL 01	Violet BLP**	
Orange H2GL	Violet RL**	
Orange GRL	Blue A2R	
Orange 6RL	Blue A4R	
Scarlet 4RF	Blue BG	
Red B	Green GNX	
Red D3G	Brown HFR	
Red HB	Brown RL	

✤ = diarylide

★★= indicates a high potential to bleed

🔹 = diarylide

**= indicates a high potential to bleed

Colorants for Unsaturated Polyester (UP)						
Product name		Light fastness				
	Influence on Curing	Full shade (0.025 %)				
PV Fast						
Yellow HR 02*		8				
Yellow HR*		7-8				
Orange GRL		7				
Red B		7-8				
Red E3B		7-8				
Red E5B		8				
Violet BLP		7-8				
Violet RL		7-8				
Blue A2R		8				
Blue BG		8				
Green GNX		8				

Graphtol		
Yellow H10G*		7-8
Yellow GG*		7-8
Orange RL*	-	8
Red HFG	-	8

Solvaperm		
Yellow G	-	7
Orange 3G		6
Red G	+	7
Red BB		7
Red Violet R		6-7
Violet RSB		7
Green G		7

Hostasol			
Yellow 3G		7-8	
<pre>= no significant influence on reaction time</pre>	+ = speeds reaction time up significantly	* = diarylde	
- = slows reaction time down significantly	= slows reaction time down dramatically		

3 Colorant Technical Information

3.1 Chemical and Physical data

PV Fast pigments Graphtol pigments DrizPearls Hostaprint pigment preparations Hostacryl pigment preparations Polysynthren polymer soluble colorants Solvaperm dyes Hostasol fluorescent dyes

3.2 Solvent Extraction data

PV Fast pigments Graphtol pigments

3.3 Solvent Solubility data

Solvaperm dyes Polysynthren dyes Hostasol dyes
3 Colorant Technical Information

3.1 Chemical and Physical data

Pigments								
Product name	Colour Index	Chemical designation	Density [g/cm ³]	Specific surface [m²/g]	Average particle size [nm]	Bulk volume [l/kg]	Acid resistance	Alkali resistance
PV Fast								
Yellow H9G	Pigment Yellow 214	Disazo/Benzimidazolone	1.35	44	165	6.0	5	5
Yellow H2G	Pigment Yellow 120	Benzimidazolone	1.52	29	119	6.7	5	5
Yellow HG 01	Pigment Yellow 180	Benzimidazolone	1.43	62	93	4.1	5	5
Yellow HG	Pigment Yellow 180	Benzimidazolone	1.46	28	234	10.0	5	5
Yellow H2GR	Pigment Yellow 191	Monoazopyrazolone, Ca	1.69	38	131	5.0	5	5
Yellow HGR	Pigment Yellow 191	Monoazopyrazolone, Ca	1.77	20	296	7.8	5	5
Yellow HR 02*	Pigment Yellow 83	Diarylide Yellow	1.49	80	35	4.0	5	5
Yellow HR*	Pigment Yellow 83	Diarylide Yellow	1.47	22	31	4.0	5	5
Yellow H3R	Pigment Yellow 181	Benzimidazolone	1.48	27	302	6.0	5	5
Orange H4GL 01	Pigment Orange 72	Benzimidazolone	1.51	39	138	4.8	5	5
Orange H2GL	Pigment Orange 64	Benzimidazolone	1.62	28	167	5.4	5	5
Orange GRL	Pigment Orange 43	Perinone	1.54	38	153	3.0	5	5
Orange 6RL	Pigment Orange 68	Metal Complex	1.60	23	292	4.0	5	5
Scarlet 4RF	Pigment Red 242	Disazo Condensation	1.61	41	285	5.4	5	5
Red B	Pigment Red 149	Perylene	1.40	72	26	3.2	5	5
Red D3G	Pigment Red 254	Diketo-pyrrollo-pyrrole	1.62	28	182	2.5	5	5
Red HB	Pigment Red 247	Naphtol AS, Ca	1.44	26	177	4.0	5	5
Red 3B	Pigment Red 144	Disazo Condensation	1.52	30	258	3.0	5	5
Red BNP	Pigment Red 214	Disazo Condensation	1.57	39	256	5.3	5	5
Red HF4B	Pigment Red 187	Naphthol AS	1.45	66	101	3.5	5	5
Red E3B	Pigment Violet 19	Quinacridone	1.47	39	189	4.0	5	5
Red E5B	Pigment Violet 19	Quinacridone	1.47	65	101	5.0	5	5
Pink E2G	Pigment Red 122	Quinacridone	1.45	82	76	2.2	5	5
Pink E	Pigment Red 122	Quinacridone	1.47	65	92	3.2	5	5
Pink E 01	Pigment Red 122	Quinacridone	1.45	63	132	3.2	5	5
Violet ER	Pigment Violet 19	Quinacridone	1.51	59	103	5.6	5	5
Violet BLP	Pigment Violet 23	Dioxazin	1.49	105	58	5.0	5	5
Violet RL	Pigment Violet 23	Dioxazin	1.49	83	39	3.5	5	5
Blue A4R	Pigment Blue 15:1	Cu Phthalocyanine Blue, α -Mod.	1.61	70	54	4.6	5	5
Blue A2R	Pigment Blue 15:1	Cu Phthalocyanine Blue, α -Mod.	1.63	64	25	3.5	5	5
Blue AV	Pigment Blue 15:1	Cu Phthalocyanine Blue, α -Mod.	1.19	-	-	1.7	5	5
Blue BG	Pigment Blue 15:3	Cu Phthalocyanine Blue, β -Mod.	1.62	57	90	4.0	5	5
Green GNX	Pigment Green 7	Cu Phthalocyanine Green	2.06	39	49	3.3	5	5
Brown HFR	Pigment Brown 25	Benzimidazolone	1.52	90	61	5.0	5	5
Brown RL	Pigment Brown 41	Disazo Condensation	1.58	52	188	4.8	5	5

Pigments								
Product name	Colour Index	Chemical designation	Density [g/cm ³]	Specific surface [m²/g]	Average particle size [nm]	Bulk volume [l/kg]	Acid resistance	Alkali resistance
Graphtol								
Yellow H10G*	Pigment Yellow 81	Diarylide Yellow	1.65	22	182	4.9	5	5
Yellow GG*	Pigment Yellow 17	Diarylide Yellow	1.39	63	45	4.0	5	5
Yellow 3GP	Pigment Yellow 155	Bisacetoacetarylide	1.40	52	_	5.0	5	5
Yellow GXS*	Pigment Yellow 14	Diarylide Yellow	1.39	39	94	7.8	5	5
Yellow GR*	Pigment Yellow 13	Diarylide Yellow	1.34	39	70	4.0	5	5
Yellow H2R	Pigment Yellow 139	Isoindoline	1.66	59	75	6.0	5	5
Orange GPS*	Pigment Orange 13	Disazopyrazolone/Diarylide	1.41	38	130	4.8	5	5
Orange RL*	Pigment Orange 34	Disazopyrazolone/Diarylide	1.40	65	60	6.4	5	5
Red HFG	Pigment Orange 38	Naphtol AS	1.45	67	155	3.2	5	5
Red LG	Pigment Red 53:1	β-Naphthol, Ba	1.86	49	100	4.0	5	5
Red LC	Pigment Red 53:1	β-Naphthol, Ba	1.82	42	159	6.0	5	5
Red BB*	Pigment Red 38	Disazopyrazolone/Diarylide	1.45	23	170	7.0	5	5
Red F3RK 70	Pigment Red 170	Naphtol AS	1.44	19	307	4.0	5	5
Fire Red 3RLP	Pigment Red 48:3	BONA, Sr	1.84	28	208	5.5	5	5
Red HF2B	Pigment Red 208	Benzimidazolone	1.36	49	61	7.1	5	5
Red F5RK	Pigment Red 170	Naphthol AS	1.40	25	214	3.9	5	5
Red 2BN	Pigment Red 262	Disazo Condensation	1.42	60	171	3.0	5	5
Red P2B	Pigment Red 48:2	BONA, Ca	1.67	52	82	4.1	4	4
Carmine HF4C	Pigment Red 185	Benzimidazolone	1.46	50	151	6.7	5	5
Carmine HF3C	Pigment Red 176	Benzimidazolone	1.41	60	124	3.2	5	5
Rubine 6BP	Pigment Red 57:1	BONA, Ca	1.68	60	76	4.2	4-5	4-5
Bordeaux HF3R	Pigment Violet 32	Benzimidazolone	1.78	44	155	5.4	5	5
Blue AN	Pigment Blue 15	Cu Phthaloblue, non-stab.	1.60	66	68	3.5	5	5
DrizPearls								
Yellow 3GP	Pigment Yellow 155	in a modified wax carrier	1.27	-	177*	3.3	5	5
Yellow HG	Pigment Yellow 180	in a modified wax carrier	1.28	-	190*	3.0	5	5
Red F3RK 70	Pigment Red 170	in a modified wax carrier	1.29	-	320*	2.2	5	5
Red E5B	Pigment Violet 19	in a modified wax carrier	1.29	-	305*	2.1	5	5
Pink E	Pigment Red 122	in a modified wax carrier	1.29	-	299*	3.7	5	5

in a modified wax carrier

in a modified wax carrier

in a modified wax carrier

1.33

1.41

1.66

241*

275*

180*

5

5

5

5

5

5

2.1

2.5

2.0

✤ = diarylide

Violet RL

Blue BG

Green GNX

* = size of agglomerates in μ m

Pigment Violet 23

Pigment Blue 15:3

Pigment Green 7

Pigment preparations										
Product name	Colour Index	Chemical designation	Density [g/cm ³]	Acid resistance	Alkali resistance					
Hostaprint										
Yellow GG 32*	Pigment Yellow 17	Diarylide Yellow	1.35	5	5					
Yellow H4G 32	Pigment Yellow 151	Benzimidazolone	1.42	5	3					
Yellow 3GP 32	Pigment Yellow 155	Bisacetoacetarylide	1.36	5	5					
Yellow HG 32	Pigment Yellow 180	Benzimidazolone	1.37	5	5					
Yellow HR 32*	Pigment Yellow 83	Diarylide Yellow	1.38	5	5					
Yellow HGR 32	Pigment Yellow 191	Monoazopyrazolone, Ca	1.48	5	5					
Yellow H2R 32	Pigment Yellow 139	Isoindoline	1.35	5	5					
Orange H4GL 32	Pigment Orange 72	Benzimidazolone	1.40	5	5					
Red HFG 32	Pigment Orange 38	Naphtol AS	1.36	5	5					
Red B 32	Pigment Red 149	Perylene	1.34	5	5					
Red BB 32*	Pigment Red 38	Disazopyrazolone/Diarylide	1.37	5	5					
Red D3G 32	Pigment Red 254	Diketopyrrollo-pyrrole	1.46	5	5					
Red BNP 32	Pigment Red 214	Disazo Condensation	1.42	5	5					
Red HF2B 32	Pigment Red 208	Benzimidazolone	1.35	5	5					
Carmine HF4C 32	Pigment Red 185	Benzimidazolone	1.36	5	5					
Red E5B 32	Pigment Violet 19	Quinacridone	1.38	5	5					
Pink E 32	Pigment Red 122	Quinacridone	1.37	5	5					
Bordeaux HF3R 32	Pigment Violet 32	Benzimidazolone	1.37	5	5					
Violet ER 32	Pigment Violet 19	Quinacridone	1.39	5	5					
Violet RL 32	Pigment Violet 23	Dioxazin	1.39	5	5					
Blue A4R 32	Pigment Blue 15:1	Cu Phthalocyanine Blue, α -Mod.	1.43	5	5					
Blue A2R 32	Pigment Blue 15:1	Cu Phthalocyanine Blue, α -Mod.	1.44	5	5					
Blue B2G 32	Pigment Blue 15:3	Cu Phthalocyanine Blue, β -Mod.	1.44	5	5					
Green GG 32	Pigment Green /	Cu Phthalocyanine Green	1.62	5	5					
Brown RL 32	Pigment Brown 41	Disazo Condensation	1.43	5	5					
Brown HFR 32	Pigment Brown 25	Benzimidazolone	1.39	5	5					
Black L 32	Pigment Black /	Carbon Black	1.54	5	5					
Vollow CP 20*	Pigmont Vollow 12	Diarylida Vallow	1 12	5	5					
Vollow HB 20*	Pigment Vellow 83	Diarylide Vellow	1.12	5	5					
	Pigment Orange 13		1.00	5	5					
Bed I C 30	Pigment Bed 53:1	B-Nanhthol Ba	1.13	5	5					
Red B 30*	Pigment Red 38	Disazonyrazolone/Diarylde	1.21	5	5					
Red HE2B 30	Pigment Red 208	Benzimidazolone	1.10	5	5					
Rlue Δ2R 30	Pigment Blue 15:1	Cu Phthalocyanine Blue <i>g</i> -Mod	1.11	5	5					
Green GG 30	Pigment Green 7	Cu Phthalocyanine Green	1 48	5	5					
Hostacryl			1.10	Ū	Ū					
Yellow Oxide BV	Pigment Yellow 184	Bismuth Vanadate	1.87	5	5					
Pink E	Pigment Red 122	Quinacridone	1.26	5	5					
Blue A4R	Pigment Blue 15:1	Cu Phthalocyanine Blue, α -Mod.	1.30	5	5					
Green GNX	Pigment Green 7	Cu Phthalocyanine Green	1.43	5	5					
Brown HFR	Pigment Brown 25	Benzimidazolone	1.26	5	5					
	-									

Colorants						
Product name	Colour Index	Chemical designation	Density [g/cm ³]	Acid resistance	Alkali resistance	Melting point [°C]
Polysynthren						
Yellow GG	Solvent Yellow 133	Methine	1.41	5	5	n.a.
Yellow GS	Solvent Yellow 163	Anthraguinone	1.38	5	5	182
Yellow NG	Pigment Yellow 147	Anthraquinone	1.56	5	5	> 300
Yellow RL	Pigment Yellow 192	Heterocyclic	1.22	-	-	> 320
Golden Yellow GR	Pigment Yellow 196	Perinone	1.53	5	5	295
Red GG	Solvent Red 212	Ni-azomethine	1.26	5	5	> 260
Red GFP	Solvent Red 135	Perinone	1.77	5	5	318
Violet G	Solvent Violet 49	Methine	1.62	5	5	> 300
Blue R	Solvent Blue 122	Anthraquinone	1.43	5	5	239
Blue RLS	Solvent Blue 45	Anthraquinone	1.29	5	5	200
Blue RBL	Solvent Blue 104	Anthraquinone	1.22	5	5	240
Brown 3RL	Pigment Orange 70	Azomethine	1.58	5	5	365
Brown R	Solvent Brown 53	Azomethine	1.66	5	5	> 350
Solvaperm						
Vollow G	Disporso Vollow 64	Quinonhthalono	1 72	Б	5	226
Vellow 2G	Solvent Vollow 93	Mothino	1.72	5	5	190
Vellow 2G	Solvent Vellow 114	Quinonbthalana	1.55	5	5	26/
Orango 3G	Solvent Orango 60	Porinono	1.47	5	5	204
Red 2G	Solvent Bed 179	Perinone	1.42	5	5	250
Red G	Solvent Red 135	Perinone	1.45	5	5	200
Red PFS	Solvent Red 111	Anthraquinone	1.70	5	5	170
Red BB	Solvent Red 195	Monoazo	1.41	5	5	214
Red Violet B	Solvent Violet 59	Anthraquinone	1 39	5	5	186
	Disperse Violet 26	Antinaquinone	1.55	5	5	100
Violet FBL	Solvent Violet 37	Anthraquinone	1.24	5	5	172
Violet RSB	Solvent Violet 13	Anthraquinone	1.40	5	5	190
Blue 2B	Solvent Blue 104	Anthraquinone	1.23	5	5	240
Green GSB	Solvent Green 3	Anthraquinone	1.32	5	5	215
Green G	Solvent Green 28	Anthraquinone	1.24	5	5	245
Hostasol						
Vellow 20	Colvert Valle 00	Nashtalinida	1 17	F	-	00
Tellow 36	Solvent Vellow 98	Thioventh honorethrone	1.1/	5	5	98
neu uu	Solvent Urange 63	inioxantii.penzantiirone	1.51	Э	C	320

5 5

1.60

5 5

312

Red 5B

Vat Red 41

Thioindigo

3.2 Solvent Extraction data

Pigments																		
Product name	Water	Ethanol	lsopropanol	Butanol	Methyl ethyl ketone	Cyclohexanone	White spirit	Toluene	Xylene	Ethyl acetate	Butyl acetate	Dibutylphthalate	Dioctylphthalate	Butyl glycol	Paraffin	Linseed oil	Coconut oil	Di-isodicylphthalate
PV Fast																		
Yellow H9G	5	5	5	5	4-5	5	5	5	5	5	5	5	5	5	5	5	5	5
Yellow H2G	5	4-5	4-5	4	4-5	4	5	5	5	5	5	5	5	4-5	5	5	5	5
Yellow HG 01	5	5	5	5	5	4-5	5	5	5	5	5	5	5	5	5	5	5	5
Yellow HG	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5
Yellow H2GR	3	4-5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	4	5
Yellow HGR	3	4-5	5	5	5	5	5	5	4-5	5	5	5	5	5	5	5	5	5
Yellow HR 02*	5	5	5	5	4-5	4-5	5	4-5	4-5	4-5	4-5	4-5	5	4-5	5	5	5	5
Yellow HR*	5	5	4-5	4-5	4-5	4-5	5	4-5	4-5	4-5	4-5	4-5	4-5	4-5	5	5	5	5
Yellow H3R	4-5	4-5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5
Orange H4GL 01	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5
Orange H2GL	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5
Orange GRL	5	5	5	5	5	4-5	5	4-5	4-5	5	5	5	5	5	5	5	5	5
Orange 6RL	5	5	5	5	5	5	5	5	5	5	5	5	5	4-5	5	5	5	5
Scarlet 4RF	5	5	5	5	4	4	5	4	4	4	4-5	5	5	4-5	5	5	5	5
Red B	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5
Red D3G	5	4-5	5	4-5	4-5	4-5	5	5	5	4-5	4-5	5	5	4-5	5	5	5	5
Red HB	4-5	4-5	4-5	4-5	3-4	4	4-5	4	4	4	4	4-5	4-5	4	4-5	4-5	4-5	4-5
Red 3B	5	5	5	5	4-5	4-5	5	5	5	5	5	5	5	5	5	5	5	5
Red BNP	5	5	5	5	4-5	4-5	5	4	4	4-5	4-5	5	5	4-5	4-5	5	4-5	5
Red HF4B	5	5	5	5	4-5	4-5	5	5	5	4-5	5	5	5	4-5	5	5	5	5
Red E3B	5	4-5	4-5	4-5	4-5	4-5	5	5	4-5	4-5	4-5	5	5	4-5	5	5	4-5	5
Red E5B	5	4-5	4-5	4-5	4-5	4	5	5	5	4-5	4-5	5	5	4	5	4-5	4-5	5
Pink E2G	5	4	4-5	4-5	4-5	4	5	5	5	4-5	5	5	5	3-4	5	5	5	5
Pink E	5	4	4-5	4-5	4-5	4-5	5	5	5	5	5	5	5	4	5	5	5	5
Pink E 01	5	4-5	5	4-5	5	4-5	5	5	5	5	5	5	5	4	5	5	5	5
	4-5	4	4	4	4	4	5	5	5	4-5	4-5	5	5	4	5	5	5	5
Violet BLP	5	5	5	5	4-5	4-5	5	4-5	4-5	4-5	4-5	4-5	5	4-5	5	5	4-5	5
	5	5	5	5	4-5	4-5	5	5 4 E	С 4 Е	5	5	5	5	5	5	5	4-5 E	5
	5	5	5	5	C A E	4-5	5	4-5	4-5	5	5	5	5	5	5	5	5	5
	5	J 4_5	J 1_5	J 1_5	4-5	4-5	5	4-5	4-5	J 1_5	J 1_5	5	5	J 1_5	5	5	5	5
Blue BG	5	4-J	4-J	4-J	4	4	5	4-J	4-J	4-J	4-J	5	5	4-J	5	5	5	5
Green GNX	5	5	J 1-5	J 1-5	4-J	4-J	5	J 1-5	4-J	J 1-5	J 1-5	5	5	4-J	5	5	5	5
Brown HER	5	4	4-5	4 3	4	4	4-5	4-5	4-5	4-5	4-5	4-5	5	4 3	4-5	5	4-5	5
Brown BI	5	5	5	5	4	4	5	4-5	4-5	4-5	4-5	5	5	4-5	5	4-5	4	5
D. OWN TIE	0	0	0	0	Ŧ	Ŧ	0	70	10	70	70	0	0	75	0	70	-	0

Pigments																		
Product name	Water	Ethanol	Isopropanol	Butanol	Methyl ethyl ketone	Cyclohexanone	White spirit	Toluene	Xylene	Ethyl acetate	Butyl acetate	Dibutylphthalate	Dioctylphthalate	Butyl glycol	Paraffin	Linseed oil	Coconut oil	Di-isodicylphthalate
Graphtol																		
Yellow H10G*	5	5	5	5	4-5	4-5	5	4-5	4-5	4-5	4-5	4-5	4-5	4-5	5	5	4-5	5
Yellow GG*	5	5	5	3-4	3-4	5	3	3	3	3-4	3-4	4	5	4-5	4	5	4	5
Yellow 3GP	5	5	5	5	4	4	5	4-5	5	4	4-5	5	5	5	5	5	5	5
Yellow GXS*	5	5	5	5	5	4	5	4	4	5	5	5	5	5	5	5	5	5
Yellow GR*	5	5	5	5	4-5	4	4-5	3	3	4-5	4-5	4-5	5	4-5	4-5	5	4-5	5
Yellow H2R	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	4	5	5
Orange GPS*	5	4	4	3-4	3	3	4	2-3	2-3	3	3	3	4	3	4	3-4	2-3	4-5
Orange RL*	5	5	5	5	4-5	3-4	5	3-4	3-4	4-5	4-5	5	5	4-5	5	5	4-5	5
Red HFG	5	4	4-5	4-5	4	4	5	4-5	5	5	5	5	5	-	5	4-5	5	-
Red LG	4-5	4	4	4	4	3-4	4-5	4-5	4-5	4-5	4-5	4-5	5	3-4	4-5	5	4-5	5
Red LC	5	4	4-5	4-5	4	4	4-5	4-5	4-5	4-5	4	4-5	4-5	4	5	4-5	5	4-5
Red BB*	5	4-5	4-5	4-5	4-5	4-5	5	4	4	4-5	4-5	4-5	5	4-5	5	5	5	5
Red F3RK 70	5	5	5	5	4-5	4-5	5	5	5	5	5	5	5	5	5	5	5	5
Fire Red 3RLP	3-4	4	4-5	4-5	4-5	4-5	4-5	4-5	4-5	4-5	4-5	4-5	5	4	5	5	5	5
Red HF2B	5	5	5	5	4-5	4-5	5	5	5	5	5	5	5	5	5	5	5	5
Red F5RK	5	4	4-5	4-5	4	3-4	5	4-5	4-5	4-5	4-5	4-5	5	4-5	5	4-5	4-5	5
Red 2BN	5	5	5	5	4	3-4	5	4	4	4-5	4-5	5	5	4-5	4	5	4	5
Red P2B	5	4-5	4-5	5	5	4-5	5	5	5	4-5	4-5	5	5	4-5	5	5	5	5
Carmine HF4C	5	4-5	4-5	4-5	4-5	4-5	5	5	5	5	5	5	5	4-5	5	5	5	5
Carmine HF3C	5	4-5	4-5	4-5	4-5	4-5	5	5	5	4-5	4-5	5	5	4-5	5	5	5	5
Rubine 6BP	4	4-5	4-5	4-5	4-5	4-5	5	5	5	5	5	5	5	4	5	5	5	5
Bordeaux HF3R	5	4-5	4-5	4-5	4-5	4-5	5	4-5	4-5	4-5	5	5	5	4-5	5	5	5	5
Blue AN	5	5	5	5	4-5	4-5	5	5	5	5	5	5	5	4-5	5	5	5	5

3.3 Solvent Solubility data

Dyes								
Product name	Ethanol	Benzyl alcohol	Acetone	Ethyl acetate	Butyl acetate	Methylene chloride	Toluene	Xylene
Solvaperm								
Yellow G	< 1	2	1	< 1	1	4	2	2
Yellow 3G	< 1	4	8	9	10	190	25	25
Yellow 2G	< 1	2	< 1	6	< 1	6	3	1
Orange 3G	< 1	4	1	1	1	10	5	5
Red 2G	< 1	3	< 1	1	< 1	1	3	2
Red BB	< 1	1	< 1	1	< 1	11	2	1
Red G	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1
Red PFS	< 1	10	4	5	4	50	7	8
Red Violet R	7	6	20	15	20	40	12	12
Violet FBL	< 1	10	9	13	13	14	10	10
Violet RSB	< 1	4	1	4	3	12	7	8
Blue 2B	< 1	4	3	4	10	240	85	25
Green G	< 1	4	2	4	4	55	11	30
Green GSB	< 1	3	< 1	1	3	20	10	8

Polysynthren								
Yellow GG	< 1	3	2	2	3	5	1	1
Yellow GS VP 2667	< 1	15	14	15	15	250	95	60
Yellow NG VP 2611	< 1	< 1	< 1	< 1	1	2	< 1	< 1
Yellow RL	< 1	< 1	2	-	-	< 1	1	-
Golden Yellow GR	< 1	3	1	1	< 1	2	1	1
Red GG VP 2760	< 1	< 1	< 1	1	1	< 1	1	< 1
Red GFP	-	< 1	< 1	< 1	< 1	< 1	< 1	< 1
Violet G	< 1	< 1	1	1	1	1	1	< 1
Blue R	< 1	2	2	2	3	6	4	1
Blue RLS	5	100	10	10	5	75	< 1	10
Blue RBL	< 1	4	3	4	10	240	85	25
Brown 3RL	< 1	4	< 1	< 1	< 1	3	< 1	2
Brown R	< 1	2	1	< 1	1	1	1	1

Hostasol								
Yellow 3G	< 1	4	1	3	3	140	65	15
Red GG	< 1	1	< 1	< 1	1	2	1	1
Red 5B	< 1	< 1	< 1	< 1	1	2	< 1	1

4 **Test conditions**

Concentration for SD ¹/₃ Hue angle Heat resistance Light fastness in HDPE, PP, PS, ABS, PC Light fastness in PVC Warpage Migration - bleed fastness Migration resistance (unvulcanised rubber) Determination of limit concentration in PVC Physical and chemical properties Test compounds

4 Test conditions

The values quoted for the fastness properties and the concentrations to standard depth of shade only apply for our test conditions.

Any change in operating parameters, e.g. type and settings of the equipment, specific polymer substrate, concentrations, processing temperature and time can result in different values.

Concentration for SD $^{1}/_{3}$

The value quoted is the weight in grams (g) colorant per kg polymer required to obtain SD $1/_3$ according to DIN 53235. For HDPE, PP, PS, ABS, PC and PA the value relates to the pigment concentration with 1 % TiO₂, and for PVC with 5 % TiO₂.

Hue angle

The hue angle has been determined by colorimetry according to DIN 5033, part 3, from the measured X_{10} , Y_{10} and Z_{10} tristimulus values determined at standard illumination D65. The values listed in the tables refer to the opaque coloration in SD $1/_3$.

Heat resistance

Resistance to heat was tested according to DIN EN 12877 in HDPE, PP, PS, ABS, PC and PA at SD 1 /₃ with 1 % titanium dioxide in the injection molding process. The values quoted are the temperatures in °C at which, after a dwell time of 5 min, a color change equivalent to a $\Delta E^{*}_{ab} = 3$ (DIN 6174) is obtained.

Light fastness in HDPE, PP, PS, ABS, PC, PMMA

The light fastness in white reduction was determined on injection molded plaques at SD $1/_3$ with 1 % titanium dioxide in a Xenotest 1200 W according to ISO 4892. For the light fastness in full shade, the same pigment concentration was tested without titanium dioxide. Assessments were against the 8-step blue wool scale, where 8 refers to very good light fastness and 1 very poor light fastness.

Light fastness in PVC

The light fastness in white reduction was determined at 0.1 % pigment with 0.5 % titanium dioxide in a Xenotest 1200 W according to ISO 4892. The same concentration without titanium dioxide was tested for the light fastness of transparent formulations. Assessments were against the 8-step-blue-wool scale.

Warpage

The influence of a pigment to induce warpage was tested for by measuring the dimensional changes in the horizontal and vertical planes of a rectangular injection molded plate in HDPE comparing colored (0.1 % pigment) and uncolored plates.

The warpage classes are as follows:

Class 1 (suitable for low warpage applications):	< 10	%
Class 2 (limited suitability):	11-20	%
Class 3 (not suitability for low warpage application	ns): > 20	%

Migration

Bleed fastness

Fastness to bleeding was tested in plasticised PVC by direct contact of a pigmented film (0.1 %) for 2 h at 140 °C with a white-pigmented film. Staining of the white pigmented film was evaluated against the "5 step grey scale for assessing staining" according to DIN EN 20105-A03 whereby "5" denotes no bleeding.

Migration resistance (unvulcanised rubber)

The coloration is evaluated using a white unvulcanised rubber web or small sheet (winding), which has been in contact with the colored unvulcanised rubber web during vulcanisation in the open steam process. Staining of the white rubber sheet was evaluated against the "5 step grey scale for assessing staining" according to DIN 20105-A03 whereby "5" denotes no bleeding.

Determination of limit concentration in PVC

The limit concentration in PVC is the lowest concentration at which a colorant is resistant to a temperature 200 °C. This is tested for in plasticised and unplasticised PVC in a range of pigment concentrations from 0.005 % to 0.5 % plus 0.5 % titanium dioxide. The results are compared visually against colorations which have been prepared under standard conditions (P-PVC at 130 °C; U-PVC at 160 °C).

Physical and chemical properties Density

The density was determined in accordance with DIN/EN/ISO 787 part 23.

Specific surface

The specific surface of pigment powders was determined by the BET method.

Particle size distribution by volume

Particle size distribution is determined by image analysis of transmission electron microscope images. By inspection of the images, primary particles are identified and their size is measured using a graphic tablet. From the sizes of approximately 1000 particles, size distribution by volume is calculated, and the median diameter D_{50} is used as a measure of mean particle size.

Bulk volume

The bulk volume is the quotient derived from the volume of a powder (including free space and voids) and its mass after the powder has been poured into a measuring vessel in the manner described in the regulations.

Resistance to acids and alkalis of pigments and dyestuffs

To determine the resistance

- of pigments to acids and alkalis, strips of plasticised PVC
- of dyestuffs to acids and alkalis, strips of rigid PVC

colored with 0.1 % colorant and 0.5 % titanium dioxide were placed for 3 days in 5 % hydrochloric acid and 5 % caustic soda solutions respectively. Then compared with the untreated films. Assessments were made by references to the 5-step grey scale in accordance to DIN 54001. Step 5 means no change in shade.

Test compounds

High density polyethylene (HDPE)	Sabic ^{®+} HDPE M 80064
Polypropylene (PP)	Moplon ^{®+} HP 501 H
Plasticised PVC	own test compound
Rigid PVC	own test compound
Polystyrene (PS)	Crystal ^{®+} Grade 172 L
Acrylonitrile-Butadiene-	
Styrene-Copolymer (ABS)	Magnum ^{®+} 3453 AS
Polymethylmethacrylate (PMMA)	Plexiglas ^{®+} 6N
Polycarbonate (PC)	Lexan ^{®+} 124 R
Polyethylene terephthalate (PET)	Polyclear ^{®+} T86
Polybutylene terephthalate (PBT)	Celanex ^{®+} 2500
PA6	Akulon ^{®+} M223D
PA66	Zytel ^{®+} E 101
Rubber	own test compound
Polyoxymethylene (POM)	Hostaform ^{®+} C 9021

Solvent fastness of pigments

An assessment is made of the coloration of a solvent by a pigment in comparison with a scale of standardized comparative solutions.

For every solvent, about 1 ml pigment powder is transferred into a folded filter, the filter will be closed and immersed into the test tubes with approx. 20 ml of each solvent mixture. The sealed test tubes will be stored for 24 hrs. before evaluation. For the evaluation the filter with the pigment is removed and the coloration of the solvents is compared with a scale of standard solutions. The lowest rating is 1, the best rating is 5 with no coloration visible.

Solvent solubility of dyes

The solubility figures given represent the amount of dyestuff in grams which dissolves at room temperature in one liter solvent or solvent mixture without any significant residue.

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