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creating essentials

TROGAMID® CX

The Outstanding Material for Optics

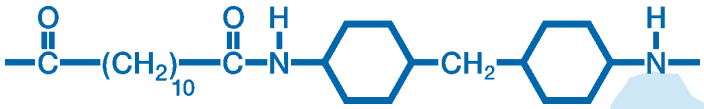
WE MAKE IT CLEAR

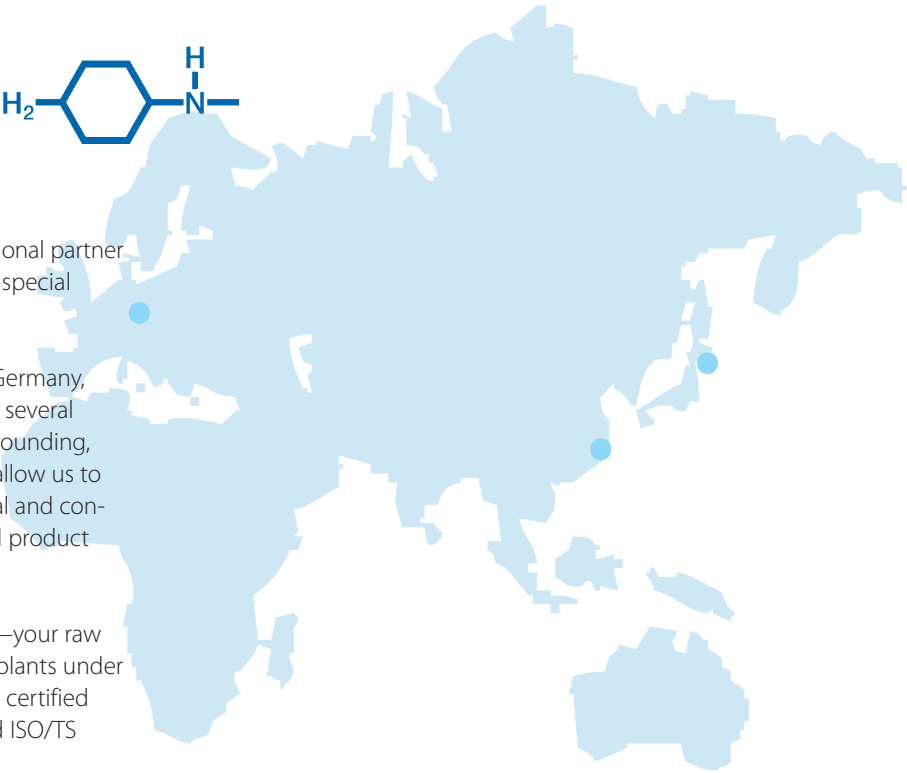
Content

1 Introduction

Degussa High Performance Polymers: Your professional partner in development
Degussa AG's High Performance Polymers Business Unit produces customized products, systems, and semi-finished goods based on high-performance polymers. Our plastics have proven their worth in the automotive, communications and electrical engineering industries, in the sports world, and in medical technology for approximately 40 years. We have established a presence in the field of optics with our unique transparent polyamide, which we market under the name TROGAMID® CX**.**

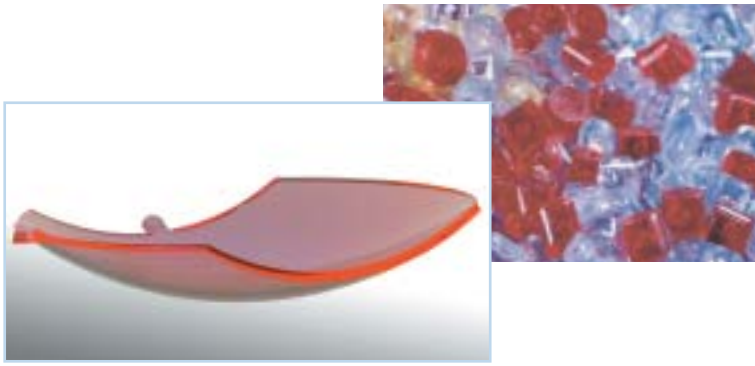
Figure 1: Molecular composition of TROGAMID CX7323





We stand by your side as a professional partner in development and a supplier of special materials:

- In our development centers in Germany, Japan, and soon China, we have several high-tech polymerization, compounding, and processing plants that will allow us to accompany you in a professional and constructive manner from the initial product concept up to series maturity.
- We manufacture our products—your raw materials—in highly advanced plants under strict quality guidelines that are certified according to ISO 9001:2000 and ISO/TS 16949.
- Our worldwide network of employees makes it possible for you to reach a contact close to your development or manufacturing site.
- Our technical service specialists are readily available to you worldwide to answer any indepth technical questions you may have, or if you need support in processing our materials.



Introduction

Glasses are a fashion statement

The development of optical glasses began as early as over a thousand years ago. Even earlier, humans realized that dazzling sunlight was hard on the eyes, especially in areas with strong reflection, such as large expanses of water, ice, or snow. It is said that the Emperor Nero followed the fights in the arena while looking through an emerald, a sign that the use of colored materials for protection from sunlight was already known in the first century.

Today, fashion and comfort are the driving forces in the development of high-end materials for eyeglass frames and eyeglasses. Top priority is allocated to the following requirements:

- light weight
- unbreakability
- scratch resistance
- chemical and stress-cracking resistance
- non-allergenic
- easy to process, and
- good machinability, for example, drilling, grinding, milling

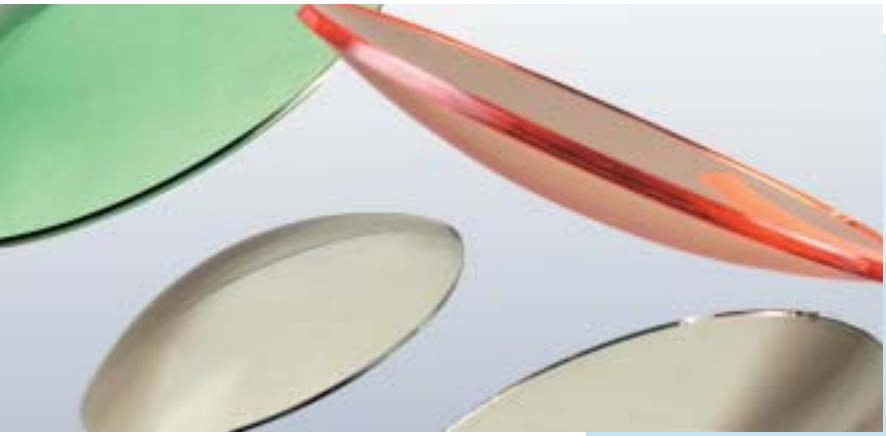
There is no other transparent material that combines the properties of an amorphous polymer with those of a semi-crystalline polymer like the transparent polyamide TROGAMID CX, which was developed by High Performance Polymers. This combination of properties means that it can be used to produce both filigree frames and plastic lenses.

TROGAMID CX: a microcrystalline polyamide

Amorphous polyamides feature prominently among transparent polymeric materials. They combine the transparency and processing behavior of amorphous materials with the advantages characteristic of polyamides, like toughness, rigidity, abrasion resistance, and chemical and stress-cracking resistance.

When special aliphatic and cycloaliphatic monomers are used, transparent polyamides can be made that have inherently better UV resistance, like TROGAMID CX9704. In addition, carefully selected monomers yield a crystallizable polyamide, such as TROGAMID CX7323, a PA PACM 12. The crystallites are so small that they don't scatter visible light. This makes the material appear transparent to the human eye—a property known as microcrystallinity.

Not only does the crystallinity demonstrate excellent stress-cracking resistance in comparison to all other known transparent polyamides; it is also adjusted in such a manner that it has no adverse effect on shrinkage behavior. It is therefore by nature an unparalleled transparent material that combines the properties of semi-crystalline molding compounds with those of amorphous materials.



2 Mechanical and Physical Properties

Table 1: Mechanical and physical properties of TROGAMID CX relevant to eyeglass manufacture

Property		Test method	Unit	TROGAMID	
				CX7323	CX9704
Density	23 °C	ISO 1183	g/cm³	1.02	1.02
Tensile test	23 °C	ISO 527-1/-2			
Stress at yield			MPa	60	60
Strain at yield			%	8	8
Strain at break			%	>50	>50
Tensile modulus	23 °C	ISO 527-1/-2	MPa	1400	1400
CHARPY impact strength		ISO 179/1eU			
	23 °C		kJ/m²	N	N
	0 °C		kJ/m²	N	N
	-30 °C		kJ/m²	N	N
CHARPY notched impact strength		ISO 179/1eA			
	23 °C		kJ/m²	16 C	11 C
	0 °C		kJ/m²	15 C	11 C
	-30 °C		kJ/m²	14 C	10 C
Shore hardness D		ISO 868		81	81
Water absorption	Saturation	ISO 62	%	3.5	3.5
Mold shrinkage		ISO 294-4			
in flow direction			%	0.7	0.4
in transverse direction			%	0.8	0.5

Other TROGAMID CX grades are described in our brochure "TROGAMID® Transparent Polyamides with a Unique Combination of Properties" in the TROGAMID® CX series.

Abrasion and scratch resistance

The demand on abrasion and scratch resistance for materials in optics is very high. With a value of 18 mg per 100 revs, TROGAMID CX thus outperforms even standard grades of polycarbonate (PC) or polymethyl methacrylate (PMMA). The values given in the following table have been determined using the Taber Abrasion method (according to DIN 53754).

Property	Test method	Unit	TROGAMID CX7323	amorphous PA	PC	PMMA
Abrasion resistance	DIN 53754	mg/100 rev.	18	23	27	66
Scratch resistance	DIN 52347	% turbidity increase	32	28	40	30

3 Optical Characteristics

The properties of TROGAMID CX compounds first of all predestine these materials for the manufacture of eyeglass frames: their good flowability during injection molding, their ratio of rigidity to toughness and their high dynamic load capacity also makes them suitable for filigree frames, the manufacture of which had been possible until recently only with titanium alloys. Second, because of its inherent chemical and stress-cracking resistance, which other transparent polyamides fail to attain, TROGAMID CX7323 also perfectly fits the bill for first-class eyeglasses .

Plastic Lenses

Opticians can choose among a variety of plastic lenses with different optical characteristics. TROGAMID CX7323 features excellent, permanent, crystal-clear transparency and outstanding optical properties, in spite of its microcrystalline character.

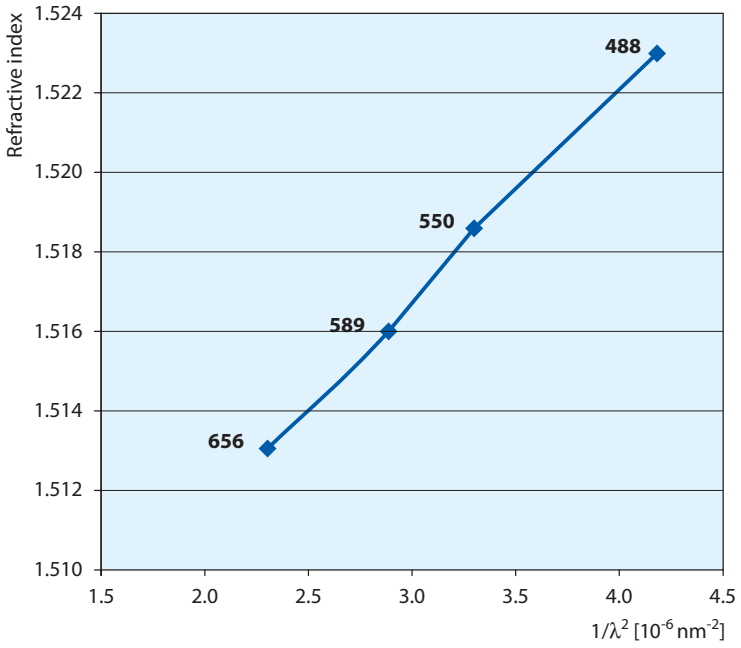
- Its light **transmission** in the range of visible light is over 85%, even at a wall thickness of 4 mm. At a wall thickness of 2 mm, TROGAMID CX7323 has a total transmission (standard illuminant D65/ 2°) of approximately 92%, which is very close to the transparency of PMMA. Standard illuminant D65 corresponds to daylight.

Transmission 92%

- Its **refractive index** n_D at 589 nm is 1.516, which is better than that of PMMA. The refractive index indicates how strongly a light beam is deflected when it enters a material. This value is important in the design of optical systems in the field of imaging optics.

$n_D^{20} = 1.516$

Figure 2: Refractive index of TROGAMID CX7323 (T = 20 °C)



- The value of the refractive index is influenced by a number of variables, particularly the wavelength of the incident light. A parameter known as the **Abbe number** expresses this dependency. A high Abbe number means that the refractive index changes slightly as a function of wavelength. When a polychromatic light beam, such as that provided by daylight, passes through a material possessing a high Abbe number, it remains better focused. TROGAMID CX7323 features an outstanding Abbe number of 52.

- As regards **birefringence**, TROGAMID CX7323 exhibits a behavior similar to that of polycarbonate. Birefringence, also known as "double refraction", is an optical property of anisotropic transparent materials. From the perspective of physics, this property can be described by a model in which the material splits the incident light beam into two beams. These two beams have different velocities and experience slightly different refractive indexes. This results in interference patterns, which may be considered when the optical suitability of a material is determined. In practice, the phenomenon of birefringence occurs in all optical materials without exception. The underlying anisotropy depends not only on the internal structure of the material, but to a large extent also on the processing of the material into a particular molded part. Stresses that are "frozen" in the molded part when the melt cools down are believed to be a factor. Relative reference values are often used in practice to characterize the birefringence of transparent plastics.

Abbe number 52

- The dependence of the refractive index on temperature is given by the differential **dn/dt**. TROGAMID CX7323 is well positioned here compared to other optical plastics.

- If we consider the increasing temperature requirements in many applications, the improved **temperature resistance** of TROGAMID CX7323 represents yet another advantage over PMMA. This applies both in the loaded state and in heating without additional load.

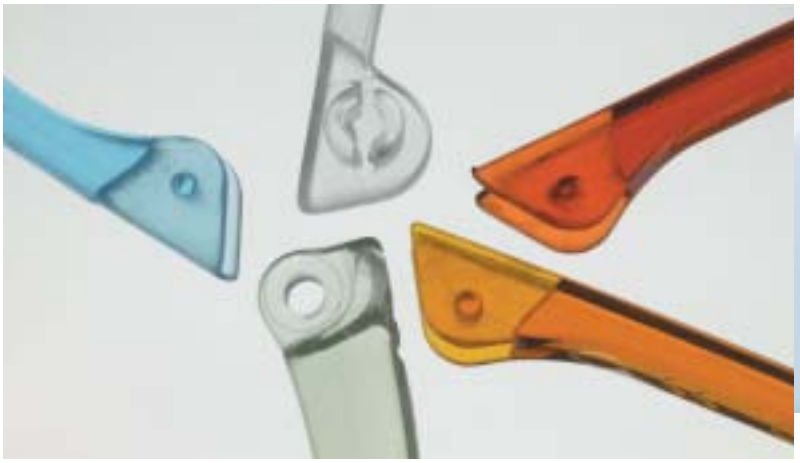


Table 2: Material properties for optical applications

	Test method	Unit	PMMA	PC	TROGAMID CX7323
Optical properties					
Transmission at 2 mm (total transmission, illuminant D65/ 2°)	ISO 13468-2	%	92.1	89.8	91.7
Refractive index 20 °C	DIN 53491				
n_f 488 nm					1.523
n_d 589 nm			1.493	1.586	1.516
n_c 656 nm					1.513
Abbe number	DIN 53491		58	34	52
dn_d/dt	DIN 53491	10^{-4} K^{-1}	-1	-1.4	-1.6
Thermal properties					
Glass transition temperature 10 K/min		°C	110	145	140
Melt temperature 10 K/min		°C			250
Linear thermal expansion	ISO 11359	10^{-4} K^{-1}			
longitudinal			0.8	0.7	0.9
transverse			0.8	0.7	0.9
Temperature of deflection under load Method A 1.8 MPa	ISO 75-1/2	°C	95	125	105
Others					
Density 23 °C	ISO 1183	g/cm³	1.19	1.2	1.02

4 Chemical Properties

Stress-cracking and chemical resistance
Looking beyond its optical characteristics, excellent stress-cracking and chemical resistance also make TROGAMID CX7323 exceptionally suitable for eyeglasses. The threaded joints or adhesives needed for rimless glasses, for example, will not cause any stress cracking. Stress-cracking corrosion resulting from components migrating out of other plastic frames or from corrosive media in eyeglass cleaning solutions (see photograph) is similarly no problem. A detailed compilation of TROGAMID's chemical resistance can be found in our brochure "TROGAMID® Transparent Polyamides with a Unique Combination of Properties" in the TROGAMID® CX series.

amorphous PA

TROGAMID CX7323

UV radiation/weathering
If any plastic is exposed to short-wave light of wavelengths less than 300 nm, molecular mass diminishes at an increasing rate, leaving moldings or semi-finished products brittle. Pure aliphatic monomers make TROGAMID CX7323 highly stable against UV light and weathering. This also applies to its mechanical properties and coloring (yellowing) during weathering. The addition of UV and weathering stabilizers is usually not necessary. The color change of TROGAMID CX7323 is comparable to values for PMMA. Natural-colored TROGAMID CX7323 showed no change in CHARPY impact strength after 2000 hours of artificial weathering (Xenon test Alpha S120). The use of pigments and colorants may have an effect on UV and weathering stability. At any rate, suitability should be tested in each case.
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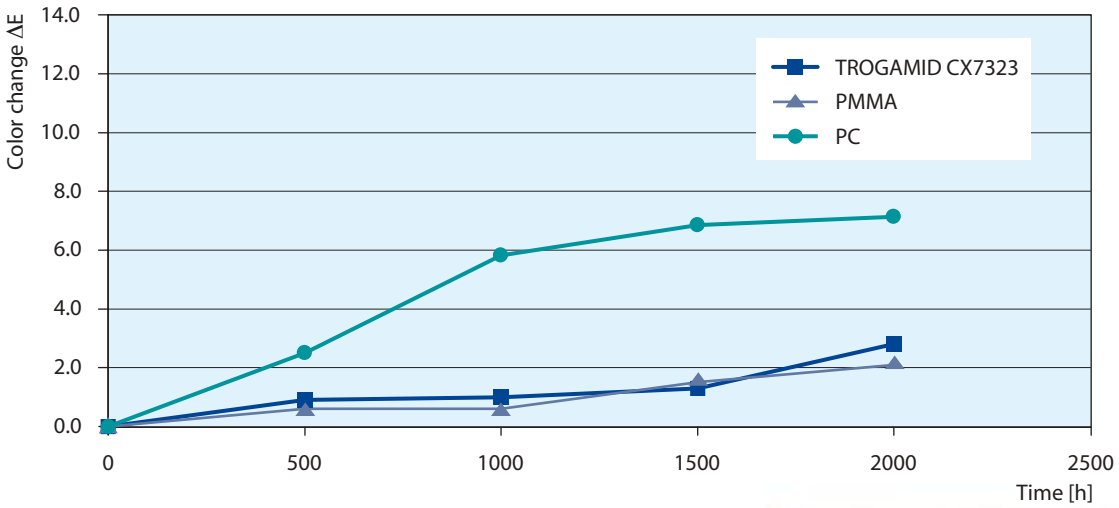
Figure 3: TROGAMID CX7323 color change ΔE (artificial weathering, Xenon test Alpha 150 S)



5 Tinting, Coating and Laser-Processing

TROGAMID CX7323 has a combination of excellent optical properties and outstanding mechanical characteristics that make it the material of choice for use in optical applications. Its chemical stability stands out in particular. In addition to these properties, it is excellently coatable.

Tinting
Lenses made of TROGAMID CX can be tinted in dipping baths without a problem. The adhesion of the color system is so good that not even further mechanical processing will cause discoloring. This makes it possible to machine tinted lenses without trouble. The system also remains resistant to stress-cracks. Systems by TCN (Techniques Chimiques Nouvelles, 8 bis, Allée Marie-Louise, 92240 Malakoff, France; e-mail: tcn@wanadoo.fr) come into consideration as color systems.

Coating
In addition to tinting, optical applications also often require surfaces to be modified. Not only does surface modification improve scratch resistance through hard coatings, it is also important in creating additional properties such as antireflection and filter functionalities.

The Fraunhofer Institute for Applied Optics and Precision Engineering (IOF) in Jena, Germany, tested TROGAMID CX7323 in a low-pressure plasma process and verified its excellent adhesion properties and the high stability of its coatings. TROGAMID CX7323 met the adherence requirements according to ISO 9211-02003, "Tape Test, Snap." The system is stable against environmental exposure in the temperature range of –10 °C to 70 °C (ISO 9022-2). This makes TROGAMID CX7323 particularly suitable for the plasma-ion assisted deposition of multifunctional optical interference coatings, for example

- scratch-resistant antireflection coating AR-hard® (1 to 3 µm thickness)
- AR-hard combined with UV cut-off filter
- antireflection for laser wavelengths
- beam splitter coatings

Laser-processing
There are specially modified TROGAMID CX grades that can be marked by laser, or also welded by laser, transparent-to-transparent, without affecting their optical properties.

6 Ecology and Registrations

Registrations
TROGAMID CX7323 is not allergenic. This has been confirmed by the United States Pharmacopoeia, which gave him highest rating USP Class VI. It also meets the requirements of ISO 10993. The material is also resistant to all media it is likely to come into contact with, such as skin lipids, skin care creams, cosmetics and parfumes.

The lenses can also be fixed by bonding or non-metallic screws made of TROGAMID. This is important for wearers of glasses suffering from allergies. According to the opticians' trade association, about 40% of wearers of glasses show allergies, particularly to metals, but also to certain polymer additives, whose migration from other plastic eyeglasses cannot be ruled out.

Ecology
TROGAMID resins are non-hazardous substances that are not governed by any particular safety regulations. TROGAMID CX resins are classified under Water Hazard Class 0. They can be disposed of in landfills or incinerated as normal household waste in accordance with local ordinances. Further information can be obtained from the TROGAMID CX material safety data sheets that we send upon request.

Use of regranulate
The recycling of TROGAMID is generally preferable to disposal, at least for economic reasons. The molding compound is processed on standard injection molding machines. For frames or dark lenses, up to 40% regranulate from sprue or scrap can be added without any loss in mechanical or optical properties, depending on quality and the processing method. Regranulates of different colors can be used with a color batch developed especially for eyeglass frames in subdued dark colors, thus saving costs.

Coloring
For coloring no pigments or additives containing cadmium are used.

Processing
No dangerous by-products are formed if TROGAMID CX is processed correctly. Care should be taken, however, to ventilate the working area properly. If the melt is discolored or black specks appear, this is a sign that the material has degraded during processing. Degraded material should be removed quickly from the machine and cooled under water to minimize any offensive odors or fumes. At higher temperatures, most TROGAMID CX resins will burn. At melt temperatures between 360 °C and 370 °C, flammable gases are released. Combustion with a sufficient supply of air produces carbon monoxide, carbon dioxide, water, and nitrogen containing compounds as end products. Since the crack and combustion spectrum depends to a great extend on the combustion conditions, it is not possible to make any general statement here.

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