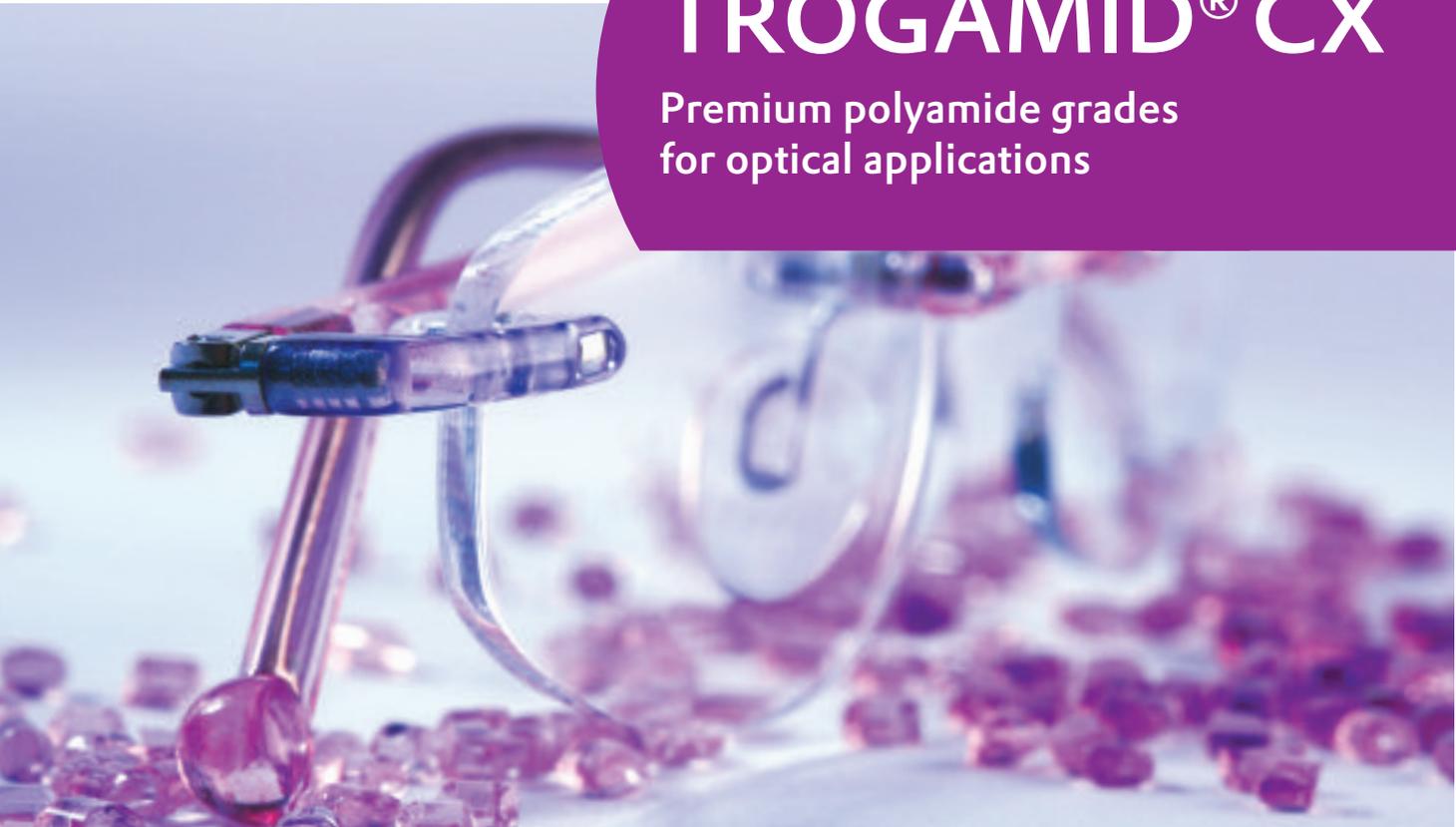


TROGAMID[®] CX

Premium polyamide grades
for optical applications





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Evonik Industries is the German-based creative industrial group which operates in the three business areas Chemicals, Energy and Real Estate. Evonik is a global leader in specialty chemicals.

Together with the Acrylic Polymers and Acrylic Monomers Business Lines the High Performance Polymers Business Line is a part of the Performance Polymers Business Unit.

1 Introduction

Evonik's High Performance Polymers Business Line 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.

We escort you along the lifecycle of your product, from the initial product idea up to series maturity. Accept our invitation to benefit from our expertise in various technical fields like surface technology, process technology, polymer design and compounding. Identify and commercialize the most attractive and innovative new products in partnership with Evonik High Performance Polymers.

To speed your time-to-market for your product, we offer a full line of services:

- cooperative product development
- chemical and physical analytical testing
- global on-site support for planning your production processes
- product trials in our technical centers in Germany and China

After product launch, take advantage of our production and warehouse locations as well as our expertise in global supply chain management and on-site production maintenance support.

These services in conjunction with our top quality products will further improve your selling position and the profitability of your business.

We manufacture our products—your raw materials—in highly advanced plants under strict quality guidelines that are certified according to ISO 9001:2008.



2 TROGAMID® CX: A family of advanced transparent polyamides for optical applications

Transparent polyamides are broadly established in the technically demanding fields of automotive, electronics and constructions. The TROGAMID® CX family combines the transparency and processing behavior of amorphous materials with the advantages 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® myCX, 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.

TROGAMID® CX9704 is the perfect choice for the manufacturing of spectacle frames. It makes possible:

- freedom of design in shape and color
- ultra thin frame constructions
- light weight eyeglass frames
- durability, robustness and flexibility

In contrast to other transparent amorphous materials, the microcrystalline TROGAMID® myCX demonstrates excellent stress-cracking resistance. It is an unparalleled transparent material that combines the properties of a semi-crystalline molding compound with those of amorphous materials.

For lenses that satisfy the most demanding customer, TROGAMID® myCX is preferred because it:

- provides the highest comfort due to its very low weight
- offers excellent optical properties
- delivers the highest safety level possible in sunglass lenses
- can be combined with all potential frame materials
- assures highest durability in top quality sunglasses
- prevents crack formation by stress or chemical attack

TROGAMID® myCX allows the most efficient production of lenses due to its unique characteristics.

Special product modifications, e.g., stabilizers, absorbers, colors, or fillers can be made on request.

Glasses

Glasses are a fashion statement. Additionally, durability, comfort and safety are the driving forces in the development of high-end materials for eyeglass frames and lenses. TROGAMID® CX is the leading material choice for:

- comfort due to ultra low weight
- durability because of excellent mechanical performance
- safety through resistance to stress cracking

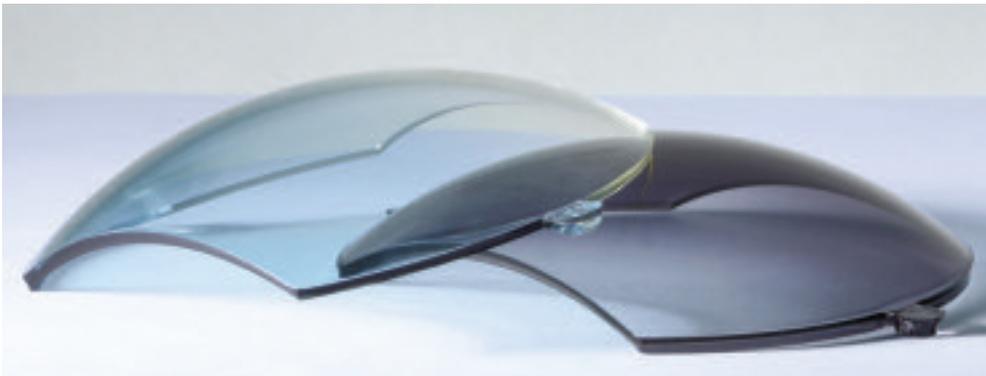
There is no other transparent material that provides this combination of properties and excellence.



3 Optical characteristics

Material properties for optical applications

Properties	Test method	Unit	PMMA	PC	TROGAMID® myCX
Optical properties					
Transmission at 2 mm (total transmission, illuminant D65/2°)	ISO 13468-2	%	92.1	89.8	91.7
Refractive index					
20 °C n_f 488 nm	DIN 53491				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					
longitudinal	ISO 11359	$10^{-4} K^{-1}$	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/cm^3	1.19	1.2	1.02



Plastic frames

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® myCX 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® myCX features excellent, permanent, crystal-clear transparency and outstanding optical properties, in spite of its micro-crystalline character.

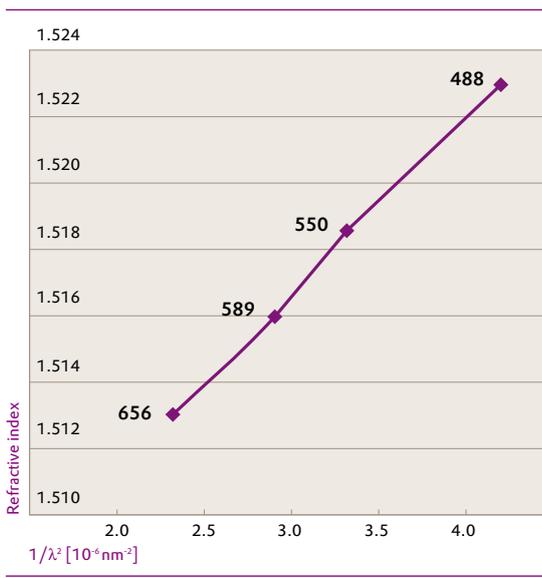
- Its **light transmission** in the range of visible light is over 85%, even at a wall thickness of 4 mm. At a wall thickness of 2 mm, TROGAMID® myCX has a total transmission (standard illuminant D65/2°) of approximately 92%, which clearly exceeds the transparency of PC (90%).

- 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.

Transmission 92%

$$n_D^{20} = 1.516$$

Refractive index of TROGAMID® myCX (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® myCX features an outstanding Abbe number of 52.

Abbe number 52

- As regards **birefringence**, TROGAMID® myCX 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.

- The dependence of the refractive index on temperature is given by the differential dn/dt . TROGAMID® myCX 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® myCX represents yet another advantage over PMMA. This applies both in the loaded state and in heating without additional load.



4 Mechanical and physical properties

Mechanical and physical properties of TROGAMID® CX relevant to eyeglass manufacture

Property	Test method	Unit	TROGAMID® myCX	TROGAMID® CX9704	
Density	23 °C	ISO 1183	g/cm ³	1.02	1.02
Tensile test	23 °C	ISO 527-1/-2	MPa	60	60
Stress at yield					
Strain at yield					
Strain at break					
Tensile modulus	23 °C	ISO 527-1/-2	MPa	1400	1400
CHARPY impact strength		ISO 179/1eU	kJ/m ²	N	N
	23 °C				
	0 °C				
	-30 °C				
CHARPY notched impact strength		ISO 179/1eA	kJ/m ²	14 C	11 C
	23 °C				
	0 °C				
	-30 °C				
Shore hardness D		ISO 868		81	81
Water absorption	Saturation	ISO 62	%	3.5	3.5
Mold shrinkage		ISO 294-4	%	0.7	0.4
	in flow direction				
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).

Abrasion and scratch resistance

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

5 Chemical properties

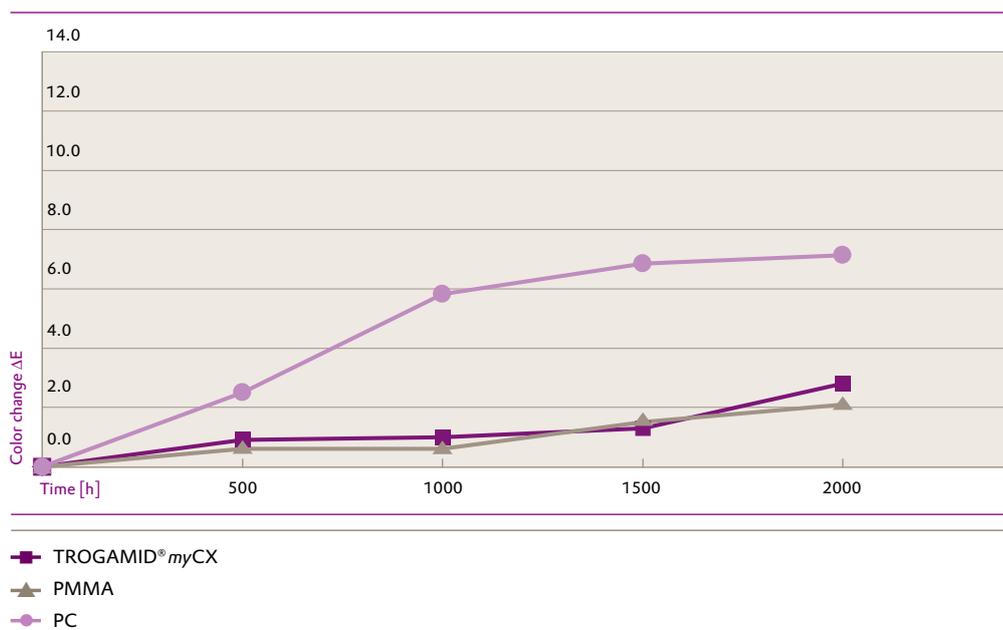
Stress-cracking and chemical resistance

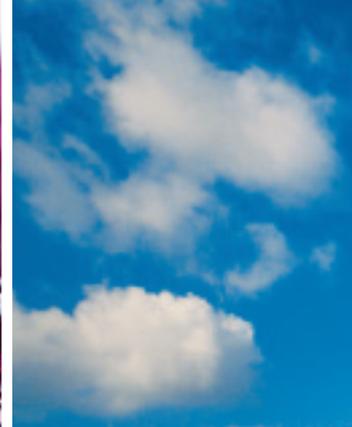
Looking beyond its optical characteristics, excellent stress-cracking and chemical resistance also make TROGAMID® myCX exceptionally suitable for eye-glasses. The threaded joints or adhesives needed for rimless glasses, for example, will not cause any stress cracking. Stress-cracking corrosion resulting from components migrating out of other plastic frames or from corrosive media in eyeglass cleaning solutions 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.

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® myCX 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® myCX is comparable to values for PMMA and significantly lower than those for PC. Natural-colored TROGAMID® myCX 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.

TROGAMID® myCX color change ΔE (artificial weathering, Xenon test Alpha 150 S)





6 Processing and post treatment

TROGAMID® *my*CX 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® *my*CX in a low-pressure plasma process and verified its excellent adhesion properties and the high stability of its coatings. TROGAMID® *my*CX 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® *my*CX particularly suitable for the plasma-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.





7 Ecology and registrations

Registrations

TROGAMID® myCX 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 perfumes.

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 byproducts 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 extent on the combustion conditions, it is not possible to make any general statement here.

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