Makrolon®

The chemical resistance

The property values listed in the Makrolon® Technical Information have been established on standardized test specimens produced in accordance with the standardized procedures. The tests are generally performed in a surrounding medium of clean air.

If a finished part in Makrolon® is in contact with other media, its properties may undergo considerable change.

1. Influencing parameters

The extent to which the properties of the material are influenced is a function of the:

- composition of the surrounding media
- temperature
- duration of exposure
- level of inherent or applied stress and strain prevailing in the molded part

2. Types of damage

A distinction can be drawn between different types of damage. It is also possible for individual surrounding media to act simultaneously following more than one type of damage.

Dissolution or swelling

Low-molecular, aromatic, halogenated and polar components migrate into the polycarbonate. The damage can range from a tacky surface to complete dissolution.

Stress cracking

A number of chemicals penetrate the surface slightly, in small quantities, and cause a concentration gradient to develop in the polycarbonate, thereby loosening the bonding forces between the molecules. Stresses prevailing in the molded part then relax by causing stress cracks to form. Stress cracks can affect the appearance of a molded part. The pronounced notched effect of the stress cracks leads to a pronounced deterioration in a number of mechanical properties – and particularly in those that can be derived from the impact, flexural and tensile tests. With transparent grades, the stress cracks are generally easy to see. In opaque grades it is frequently impossible to detect them. Mechanical tests are then required, with the impact strength or flexural strength generally being taken as indicator properties in laboratory tests.

Molecular degradation

A number of the properties of Makrolon® are determined by the size of its molecules. If a contact medium causes a reduction in molecular weight through a chemical reaction then this will affect especially the tough and resilient properties of the material. The molecular weight level has virtually no influence on electrical properties and only a slight influence on thermal properties.

As an ester of bisphenol A and carbonic acid, polycarbonate will gradually be split into these components again by water at a high temperature, for instance. Alkalis act as pronounced catalysts during hydrolysis. Acid catalysis is only weak.

Alcohols and carboxylic acids can similarly lead to molecular degradation through ester interchange. Amines can cause pronounced molecular damage in some cases through transamination. Ammonia and low-molecular, aliphatic, primary and secondary amines are particularly aggressive in the presence of traces of water. High-molecular, slightly basic amines are less critical.

Oxidative damage

The potential oxidative damage that can occur with a number of other polymers, such as natural rubber and polypropylene, plays a relatively minor role with polycarbonate. Makrolon® is relatively stable vis-à-vis oxidizing agents. Hence, the reaction with atmospheric oxygen is only of minor significance, even in the absence of stabilizers and at temperatures in excess of 100°C. This is why Makrolon® displays remarkably high stability vis-à-vis 10% nitric acid and hydrogen peroxide by comparison to a large number of other polymers.

Influence of temperature and duration of exposure

The time that elapses before damage occurs becomes shorter as the temperature rises. The exposure time required for initial damage ranges from just a few seconds to more than 1000 hours as a function of the chemical involved, the temperature and the stress level. When molded parts with pronounced stresses are immersed in propylene carbonate, for instance, stress cracks will occur in less than one minute. Low-stress moldings in appropriate Makrolon® grades, by contrast, will withstand frequent cleaning with a 2% aqueous sodium hydroxide solution at 80°C. The residence time should be kept short and the aggressive medium removed from the molded part surface in its entirety after use.

3. Molded part testing to meet practical requirements

If finished parts are likely to come into contact with aggressive media during use, then it is essential to subject them to the appropriate form of testing. Information on compatibility that has been obtained in the laboratory can only be viewed as a guide. The stress states prevailing in the molded part, together with the force acting from outside, can lead to considerably different results.

Short-time contact with aggressive media at below the damage threshold assumes that the medium is removed in its entirety and does not remain in prolonged contact with the material through capillary forces, such as at screw connections or the like. Practical tests are absolutely essential for applications of this type.

In the case of contact with what are essentially compatible solids, it is possible for a component which is capable of migration to move over to the polycarbonate in the course of long-term contact and damage it. One example of this is the contact between polycarbonate and plasticized PVC, in components like terminal strips and PVC insulation, where plasticizers such as dioctyl phthalate, which trigger stress corrosion cracking, cause damage to the polycarbonate.

Stress crack will only develop, however, if tensile stresses prevail in the molded part as a result of its production and/or are applied from the outside. If the molded part is completely stress free or is subject solely to compressive stress, then no stress cracking will occur. If a plasticized PVC tube is mounted on a stress-free polycarbonate pipe, for instance, the polycarbonate will simply swell slightly (the amount of swelling increasing with the plasticizer migration), and the components will weld together. Practical tests on the finished part are absolutely essential in this case too.

It should be borne in mind that the composition of a number of technical substances is subject to change. A laboratory test can only supply information on the batch that has been tested.

Our test laboratories have tested a series of chemicals and commercial products to establish the influence that they have on polycarbonate. If the information given below does not suffice for your purposes, kindly contact your Bayer service representative, who will establish whether we have any further experience in respect of your particular question.

4. Compatibility assessment methods

The simplest method is the template method (flexural strip method to DIN 53449-3). This involves test pieces of 80 x 10 x 4 mm^3 in size being clamped to curved templates in such a way that a graduated outer fiber strain ranging from 0 to 2% is applied. A comparative study must be conducted in air under otherwise identical conditions. What is compared is the reduction in maximum strain that produces no damage both with and without the medium.

Details on this can be found in our Technical Information Sheet "Environmental Stress Cracking – Bend strip test".

5. Assessment criteria

The information given in the table that follows is based on tests to reveal the outer fiber strain as of which Makrolon® 2800 suffered damage at 23°C, or at a higher temperature where this is indicated, over a period of 6 days. Components that lead to damage with an outer fiber strain of $\varepsilon < 1.0\%$ are routinely classified as incompatible.

6. Resistance

Resistance to chemicals
(see table on page 3)

Resistance to oils, greases, waxes and fuels

Makrolon® is resistant to most of the industrial oils, greases and waxes tested in our laboratory over 6 days at 23°C. A series of the products tested did not produce any inadmissible changes in test pieces made of Makrolon® 2800 after 6 days at 60°C either. Resistance is only assured if the technical products are free of low-molecular, aromatic and polar components and of other components that trigger stress corrosion cracking. It should be borne in mind that oils heated to a high temperature can decompose and then form aggressive components. Makrolon® is not resistant to the standard carburetor and diesel fuels. The low-molecular, aromatic hydrocarbons that are present in carburetor fuel, in particular, cause cracking in parts that are subject to stress.

Resistance to sealing compounds and plastics

Makrolon® is resistant to a large number of sealing compounds for 6 days at 23°C and for 6 days at 60°C.

Details on this can be found in our Technical Information Sheet "Sealing compounds for use with Makrolon®". A condition of this resistance is that there should be no aggressive components, such as plasticizers or solvents, which migrate out of the compound and attack the polycarbonate. The same situation also applies to contact with other plastics. Although high-molecular plastics have an inert effect on Makrolon®, the polycarbonate can be damaged by migrating plasticizer (e.g. plasticized PVC), physical blowing agents (from a number of foamed plastics) and out gassing amines (e.g. decomposition products from vulcanization accelerators in rubber or amines from amino plastic). In the same way, if polycarbonate is subjected to joint heat treatment with polyamide 6, it is possible for ε caprolactam to migrate from the PA to the PC and cause degradation.

Tests should thus be conducted in each case in order to establish whether the material components will be sufficiently compatible in service.

Resistance to adhesives

Makrolon® is resistant to a series of adhesives. Details on this can be found in our Technical Information Sheet "The Adhesive Bonding of Makrolon®".

Resistance to paints

In the case of paints containing solvents, stress cracking or swelling may occur as a function of the solvent and the flash-off conditions. Through correctly – tailored solvent aggressiveness and flash-off conditions, it is possible to achieve paints that do not damage polycarbonate. The hardened paint can even enhance the media compatibility of the finished part. Makrolon® is also sufficiently resistant to two-component paints if the individual components do not cause any damage in the short period between the application and the hardening of the paint. Makrolon® is not resistant to turpentine and hence not resistant to paints containing turpentine either.

Resistance to chemicals

	6 days/23°C	6 days/50°C
Acetic acid, 10% in water	+	+
Acetone	swells	
Ammonia, 0.1% in water	-	
Ammonium nitrate, 10% in water/neutral	+	-
Benzene	swells	
Benzine (free from aromatic hydrocarbons)	+	+
Butyl acetate	-	
Carbon tetrachloride	swells	
Chloroform	dissolves	
Citric acid, 10% in water	+	
Dibutyl phthalate	-	
Diethyl ether	-	
Dimethyl formamide	dissolves	
Dioctyl phthalate	-	
Dioxane	dissolves	
Ethanol (pure)	+	+
Ethyl acetate	swells	
Ethylamine	-	
Ethylene chloride	swells	
Ethylene glycol, 1:1 with water	+	+
Glycerin	reacts	
Hexane	+	+
Hydrochloric acid, 10% in water	+	+
Hydrogen peroxide, 30% in water	+	
Iron(III) chloride, saturated/aqueous solution	+	+
Isooctane (2,2,4-Trimethylpentane), pure	+	+ (40°C)
Isopropanol (pure)	+	
Methanol	-	
Methylethyl ketone	swells	
Methylamine	reacts	
Methylene chloride	dissolves	
Nitric acid, 10% in water	+	
n-propanol	- (30°C)	
Ozone, 1% in air	-	
Paraffin, paraffin oil, pure/free from aromatic hydrocarbons	+	+
Phosphoric acid, 1% in water	+	-
Potassium hydroxide, 1% in water	-	

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Propane	+	+
Silicone oil	+	+
Sodium carbonate (soda), 10% in water	+	- (70°C)
Sodium chloride, saturated/aqueous solution	+	+
Sodium hydroxide (caustic soda), 1% in water	-	
Sodium nitrate, 10% in water	+	
Styrene	-	
Sulfuric acid, 10% in water	+	+
Tetrachloroethane	swells	
Tetrachloroethylene	-	
Trichloroethylene	swells	
Tricresyl phosphate	-	
Triethylene glycol	+	+
Xylene	swells	

+ = resistant - = non resistant

Resistance to cleaning and washing agents

Cleaning and washing agents are a class of products with many different compositions. These frequently contain individual components to which Makrolon® is not resistant.

Makrolon® is resistant to normal soaps but not to amines, ammonia, a small number of solvent components and a large number of high-gloss drying aids. Rinsing agents incorporating high-gloss drying aids are also unsuitable for polycarbonate in some cases.

Although high-gloss drying aids can generally be classified as compatible on the basis of short-time tests, which correspond to the short rinsing times that prevail, the decisive factor is that part of the dilute high-gloss drying aid solution is left on the surface of the polycarbonate, where it concentrates and remains on the molded part for a prolonged period of time.

Details on this can be found in our Technical Information Sheet "Cleaning, Disinfection and Sterilisation of Parts in Makrolon®".

Resistance to foods and luxury foods

Makrolon® does not normally undergo any changes when in contact with the majority of foods and luxury foods, under standard conditions of use. Makrolon® is incompatible with a number of herbal and medicinal teas incorporating ethereal oils, as well as with a number of spices. Cloves, nutmeg and pimento can damage Makrolon®. It has been seen with fennel tea that brewed tea produced from fruits can contain ethereal oils in quantities that cause polycarbonate to swell.

Resistance to disinfectants, drugs and cosmetics

Some of these contain solvents or active ingredients which damage Makrolon®. Polycarbonate is incompatible with nail varnish remover and nail varnish, for instance.

If the composition and action of the individual ingredients is known, it is frequently possible to estimate the influence that the substance will have on the properties of Makrolon®. It is even better to put the finished part through an appropriate practical test. If no empirical values are available, then a test on the finished part will always be necessary.

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