Heraeus

Lamp Materials
Heraeus Quarzglas

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The origin of today's global family-held company was the innovative vision and entrepreneurial spirit of Wilhelm Carl Heraeus, a pharmacist and chemist who took over his father's pharmacy "Einhorn-Apotheke" in Hanau, Germany in 1851.

In 1856 he succeeded in melting 2 kg of Platinum in an oxyhydrogen flame and thus laid the basis of today's business of the Heraeus group. In 1899 Dr. Richard Küch followed in the success by fusing rock crystal into a high grade vitreous silica (quartz glass) by the same method.

Today, Heraeus Quarzglas routinely manufactures fused quartz and fused silica and has been doing so for over 100 years. The know-how and excellence gained over one century enables Heraeus Quarzglas to manufacture quartz glass solutions to the most demanding applications.

Heraeus Quarzglas, headquartered in Hanau, Germany, is the technology leader in manufacturing high purity quartz materials and advanced quartz components.

Heraeus Quarzglas supplies not only high quality fused quartz or fused silica but also specific know-how for demanding applications.

The experience of over a century has made Heraeus Quarzglas a global quartz glass producer with a large variety of different grades and shapes of high-purity fused quartz and fused silica.

Because of its unique optical, mechanical and thermal properties quartz glass is an indispensable material in the fabrication of high-tech products. The industrial branches working with quartz glass include semiconductor, telecommunications, lighting, solar, medical applications and chemical processing.

Heraeus Quarzglas GmbH & Co. KG,
Kleinostheim facility, Germany

Heraeus Tenevo, LLC.,
Buford facility, USA

"Einhorn" pharmacy, Hanau, Germany

Selected quartz glass products

Lamp Materials

Using the expertise of over a century in fused quartz, Heraeus Quarzglas has developed a number of fused quartz grades for demanding applications in the lamp and lighting industry.

Heraeus Quarzglas‘ Lamp Materials division offers lamp tubing in snap cut and cut to length, annealed for reduced OH-content, with fire glazed ends or with a closed end. Standard products are offered with an innovative diffuse reflector based on pure SiO_2 (HRC®) as well.

The various quartz products manufactured by Heraeus Quarzglas are used in many applications, such as:

- Special lamps for analytical equipment
- High and ultra high pressure (UHP) for digital projection
- Laser excitation and intense pulse lamps
- Laser flow tubes
- Infrared lamps for industrial processing
- Excimer UV lamps for surface cleaning (e.g. at flat panel display manufacturing)
- Low pressure UV lamps (for e.g. disinfection and water purification)
- Medium pressure Lamps (for e.g. UV-curing)
- UV lamps for medical applications and ozone generation
- i-line lamps for steppers used in semiconductor and LCD manufacturing

For an indication which material grade is best suited for a specific application, please refer to the corresponding table.

Properties and Applications of Lamp Material grades

	HLQ® 200	HLQ® 210	HLQ® 270	HLQ® 235	HLQ® 250*	HLQ® 382	M235 plus	M382 plus	Heralux® plus	Heralux® plus VUV	Suprasil® 310	Suprasil® 300	Suprasil® 130
Properties													
highest UV and VUV transmission										●	●	●	
highest resistance to VUV irradiation										◐	●		●
deep UV blocking (Ozone free)				●	●		●						
UV blocking						●		●					
devitrification resistance		◐	●						◐	●			
highest temperature resistance	◐	◐	●										
high homogeneity		●	●				●	●	●	●	●	●	●
best surface quality		●	●				●	●	●	●	●	●	●
best chemical purity			◐								●	●	●
economic grade	●			●		●							●
Applications													
172 nm excimer lamps											●		
low pressure lamps with 185 nm emission										●			●
low pressure lamps (e.g. disinfection)	●			●			●						●
high transmittance, long life sleeves for 185 nm and 254 nm applications										●	●		●
sleeves for 254 nm disinfection	●												
medium pressure lamps	●	●		●					●				
metal halide lamps	●		●										
highest pressure lamps, HID lamps, UHP			●										
short arc lamps (e.g. i-line, cinema, stage & studio)	●	◐	◐	●			●						
long arc lamps (e.g. laser excitation)		●	◐			●	◐	●	◐				
infrared lamps	●												
tanning lamps				◐	●								
medical UV laser												●	

*FDA approved

● = fully applicable ◐ = partially applicable

Vitreous Silica

Quartz glass is the purest form of glass. It consists only of silicon and oxygen (SiO_2). The natural material that comprised only of those two elements is rock crystal. The difference between the two materials (crystalline quartz and fused quartz) originates in the microstructure. Where crystalline quartz has a very ordered structure with regular rings, fused quartz is less ordered. In fused quartz the rings are of varying size, may have dangling bonds and the bonds between the corresponding ions might be strained.

The unique properties of fused quartz is determined by either the chemical makeup (the SiO bond) or by its microstructure.

The wide range of thermal stability, high optical transmission and the high chemical resistance are a result of the strong SiO bond. The amorphous structure is the reason for the low thermal expansion, excellent thermal shock resistance and high homogeneity of quartz glass.

Characteristics

Mechanical Data	electric	flame	synthetic
Density [g/cm³]	2.203		2.201
Mohs Hardness	5.5 – 6.5		
Micro Hardness [N/mm²]	8600 – 9800		
Knoop Hardness [N/mm²]	5800 – 6100		5800 – 6200
Modulus of elasticity (at 20°C) [N/mm²]	7.25 x 10^4		7.0 x 10^4
Modulus of Torsion [N/mm²]	3.0 x 10^4	3.1 x 10^4	3.0 x 10^4
Poission's ratio	0.17		
Compressive Strength (approx) [N/mm²]	1150		
Tensile Strength (approx) [N/mm²]	50		
Bending Strength (approx) [N/mm²]	67		
Torsional Strength (approx) [N/mm²]	30		
Sound velocity [m/s]	5720		

Thermal Data	electric	flame	synthetic
Softening temperature [°C]	1710	1660	1600
Annealing temperature [°C]	1220	1160	1100
Strain temperature [°C]	1125	1070	1000
Max working temp. continuous [°C]	1160	1110	950
Max working short term [°C]	1300	1250	1200

Mean specific heat J/kg·K

0 … 100°C	772
0 … 500°C	964
0 … 900°C	1052

Heat conductivity W/m·K

20°C	1.38
100°C	1.47
200°C	1.55
300°C	1.67
400°C	1.84
950°C	2.68

Mean expansion coefficient K-1

0 … 100°C	5.1×10^{-7}
0 … 200°C	5.8×10^{-7}
0 … 300°C	5.9×10^{-7}
0 … 600°C	5.4×10^{-7}
0 … 900°C	4.8×10^{-7}
-50 … 0°C	2.7×10^{-7}

Electrical resistivity in Ω x cm

20°C	10^{18}
400°C	10^{10}
800°C	6.3×10^{6}
1200°C	1.3×10^{5}

Dielectric strength in kV/mm (sample thickness ≥ 5 mm)

20°C	25 … 40
500°C	4 … 5

Dielectric loss angle (tg δ)

1 kHz	5.0×10^{-4}
1 MHz	1.0×10^{-4}
3×10^{10} Hz	4.0×10^{-4}

Dielectric constant (ε)

20°C, 0 … 10^{6} Hz	3.70
23°C, 9 … 10^{8} Hz	3.77
23°C, 3×10^{10} Hz	3.81

Manufacturing of Vitreous Silica

Quartz glass is distinguished by its starting material. If natural raw material (e.g. quartz sand or quartz crystal) is used, it is called fused quartz. If chemical precursors (e.g. $SiCl_4$) are used, it is called fused silica. In addition to the raw material quartz glass is distinguished by the production route. There are three established process groups that define the type of vitreous silica:

- **electric fused quartz**
- **flame fused quartz**
- **synthetic fused silica**

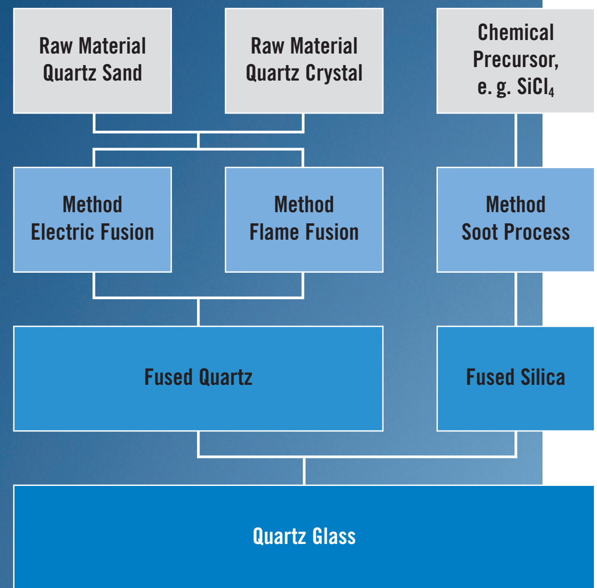
Electric Fusion Process

Electric fusion is the most commonly used melting process for manufacturing quartz glass. Electric fusion is accomplished either by an electric gas discharge (arc melting) or by applying heat generated by electric resistance.

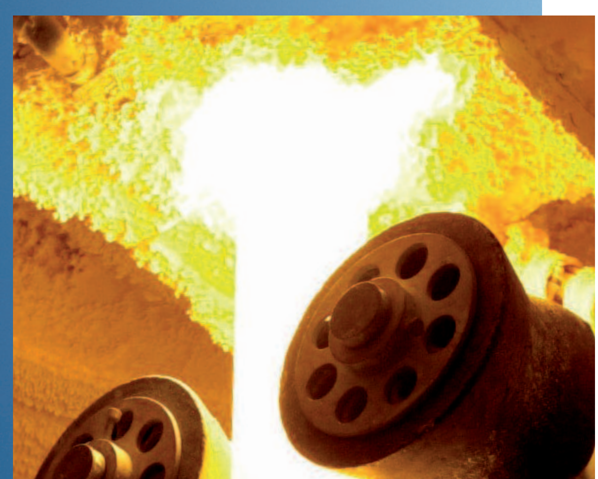
A further differentiation is made by selecting a continues or batch process. Single step electrically fused tubing is fabricated by pouring sand into the top of a vertical smelter that consists of a refractory metal crucible.

At temperatures exceeding 1800°C the ordered micro-structure of the raw material changes into the irregular glass network, glass is formed. Through an outlet in the bottom of the crucible the glass is pulled directly in the shape of tubes or as a solid, a so called ingot.

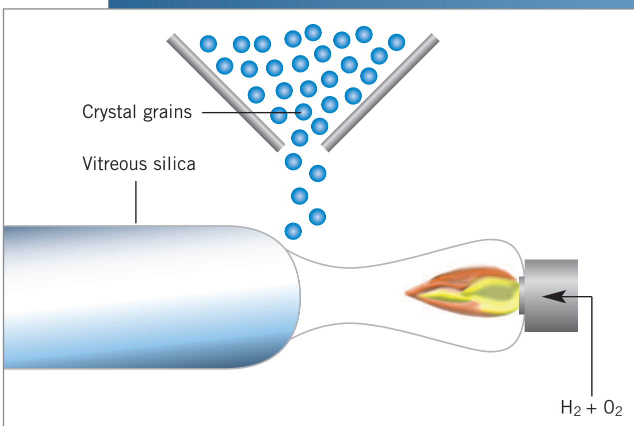
Electric fused quartz has the highest temperature resistance and highest viscosity of the vitreous silica types.



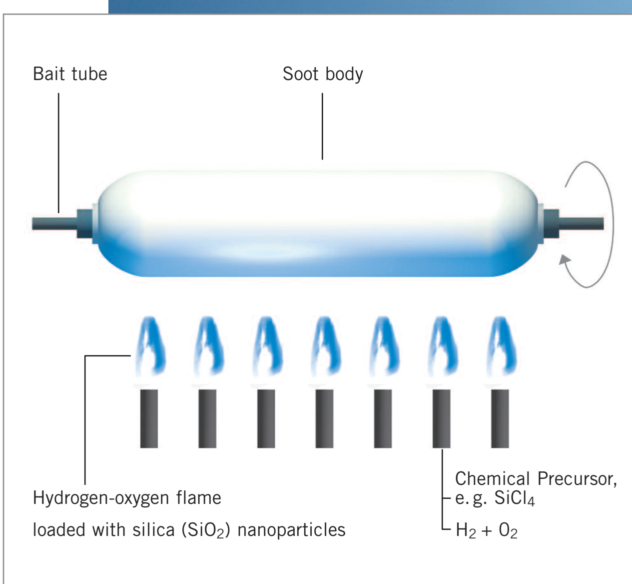
Manufacturing processes of vitreous silica



Electric fusion process



Flame fusion process



Soot process

Flame Fusion Process

Flame fusion is the most traditional form to fuse quartz. A H_2/O_2-flame is used to fuse crystalline particles to fused quartz. Heraeus chemist Dr. Richard Küch was the first to use this method on an industrial scale over 100 years ago. For a continues process small grains of the raw material are constantly trickled into a flame and fused onto a glass rod, that is slowly removed as it grows.

Flame fused quartz has better homogeneity and solarisation resistance compared to electric fused quartz.

Soot Process

In this process chemical precursors (e.g. silicon tetra-chloride,$SiCl_4$) are oxidized (burned) in a H_2/O_2 flame. The forming SiO_2 is deposited on a rotating bait tube like smoke off a candle deposits on a stick above the flame. The soot body is then vitrified into a transparent glass body in a second process step.

Because the precursors are made in an industrial chemical process, the raw materials have exceptionally high purity. Glass made of these precursors has an alkali- and metal ion content in the parts per billion (ppb) range.

Synthetic fused silica has the best transmission, the highest purity and the best solarisation resistance of all vitreous silica types.

Tube Production

Single Step Tubing

The pulling of tubing directly from the melt is the most cost efficient production process. It is available only for **electric fused quartz.**

The outlet of the crucible is ring shaped and the size of the forming tool determines the available dimensions of tubing (outer diameter, wall thickness). Because a change of the forming tool is not possible once the process started, the range of tube sizes per run is limited. A large amount of tubes must be drawn in order to justify using this process.

Tubes produced in the single step process have tight tolerances and are most economic.

Multi Step Tubing

In this process a pre-form (usually a cylinder) is locally heated and redrawn into tubing. The cylinder is either formed directly or an ingot is reshaped into a cylinder. Because the reforming of glass is independent on the actual production route of the quartz glass, multistep tubing is available in **electric** and **flame fused quartz** as well as **synthetic fused silica**. Furthermore, the additional process-steps homogenize the material usually resulting in a lower bubble content. The available finished sizes depend solely on the size of the starting cylinder.

The advantage of the multistep process is the high flexibility regarding starting material and finished sizes, as well as a relatively small batch size.

Chemical Characteristics

Fused quartz is outstandingly resistant to most liquids (metals, solutions, acids etc.). It is corroded by hydrofluoric and phosphoric acid as well as bases. Quartz glass is sensitive to traces of alkaline and alkaline earth metals, because they hasten devitrification at elevated temperatures. Devitrification is the (local) reverting of the amorphous structure to the regular crystalline structure. This takes place at higher temperatures and is visible only when the quartz body is cooled below 275°C, when the crystalline parts flake of.

Quartz glass is a very pure material consisting of SiO_2. Traces of other elements are called impurities or dopant if induced intentionally. Despite their very low concentrations, these impurities can have a significant effect on quartz glass. Purity is predominantly determined by the raw material used. Additional possibilities for contamination arise from the manufacturing method and the handling procedures. Precautions at all stages of the production process assure a high level of purity.

The most common impurities are metals (such as Al, Na and Fe among others) and water (present as OH-groups). These foreign elements are mainly integrated in the glass network and effect viscosity, optical absorption and electrical properties. They can also influence the properties of materials in contact with the quartz glass during the end user application (e.g. Lamp electrodes).

The purity of fused quartz and fused silica is outstandingly high. Synthetic fused silica from Heraeus contains a total metallic contamination below 1 part per million (ppm). For fused quartz the amount is approximately 20 ppm and consists primarily of Al_2O_3 with much smaller amounts of alkali oxides, earth alkali oxides, Fe_2O_3, TiO_2 and ZrO_2.

Metallic impurities originate mostly from natural quartz. Very carefully controlled processes are used to greatly reduce impurities in raw materials from 200 ppm to less than 20 ppm (SiO_2-purity of 99.998%).

Aluminum, as the most prevalent impurity, bonds directly into the quartz glass by substituting silicon atoms. Thus it has very low mobility even at high temperatures which makes it almost impossible to remove at any stage of the production process.

Small amounts of aluminum increase the viscosity of the quartz glass, allowing higher working temperatures.

Hydroxyl Content

In addition to the metallic impurities, fused quartz and fused silica also contain water present as OH-groups. Incorporation of OH-groups into the glass network resulting in a lower viscosity and thus lower working temperatures. Other physical properties are also affected, such as the optical transmission by the formation of absorption bands in the infrared (IR). Each production route corresponds to a typical hydroxyl content.

The lowest values are achieved by electric fusion because the glass is melted in vacuum or in a slightly reducing atmosphere (~100 ppm). The hydroxyl content in electric fused quartz can be reduced in an additional annealing step (<1-30 ppm).

Flame fusion results in significantly higher hydroxyl levels (150-200 ppm), since fusion occurs in a hydrogen/oxygen flame. This hydroxyl level cannot be reduced by annealing.

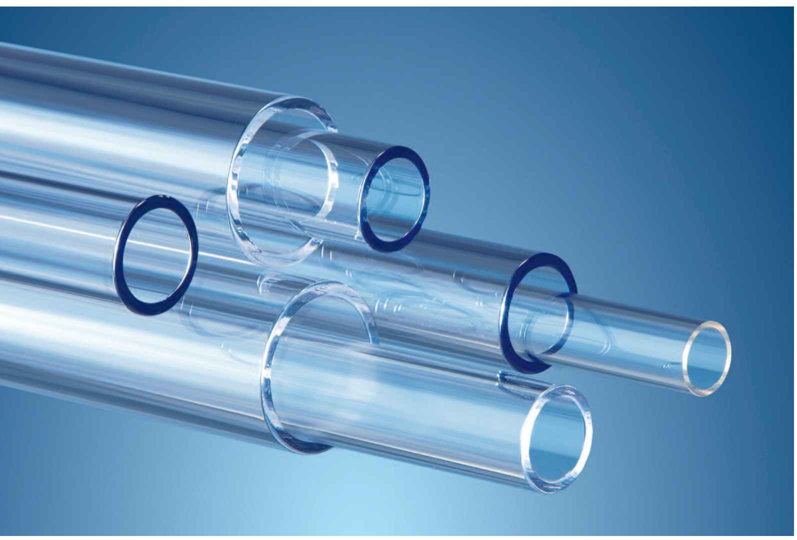
Synthetic fused silica produced by flame hydrolysis of chemical precursors has the highest hydroxyl content (up to 1000 ppm). This can be reduced, for instance by further process including chemical treatments.

Lamp Material Grades, typical impurity content (ppm)

		Li	Na	K	Mg	Ca	Fe	Cu	Cr	Mn	Al	Ti	OH
HLQ® 200	E	0.6	0.3	0.4	0.05	0.5	0.1	<0.05	<0.05	<0.05	15	1.1	*
HLQ® 210	E	0.6	0.3	0.4	0.05	0.5	0.1	<0.05	<0.05	<0.05	15	1.1	*
HLQ® 270	E	0.05	0.05	0.1	0.05	0.5	0.1	<0.05	<0.05	<0.05	15	1.1	*
HLQ® 235	E	0.6	0.3	0.4	0.05	0.5	0.1	<0.05	<0.05	<0.05	15	doped	*
HLQ® 250	E	0.6	0.3	0.4	0.05	0.5	0.1	<0.05	<0.05	<0.05	15	doped	*
HLQ® 382	E	0.6	0.3	0.4	0.05	0.5	0.1	<0.05	<0.05	<0.05	15	doped	*
Heralux® plus / VUV	F	1	1	0.1	0.1	0.1	0.2	0.1	0.1	0.05	10	0.1	130 - 220
M235 plus	F	1	1	0.1	0.1	0.1	0.2	0.1	0.1	0.05	10	doped	130 - 220
M382 plus	F	1	1	0.1	0.1	0.1	0.2	0.1	0.1	0.05	10	doped	130 - 220
Suprasil® 130	S	0.1	0.2	0.1	0.05	0.2	0.05	0.05	0.05	0.05	0.5	0.2	200 - 300
Suprasil® 300	S	0.01	0.05	0.01	0.005	0.05	0.02	0.01	0.005	0.005	0.05	0.05	<1
Suprasil® 310	S	0.01	0.05	0.01	0.005	0.05	0.02	0.01	0.005	0.005	0.05	0.05	200 - 300

** as drawn ~100 ppm, reduceable through annealing*

Doping of Quartz



As mentioned earlier, depending on concentration, impurities have an influence on transmission. For specific applications foreign elements are intentionally put into the glass.

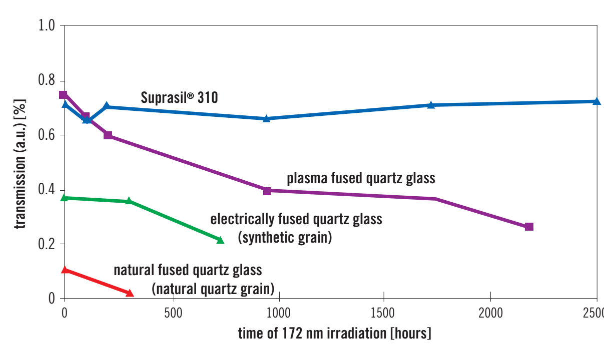
The raw material is mixed with oxides before the fusion process. This process is called doping. Doped quartz is commonly used in applications where the high transmission or thermal stability of fused quartz is required but a specific region of the light spectrum is either not wanted or even harmful to the process performed by the lamp. The most commonly known doping effect is doping with titanium to eliminate deep UV- radiation, while transmitting UV-A and UV-B radiation.

Solarization

Even though vitreous silica has a very good transmission over a broad area of the light spectrum; high energy electromagnetic radiation can damage the glassy structure. In the irregular network of vitreous silica some chemical bonds between the network partners can be strained or in other ways mismatched. These strained bonds can react with high energy photons resulting in an increasing number of lattice defects. The forming of defects by high energy photons is called Solarization. These defects as well as defects formed by impurities can act as absorption centers for photons, resulting in a decreased transmission in selected areas of the energy spectrum. (A number of scientific papers have been published dealing with solarization in vitreous silica).

The defects generated by high energy irradiation (Solarization) not only affect transmission but result in a weakened structure, and ultimately in a breaking of the glass piece. For the reasons given above annealed synthetic grades show the best resistance to solarization.

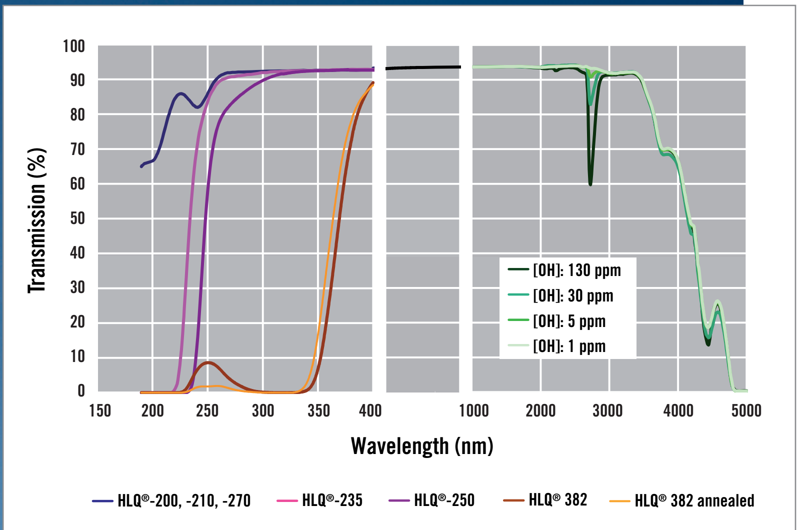
Transmission of different quartz glass types at 172 nm as a function of irradiation time



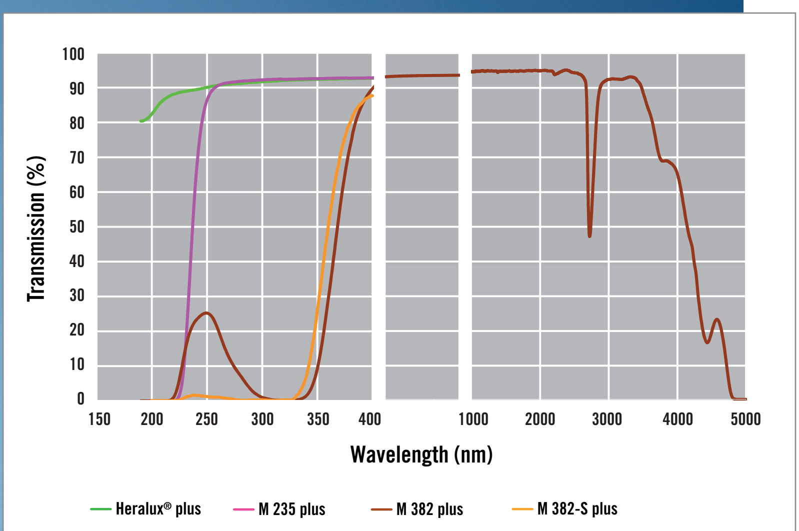
A. Schreiber, B Kühn, E. Arnold, F-J Schilling, H-D. Witzke, Radiation resistance of quartz glass for VUV discharge lamps, J. Phys. D: Appl. Phys. 38 (2005) 3242–3250

Transmission

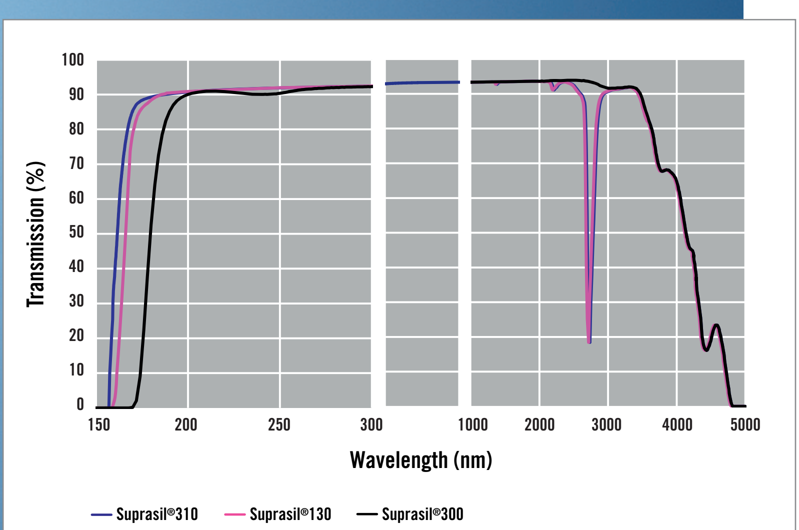
Electric Fused Quartz



Flame Fused Quartz



Synthetic Silica



Undoped fused Quartz has a very broad window of optical transmission ranging from approx. 170 nm to 3.5 µm with an absorption band at 2.73 µm depending on OH content.

The IR-absorption edge arises from lattice vibrations and its position depends on the thickness of the glass.

The exact position of the UV-absorption edge is strongly influenced by the chemical elements in the glass network (impurities or dopants) and is lowest for synthetic material.

With its good understanding of vitreous silica and the associated processes, Heraeus Quarzglas has developed a broad variety of material grades suitable for most applications. Choosing the right one depends on a number of different aspects. For further information and support in your decision making process, please get in contact with your local sales representative (see the information on the backside of this brochure).

HQS-LM Image 12.2010/V1.0_E/Lunis

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