Quartz glass and quartz glass plates

Use of quartz glass plates for UV applications

Possible applications:

Quartz glass plates are usually used in the field of UV technology to separate UV emitters from the surfaces, objects or substrates to be irradiated. Their main use is to separate different air flows or to protect against contamination or spray. Quartz glass plates have a good UV, VIS and IR permeability of approx. 210 to 4,000 nm (≥ 80%). Quartz glass is also used as a medium for filter coatings in UV applications. They are also known as transmitters.

Quartz glass plates can be manufactured and cut in many different sizes according to customer requirements. They have a slightly rippled surface and can show slight ‘streaks’. These are caused by the manufacturing process and are not quality defects. Plates polished on both sides and fire-polished plates are available on request as special designs.

Key features:

- high transmission of UV up to the IR range (200 – 4,000 nm and higher)
- high thermal stability (up to approx. 1,100 °C)
- low thermal expansion coefficient and thus good resistance to temperature change
- very low chemical reactivity
- high dielectric strength (good insulator)

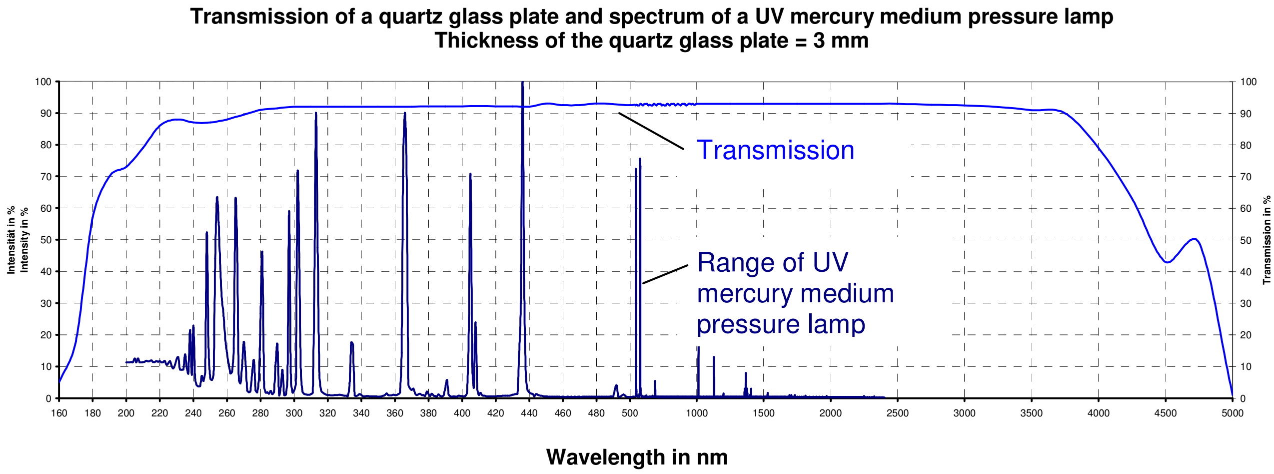

Fig. 1: Transmission curve of a quartz glass plate (blue curve) and the intensity of a UV mercury medium pressure lamp (dark blue).

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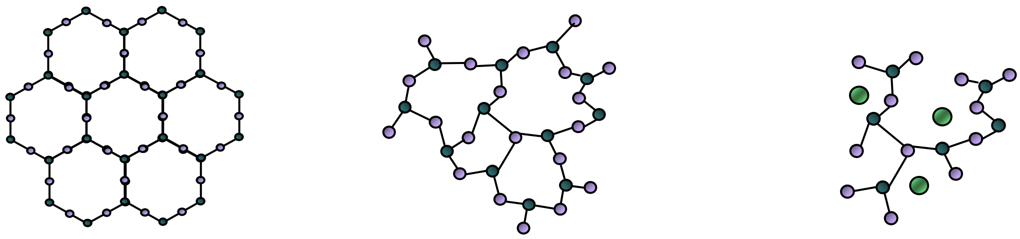
General principles:

In addition to the high temperature resistance and the good resistance to thermal shock, the extremely high transmission of quartz glass is the decisive factor for UV applications. Hardly any other material shows such a high transmission in the UV range (200 to 380 nm).

In contrast to everyday conventional glass, quartz glass consists of pure silicon dioxide (SiO_2). The amorphous form of quartz glass known to us is produced during the cooling down of molten quartz/rock crystal. As a result, the silicon atoms are still coordinated with four oxygen atoms each to tetrahedrally structured SiO_4 groups; however, the groups do not combine with each other into a regularly structured crystal. Therefore, quartz glass is no longer anisotropic and shows no crystal surfaces.



a) b) c)

Fig. 2: SiO_2 in its various forms:
a) crystalline structure with Si atoms (dark) and O atoms (blue),
b) amorphous structure (quartz glass)
c) conventional glass with embedded cations (green)

The content of extrinsic and intrinsic defects has a significant influence on the characteristics of quartz glass. The content of external contamination for rock crystal is, for example, approx. 10 ppm which is not significant for later use - after processing - for UV hardening applications; however, in laser lithography for example, this results in only high-purity, synthetic quartz glass being used there. In practice, the purity can be achieved during the manufacture by different methods (flame hydrolysis, plasma oxidation). Nevertheless, even synthetic quartz glasses with exactly the same composition show different intrinsic defects. The reason is the thermal history because the arrangement of the particles is a function of the temperature. If the temperature changes, the system reacts with a structure relaxation. This becomes manifest during the cooling of the melt by a so-called freezing of the structure relaxation. At this temperature point, the so-called glass transition temperature T_G, the chemical composition of the glass is determined. In addition to the purely intrinsic defects, the external contaminations (OH, H_2) must also be mentioned. These have an order of magnitude of 15 – 35 ppm. The OH content can be reduced using tempering by up to 3 ppm within 30 hours.

In comparison with this, conventional window glass is produced from sodium carbonate, calcium and quartz sand. It contains Na^+ and Ca^+ ions as cations which explains why both the thermal as well as the transmission characteristics are significantly worse than those of quartz glass (example BK 7: τ_i = 0.81 at 320 nm; 5 mm).

The short-wave limit of the transparency in UV is called absorption edge and is determined by electron transitions between valence band and conduction band. In contrast to the crystal, the edge position for the amorphous structure (quartz glass) is blurred which is explained by the existing structural disorder and the associated stochastic fluctuations. This also means that the short-wave absorption edge, dependent on the glass temperature, moves marginally to longer wavelengths with increasing temperature. The cause is in the transitions between expanded valence and conduction bands. This particularly plays a role for the selection of the quartz glass for UV medium pressure lamps where a tube wall temperature between 700 and 900 °C occurs in operation. The incident temperature of a quartz glass plate underneath a reflector unit is significantly lower. Therefore, the shifting of the lower absorption edge is not important in practical use. The so-called standard quality is usually used for quartz glass plates as this is more than sufficient for normal applications and shows a significantly more favourable price/performance ratio in comparison with synthetic quartz glass.

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The use of doped quartz glasses for filtering out wavelength ranges for quartz glass plates is in principle feasible, however hardly used in practice. Instead, doped quartz glass is used for the quartz glass tube of the UV lamp itself, e.g. in order to suppress the short-wave, ozone-generating UV-C part.

Application example:

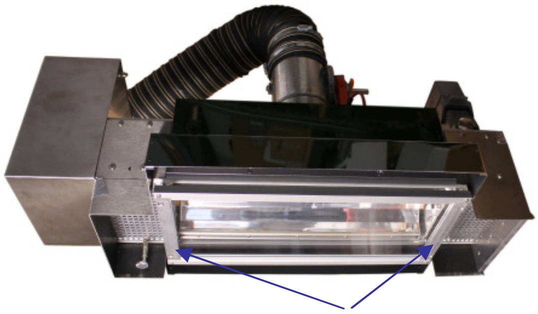

Fig. 3: Reflector unit with quartz glass plate underneath the UV lamp with holding frame (blue arrows).

Specifications:

Quartz glass plates			
Dimensions	According to customer requirements, available up to approx. 500 x 500 mm in the thicknesses 2.5; 3.0; 3.5; 4.0; 4.5 and 5.0 mm; 3 mm is a typical thickness		
Dimensional tolerances	Length and width: ± 1 mm, thickness: ± 0.3 mm		
Cut edges	Cut with glass cutter, fused on request (extra charge)		
Bubbles	Evacuated hollow space surrounded by quartz. Limits: diameter 1 mm, length 10 mm, 10 bubbles per plate		
Bubble pits	Depressions on the surface, caused by a collapsed bubble which causes clearly visible, optical irregularities. Limits: no depression more than 0.6 mm		
Scratches	Fine, unglazed, linear erosions of the surface. Limits: scratches > 0.3 mm width, max. length 150 mm, the total of all scratches must not exceed double the length of the plate.		
Repair points	A clearly visible, optical irregularity on the surface caused by the fusion of a large bubble. Limits: No repair point larger than 5% of the surface on both sides; no change of the plate thickness above 0.4 mm.		
Expansion coefficient	5.5 x 10^{-7} m/m K	Density	2.2 x 10^3 kg/m³
Thermal conductivity	1.46 W/m K	Tensile strength	5 x 10^7 N/m²
Operating temperature	max. 1,100 °C continuous	Compression strength	1.15 x 10^9 N/m²
Dielectric strength	> 40 kV/cm at 500 °C	Bending strength	6.8 x 10^7 N/m²
Chemical characteristics	Hydrolytic class according to DIN 12111 Acid resistance class according to DIN 12116 Alkaline resistance class according to DIN 52322		

Cleaning and disposal of quartz glass:

Quartz glass products must not be held with bare fingers as hand perspiration is very aggressive to quartz and causes recrystallisation (haze). Generally, products made of quartz glass must be cleaned with non-alkaline cleaning agents. Slight grease contamination can be removed with alcohol, e.g. cloths soaked in alcohol. Spirit is not suitable for cleaning as it contains denaturing substances which leave a residue.

Quartz glass should always only be touched with gloves.

Quartz glass is disposed of in landfill as ecologically harmless commercial waste.

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Physical basics:

1. Longitudinal expansion of quartz glass

The analytical calculation of the longitudinal expansion of quartz glass is possible but difficult as the absorption coefficient represents a variable which is dependent on the temperature. In practice, the average expansion coefficient α is used which is approx. 5.5x 10exp-7 1/K.

The following applies for the absolute length:

$$L_2 = L_1 [1 + \alpha \times (T_2 - T_1)]$$

Example: Accordingly, a 1 metre long quartz tube only expands by approx. 0.4 mm during heating from room temperature (20 °C) to the operating temperature of 800 °C.

2. Transmittance of quartz glass

A distinction is made between internal transmittance τ_i and transmittance τ. The transmittance τ also includes - in addition to the internal transmittance τ_I - the losses during entry to and exit from the medium (quartz glass) by reflection of the irradiation. Usually, transmittance τ is indicated. If this is not the case, τ can be calculated as follows (please note that both ρ and τ are dependent on the wavelength):

$$\tau(\lambda) = \rho(\lambda) \times \tau_i(\lambda)$$

Here, ρ is the reflection factor:

$$\rho = 2n / (n^2+1)$$

Thus, the transmittance can also be calculated using the decadic absorption coefficient k (also called decadic extinction modulus):

$$\tau = \rho \times 10 \exp(-k \times d)$$

3. Calculation of the transmittance for other material thicknesses

The indication of transmittance includes that of the material thickness. Transmittance is frequently indicated for 1 mm or also for 3 mm thick quartz glass. If transmittance needs to be calculated for a different material thickness, this is done as follows:

$$\tau(d_1) = \tau(d_2) / \exp(d_1 / d_2)$$

Example: A quartz glass of 2 mm thickness with a transmittance of $\tau = 0.9$ shows a transmittance of 0.81 for a thickness of 4 mm.

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