Quartz Glass for Optics

PROPERTIES AND FIELDS OF APPLICATION

Fused Quartz and Fused Silica are types of Quartz Glass containing primarily silica in amorphous form. They are manufactured using several different processes.

Fused Quartz is made by melting of high purity naturally occurring quartz crystals at around 2000°C using either an electrically heated furnace (electrically fused) or a gas/oxygen-fuelled furnace (flame fused). Fused Quartz is normally transparent.

Fused Silica is produced using high purity silica sand as the feedstock and is normally melted using an electric furnace, resulting in a material that is translucent or opaque. This opacity is caused by very small air bubbles trapped within the material.

Synthetic Fused Silica is made from a silicon-rich chemical precursor and there are two main grades of the material which are widely utilized for optical manufacturing.

UV grade of synthetic FS (KU-1): produced by continuous high temperature hydrolysis of silicon tetrachloride - SiCl4 in hydrogen-oxygen flame;

UV-IR grade of FS (Infrasil 302): manufactured by fusion of natural quartz crystals in an electrically heated furnace.

Both Fused Silica grades are ultra pure, single component glasses with a unique combination of thermal, optical and mechanical properties, which make them the preferred materials for use in a variety of processes and applications where other materials are not suitable. The very high purity (over 99.9%) ensures minimum contamination in process applications. These materials can routinely withstand temperatures of over 950°C and due to their very low coefficient of thermal expansion can be rapidly heated and cooled with virtually no risk of breakage due to thermal shock. All this together with excellent transmission in compare with most other glasses make them useful materials for production of superior quality optical windows, lenses, prisms, beam-splitters, beam-combiners, cold/hot mirrors, et cetera, and so on. These materials are inert to most substances, including virtually all acids, allowing their use in rather severe environments. The dielectric properties and very high electrical receptivity of these materials over a wide range of temperatures together with their low thermal conductivity allow their use as an electrical and thermal insulating material in wide range of environments. The combination of thermal, chemical, and UV stability together with high DUV transparency make them an excellent choice for projection masks for photolythography.

Tydex produces a wide range of optical components from UV-FS and UV-IR FS so please have a look at the chapters to get more information: Optics for Nd:YAG Laser; Optics for UV-VIS-NIR Lasers; Optics for Spectroscopy.

UV-FS (KU-1) features high transparency within ultraviolet and visible regions. It has no absorption bands within 170-250nm wavelength interval. It has an intensive OH-absorption band at 2600-2800nm wavelength range. This grade does not express fluorescence as a result of UV excitation and is characterized by optical-radiation stability. It is practically free from bubbles and inclusions. The nearest analogues of quartz glass KU-1 are:
Suprasil Standard (Heraeus), Spectrosil A and B (Saint-Gobain), Corning 7940 (Corning), Dynasil 1100 and 4100 (Dynasil).

UV-IR FS (Infrasil 302) combines excellent physical properties with outstanding optical characteristics from DUV (through VISible) to middle IR wavelength range and is the preferred material for transmission optics over this wide spectral diapason. It has no absorption bands from 250nm wavelength range as well as no OH-absorption at around 2700nm. It is practically free from bubbles and inclusions.

At near IR range the nearest analogue of quartz glass Infrasil 302 is KS-4V.

Below is comparative and summarizing table of the properties of these two grades of fused silica.

KU-1	Infrasil 302
Max. available diameter of the material, mm	
melted blocks of D220x200 mm-thick	melted blocks of D570 mm, thickness up to 350 mm
The edges of transmission range, nm	
160-4350	175-4350
Transmission range where an average transmission is > 90% of maximum, nm	
180-2100	260-3500
UV transmission vs wavelength for 10mm-thick sample	
170nm - above 65% 180nm - 80% 190nm - 86%	220nm - above 50% 250nm - 70% 260nm - 83%
OH-content, ppm	
< 2000	< 8
Fluorescence (after UV excitation)	
none	blue violet
Total metallic impurities, ppm	
< 5	< 25
Birefringence constant, nm/cm	
< 5	< 5
Melting method	
continuous high temperature hydrolysis of silicon tetrachloride in hydrogen-oxygen flame	fusion of natural quartz crystals in an electrically heated furnace
Annealing point, °C	
1120	1180
Softening point, °C	
1600	1730
Optical-radiation stability (Co^{60} gamma-irradiation (1.15MeV))	
stable	good, visible transmittance is not degraded significantly by ionizing radiation

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Optical Quality

KU-1	Infrasil 302
According to	
Russian State Standard #15130-86	
content of bubbles and inclusions within 100cm^3 material volume	
0 grade according to DIN58927, MIL-G-174B	0 grade according to DIN58927, MIL-G-174B
area with bubbles within 100cm^3 material volume, mm^2	
< 0.03	< 0.1
maximal bubble's diameter per 1kg of the material, mm	
< 0.2	< 0.2
material optical homogeneity at block diameter: 220mm, 190mm, 70-90mm	
delta n < 5 x 10^{-6} delta n < 5 x 10^{-6} delta n < 5 x 10^{-6}	delta n is around 6 x 10^{-6} n/a n/a

SYNTHETIC FUSED SILICA REFRACTIVE INDEX VS WAVELENGTH

(for KU-1 is valid up to 2 μm)

Wave length, μm	Refractive Index	Wave length, μm	Refractive Index	Wave length, μm	Refractive Index
0.2	1.551	0.7	1.455	1.7	1.442
0.22	1.528	0.75	1.454	1.8	1.441
0.25	1.507	0.8	1.453	1.9	1.440
0.3	1.488	0.85	1.452	2.0	1.438
0.32	1.483	0.9	1.452	2.2	1.435
0.36	1.475	1.0	1.450	2.4	1.431
0.4	1.470	1.1	1.450	2.6	1.428
0.45	1.466	1.2	1.448	2.8	1.424
0.5	1.462	1.3	1.447	3.0	1.419
0.55	1.460	1.5	1.445	3.2	1.414
0.60	1.458	1.6	1.443	3.37	1.410
0.65	1.457				

Tydex can process these materials well into 20/10 scr/dig (MIL-0-13830A) and lambda/10 @ 632 nm (TWD and surface accuracy). Standard catalogue windows and lenses (D12.7 mm and D25.4 mm) are available from our stock.

Typical transmission curves (included Fresnel reflection losses) are shown at Fig. 1 and Fig. 2.

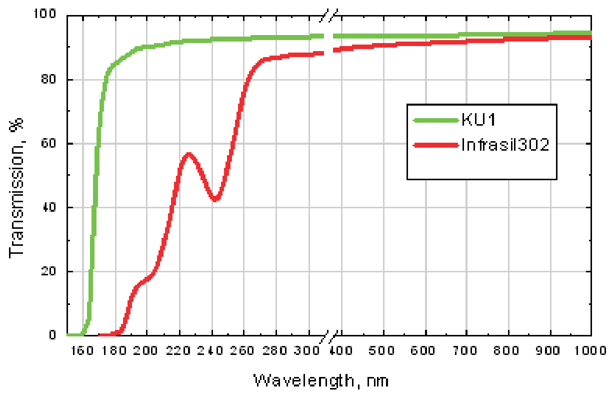

Fig.1. Transmission of KU-1 and Infrasil 302 at 150-1000 nm. Samples thickness is 10 mm.

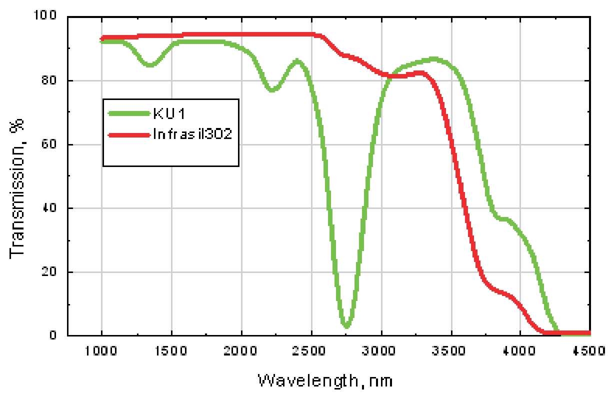

Fig. 2. Transmission of KU-1 and Infrasil 302 at 1000-4500 nm. Samples thickness is 10 mm.

Please pay attention that this article is only for your information. We do supply neither KU-1 nor Infrasil 302 in blanks or as raw materials. Our standard products are finished (polished, coated) parts.

IDENTICAL PROPERTIES OF BOTH GRADES

Density, g/cm^3		2.21
Refractive index	n_F (486nm)	1.4631
	n_d (588nm)	1.4585
	n_C (656nm)	1.4564
Abbe constant		67.8
Thermal coefficient of linear expansion at the temperature range 20-1000°C, °C^{-1}		0.55 x 10^{-6}
Knoop hardness, kg/mm^2		500
Poisson ratio, (T = 25°C)		0.17
Bulk modulus, GPa (T=25°C)		36.9
Tensile strength, MPa		50
Compressive strength, GPa		1.1
Young's modulus, GPa (T=25°C)		73
Rupture modulus, MPa (T=25°C)		50
Shear modulus, GPa (T=25°C)		31
Strain point, °C		1025
Max. service temperature, °C		950 – continuous, 1200 – limited period
Dielectric strength, kV/cm		250-400
Thermal conductivity, W/(m x K) (T = 25°C)		1.38
Specific heat capacity, J/(kg x K) (T = 25°C)		728
Chemical stability		High resistance to water and acids (except hydrofluoric)

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