Fused Silica

Types and applications

Introduction:

Fused Silica is the glass form of quartz and is thus isotropic. It is tough, hard and has a very low expansion. Normal varieties contain water that gives strong absorption in the IR. **Water-free varieties are available**.

Vitreous silica is the generic term used to describe all types of silica glass, with producers referring to the material as either **Fused Quartz** or as **Fused Silica**. Originally, those terms were used to distinguish between transparent and opaque grades of the material. **Fused Quartz** products were those produced from quartz crystal into transparent ware, and **Fused Silica** described products manufactured from send into opaque ware.

Today, however, advances in raw material beneficiation permit transparent fusions from sand as well as from crystal. Consequently, if naturally occurring crystalline silica (sand or rock) is melted, the material is simply called **Fused Quartz**. If the silicon dioxide is synthetically derived, however, the material is referred to as synthetic **Fused Silica**.

These materials are ultra pure, single component glasses (SiO_2) 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 with stand temperatures of over **1250°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.

These materials are inert to most substances, including virtually all acids, allowing their use in arduous and hostile 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 a range of environments.

Terminology

Fused Quartz is less expensive vitreous silica formed by fusing naturally occurring quartz crystal or lower grade synthetic stock material, The UV use is limited to 250nm and this material is usually used for windows covering visible wavelengths.

Fused Silica is vitreous silica formed by fusing high purity synthetic material. The UV use can be reached about 160nm.

Ultraviolet Grade Fused Silica: JGS-1 (China), equivalent to Suprasil 1 and 2 (Heraeus), Spectrosil A and B (Saint-Gobain) and Corning 7940 (Corning), Dynasil 1100 and 4100 (Dynasil).

Optical Grade Fused Quartz: JGS-2 (China), equivalent to Homosil 1, 2 & 3 (Heraeus), Dynasil 1000 & 4000 and 5000 & 6000 (Dynasil)

IR grade Fused Silica: JGS-3 (China), equivalent to Suprasil 300 (Heraeus).

UV grade Fused Silica: (JGS-1) is synthetic amorphous silicon dioxide of extremely high purity. This non-crystalline, colorless silica glass combines a very low thermal expansion coefficient with good optical qualities, and excellent transmittance in thf orientation and temperature instability inherent in the crystalline form. Fused silica is used for both transmissive ae ultraviolet. Transmission and homogeneity exceed those of crystalline quartz without the problems ond reflective optics, especially where high laser damage threshold is required.

JGS-1 is transparent in the ultraviolet and visible regions, and has no absorption bands in the 170-250 nm wavelength intervals. It has an intensive OH absorption band in the interval of wavelength 2600-2800 nm.

JGS-1 is used for optics operating in the deep UV and the visible wavelength range (Laser Lenses, Windows, Prisms, Mirrors, etc.). It is practically free of bubbles and inclusions.

Optical Grade Fused Quartz (JGS-2) provides good UV and visible transmission. It has almost the same physical and chemical properties with JGS-1. However only in thin & small sheet pieces, JGS-2 is virtually bubble-free. Elements built from larger pieces will most likely contain bubbles, so application should not be sensitive to these inclusions. But in cases where simple light gathering and strong mechanical properties are the primary goals, JGS-2 grade provides excellent performance at a low price.

Ideal Applications for JGS-2:

- Condenser optics not concerned with scatter or distortion
- High temperature and pressure applications
- Optical flats, microscope slides and sight glasses

IR grade Fused Silica (JGS-3) is super purity synthetic fused silica manufactured by melting of super pure ash in vacuum. It is transparent in the ultraviolet, visible and infrared spectral regions. It has no absorption bands in the visible region and has no OH absorption band at 2700 nm ("water band").

JGS-3 combines excellent physical properties with outstanding optical characteristics in the deep UV and the IR wavelength range. It is the preferred material for transmission optics; it is usually used in IR applications and also in those requiring very wide wavelength range from DUV to MIR. However the most common Fused Silica for infrared use is quite a bit more expensive than Silicon and slightly less expensive than Calcium Fluoride or ZnS Multi-spectral grade. Also a commercial quality of IR quartz often contains many small bubbles and should only be used for non-imaging applications.

Main Properties

Difference properties			
Parameter/Value	**JGS-1**	**JGS-2**	**JGS-3**
Maximum Size	<Φ200mm	<Φ300mm	<Φ200mm
Transmission Range (Medium transmission ratio)	0.17~2.10um (Tavg>90%)	0.26~2.10um (Tavg>85%)	0.25~3.50um (Tavg>85%)
OH- Content	1200 ppm	150 ppm	5 ppm
Fluorescence (ex 254nm)	Virtually Free	Strong v-b	Strong V-B
Impurity Content	5 ppm	20-40 ppm	40-50 ppm
Birefringence Constant	2-4 nm/cm	4-6 nm/cm	4-10 nm/cm
Melting Method	Synthetic CVD	Oxy-hydrogen melting	Electrical melting
Applications	Laser substrate: Window, lens, prism, mirror...	Semiconductor and high temperature window	IR substrate

Same properties			
Density		2.20g/cm3	
Abbe Constant		67.6	
Refractive Index (nd) at 588nm		1.4586	
Wavelength (um)	Refractive Index (n)	Wavelength (um)	Refractive Index (n)
0.200	1.55051	1.000	1.45042
0.220	1.52845	1.064	1.44962
0.250	1.50745	1.100	1.44920
0.300	1.48779	1.200	1.44805
0.320	1.48274	1.300	1.44692
0.360	1.47529	1.500	1.4462
0.400	1.47012	1.600	1.44342
0.450	1.46557	1.700	1.44217
0.488	1.46302	1.800	1.44087
0.500	1.46233	1.900	1.43951
0.550	1.46008	2.000	1.43809
0.588	1.45860	2.200	1.43501
0.600	1.45804	2.400	1.43163
0.633	1.45702	2.600	1.42789
0.650	1.45653	2.800	1.42377
0.700	1.45529	3.000	1.41925
0.750	1.45424	3.200	1.41427
0.800	1.45332	3.370	1.40990
0.850	1.45250	3.507	1.40566
0.900	1.45175	3.707	1.39936

Same properties	
Hardness	5.5 - 6.5 Mohs' Scale 570 KHN 100
Design Tensile Strength	$4.8x10^7$ Pa (N/mm^2) (7000 psi)
Design Compressive Strength	Greater than $1.1x10^9$ Pa (160,000 psi)
Bulk Modulus	$3.7x10^{10}$ Pa ($5.3x10^6$ psi)
Rigidity Modulus	$3.1x10^{10}$ Pa ($4.5x10^6$ psi)
Young's Modulus	$7.2x10^{-10}$ Pa ($10.5x10^6$ psi)
Poisson's Ratio	0.17
Coefficient of Thermal Expansion	$5.5x10^{-7}$cm/cm.°C (20°C-320°C)
Thermal Conductivity	1.4 W/m.°C
Specific Heat	670 J/kg.°C
Softening Point	1683°C
Annealing Point	1215°C
Strain Point	1120°C
Electrical Receptivity	7x107 ohm.cm (350°C)
Dielectric Properties (20°C and 1 MHz) Constant Strength Loss Factor Dissipation Factor	 3.75 $5x10^7$ V/m Less than $4x10^{-4}$ Less than $1x10^{-4}$
Velocity of Sound-Shear Wave	$3.75x10^3$ m/s
Velocity of Sound/Compression Wave	$5.90x10^3$ m/s
Sonic Attenuation	Less than 11 db/m MHz
Permeability Constants (cm^3mm/cm^2 sec cm of Hg) Helium Hydrogen Deuterium Neon	(700°C) $210x10^{-10}$ $21x10^{-10}$ $17x10^{-10}$ $9.5 x 10^{-17}$
Chemical Stability (except hydrofluoric)	High resistance to water and acids

Transmission curve see bellow: