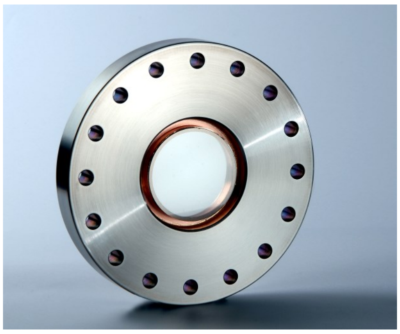
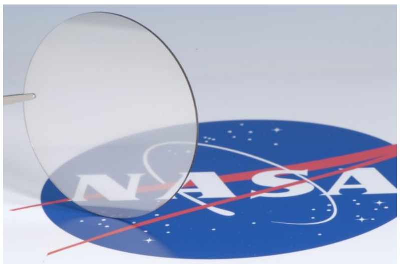
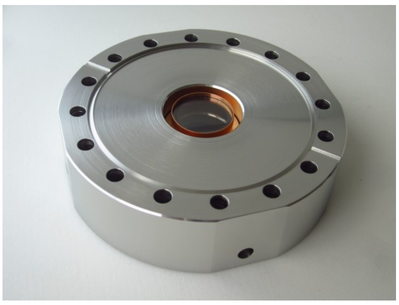
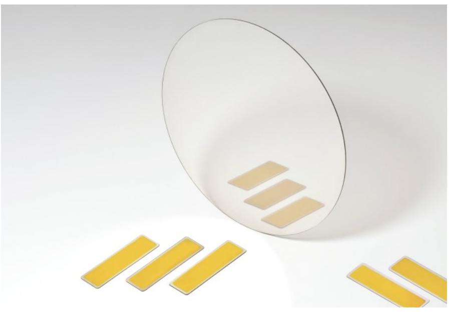
Diamond Optical Vacuum Windows







Diamond Materials is producing high quality diamond wafers that are ideal for the application as optical windows, mainly for the infrared, far infrared and terahertz range. Those diamond wafers consist of high purity polycrystalline diamond grown by high-power microwave plasma assisted CVD.

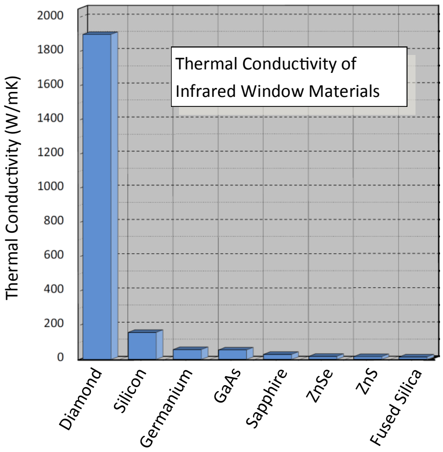


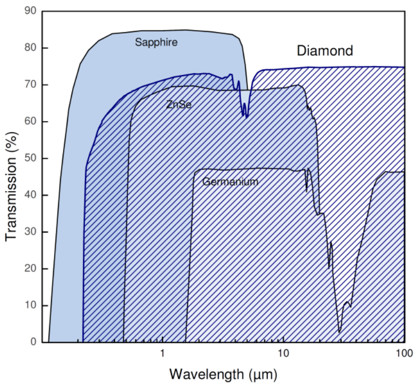
Diamond: A Window Material for Extreme Applications

Diamond exhibits a variety of extraordinary properties that make it an ideal material for demanding optical application.

It has by far the highest thermal conductivity, it exhibits the broadest spectral transmission range and it is very robust.

The transmission of diamond starts in the UV at 225 nm and covers the entire spectral range from the visible over the infrared and terahertz range up to radar frequencies.





Apart from a weak absorption band at 5 µm no further absorption affects the infrared optical transparency of diamond.

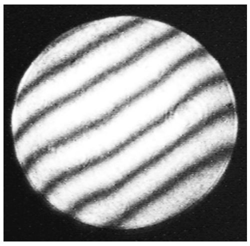
High power density optical applications like high power CO_2 lasers benefit tremendously from the huge thermal conductivity of this extraordinary material.

Material Property	Value
Spectral Transparency	225 nm to the far IR; > 70 % for λ > 10 µm
Refractive Index (infrared)	2.38 in the infrared, 2.41 at 633 nm
Band gap	5.45 eV
Dielectric constant	5.7
Absorption coefficient	< 0.10 cm^{-1} @ 10µm
Loss tangent (tanδ @140 GHz)	< 2.0×10^{-5}
Thermal conductivity	> 1800 W/mK
Tensile strength (@ 0.5mm thickness)	600 MPa (nucleation side under tension)
Thermal expansion coefficient	1.1 ppm/K (at RT), 2.6 ppm/K (20-500°C)

Surface figures and finish

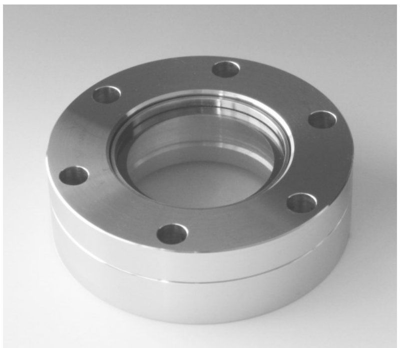
The windows used for optical applications are polished for very smooth surfaces. The standard surface roughness is <10 nm rms.

A factor to be considered when designing a window is the wave-front distortion of the transmitted light. This property is expressed e.g. by the numbers of interference fringes measured in double transmission at 633 nm. Alternatively the flatness of the surfaces can be specified. At Diamond Materials various interferometers are used to evaluate the optical properties of diamond windows.



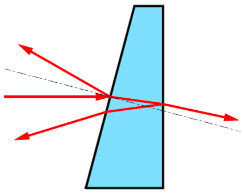
Window Properties	Value
Possible thicknesses	10 µm up to 2000 µm as a rule of thumb we recommend a thickness of 1.7% of the free aperture diameter
Free aperture	Up to 80 mm Ø
Surface finish	Roughness: < 5 nm* Flatness: λ/4 over 25 mm* Wedge: 0 - 60 arc minutes* Wavefront distortion: < 4 fringes at 633 nm over 30 mm*

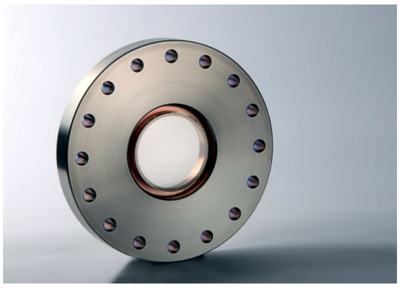
*Sample data. Please inquire for specific details

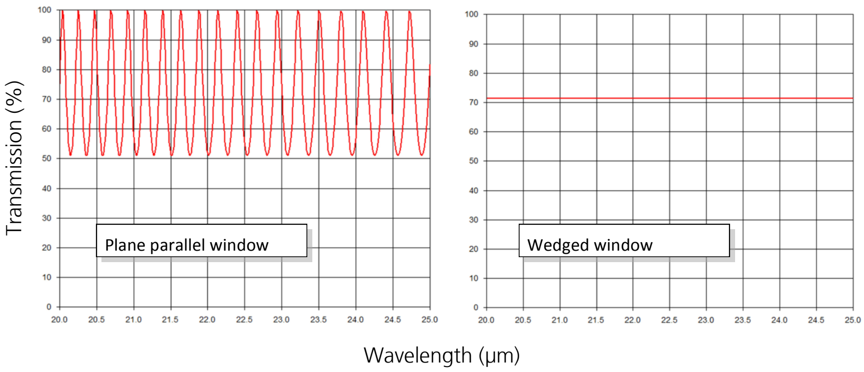


Wedged windows

At long wavelengths interference effects from surface reflections may become disturbing. In those cases wedged windows are preferable. Typically the wedge angle is 30 arc minutes but other angles are also possible. The viewgraphs below show examples of theoretical transmission spectra in the 20-25 µm wavelength range for wedged and parallel windows.







Vacuum Sealing Techniques

Diamond Materials offers various sealing techniques:

Sealing technique	Max. working temperature	Remarks
High temperature brazing	250°C	UHV compatible, very low outgassing, very leak-tight, non-detachable
Elastomer O-ring	150°C	Detachable, for HV (10^{-8} mbar) applications
Indium	100°C	Detachable Mainly for cryogenic applications
Knife-edge	250°C	Detachable, geometrical restrictions

Conflat Flanges

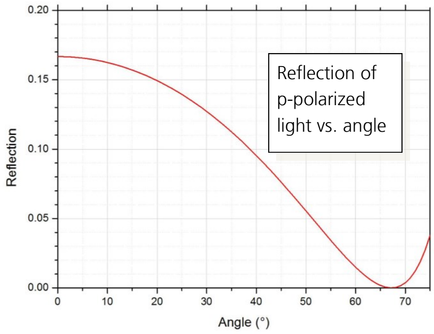
The standard flange sizes are:

European/Asian size	North American size (inches)	Window Free Aperture (mm)
DN16	1 1/3	up to 13 mm Ø
DN40	2 3/4	up to 33 mm Ø
DN63	4 1/2	up to 55 mm Ø
DN100	6	up to 74 mm Ø

Extra options:

- ☐ double sided flange
- ☐ threaded holes
- ☐ low magnetic permeability
- ☐ mechanical protect ring

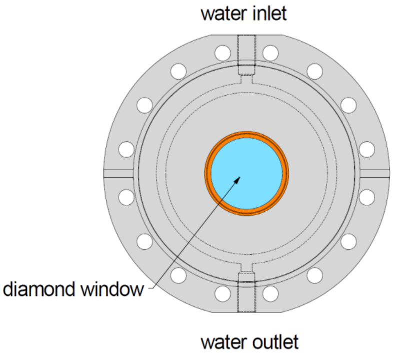
Brewster windows



Brewster windows are uncoated windows that are mounted under an inclined angle (Brewster's angle). Under those conditions the P-polarized component of the light enters and exits the window without reflection losses. For diamond the Brewster's angle is 67.2°. Hence Brewster windows exhibit a transmission of nearly 100 % irrespecitve of the radiation wavelength. This concept is of significant importance for multi-spectral applications such as free electron lasers, multi-wavelength IR lasers or terahertz optical systems.

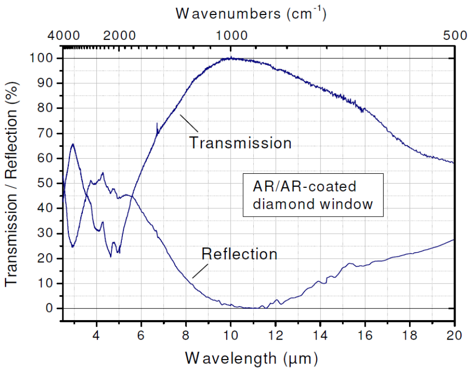
Cooling

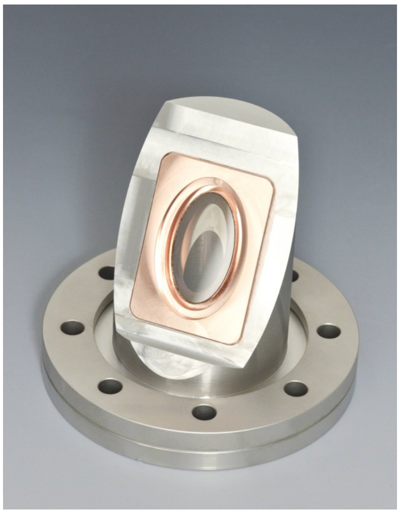
For high power applications the enormous thermal conductivity of diamond becomes important. It allows efficient heat dissipation by an appropriate edge cooling. In particular brazed windows exhibit a low thermal resistance to the vacuum flange. Hence embedded water channels are an efficient technique to dissipate the heat generated in the diamond window. For very high thermal loads Diamond Material has developed designs for ultra-high cooling efficiency.

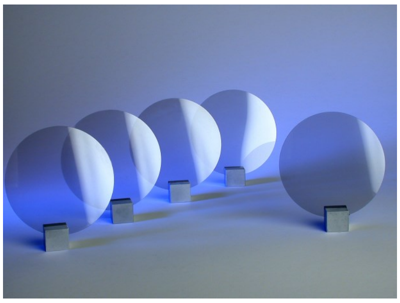


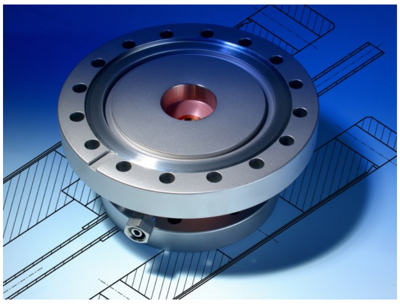
Coatings

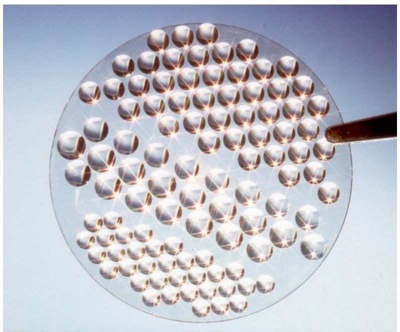
As light passes through an uncoated diamond window about 16.7 % is refelcted at each surface. Applying an AR coating on both sides will increase the throughput of the system and reduce hazards caused by reflections traveling backwards through the system (ghost images). For CVD diamond special coatings have been developed that exhibit low absorption and can handle high power densities.











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