

OPTICS

*Single Crystal CVD Diamond*



# ENABLE THE IMPOSSIBLE

— *Our single crystal CVD diamond opens the way to new horizons in product development throughout the photonics industry.*

# ENGINEERED TO ACHIEVE NEW LEVELS OF PERFORMANCE

Element Six single crystal CVD diamond components can transform many new and existing applications, in a manner not possible with traditional materials.

Diamond ATR prisms have opened up new application areas for FTIR spectroscopy by exploiting its unsurpassed optical transparency, chemical inertness and mechanical robustness.

What's more, single crystal CVD diamond can be engineered to exhibit extremely low birefringence, as well as low scatter at shorter wavelengths, to minimize beam loss and distortion.

## ENGINEERED TO EXPAND THE BOUNDARIES IN PHOTONICS

In demanding applications where the lifetime of the optic is a critical parameter in the performance of the equipment and processes, single crystal CVD diamond sets the standard.

It enables optical engineers to design new and innovative products for their industries. Crucially, single crystal CVD diamond opens up new applications which have not been possible with less extreme materials. This revolutionary material also offers the prospect of unparalleled performance and reduced cost of ownership in existing optical applications.

Optical components made of single crystal CVD diamond have been proven in the field for many years, delivering unsurpassed performance and reliability.

## THE THREE TYPES OF SINGLE CRYSTAL CVD DIAMOND

### SINGLE CRYSTAL OPTICAL GRADE

A unique optical material with:

- A wide spectral range
- Low absorption at key laser frequencies
- High thermal conductivity for heat dissipation
- Low thermal expansion

Single crystal optical grade diamond's superior ability to conduct heat eliminates thermal lensing, which can otherwise result in beam distortion or window failure. Application areas include high power laser exit windows, beam splitters, output couplers and optical components for spectroscopy and endoscopy.

### SINGLE CRYSTAL OPTICAL PLUS LOW BIREFRINGENCE

The ideal material for high end lasers:

- Low birefringence of  $\Delta n < 2 \times 10^{-5}$
- No significant change to the polarization of light

Low birefringence single crystal CVD diamond is ideal in intracavity applications and where polarized light is needed. A typical example where the optical transmission and thermal conductivity are combined is in the cavity of solid state lasers, semiconductor lasers or VECSELs.

### SINGLE CRYSTAL OPTICAL PLUS LOW ABSORPTION

A material for the most demanding applications:

- Offers the highest performance in the most extreme conditions
- Highest Raman gain coefficient of any comparable material
- Combines high thermal conductivity with the lowest losses available

Low absorption single crystal CVD diamond is used as the gain medium for Raman lasers and as a low loss intracavity heat spreader for disc lasers. The high Raman gain coefficient enables the development of, for example, new high power 'eye safe' lasers for defense and aerospace industries.

## TYPICAL APPLICATIONS

EXAMPLE APPLICATIONS	COMPONENT
High Power YAG lasers	Optical windows and lenses
High Power Solid State lasers	Active optical components (Raman), optical windows and intracavity cooling
Spectroscopy (both laboratory and on-line)	Optical windows, prisms and lenses
Semiconductor processing and inspection	Optical windows and hemispherical lenses
Terahertz and Radar applications	Optical windows and prisms
(Bio)Medical optics	Optical windows, prisms and lenses
Defense and aerospace (directed energy/imaging)	Thermal mounting and optical windows

# EXTREME PERFORMANCE PROPERTIES

## PROPERTIES OF SINGLE CRYSTAL CVD DIAMOND

All values are typical physical properties of single crystal CVD diamond suitable for optical applications.

### GENERAL

Space group	Cubic Fd3m-0 7 <sub>h</sub>	
Lattice constant (nm @ 298 K)	0.3567	
Nearest neighbour distance (nm @ 298 K)	0.1545	
Typical N <sub>s</sub> <sup>o</sup> single substitutional nitrogen concentration (ppb)	OPTICAL 100	LOW ABSORPTION 20
Density (×10 <sup>3</sup> kg/m <sup>3</sup> )	3.52	

### OPTICAL

#### REFRACTIVE INDEX

@ 10.6 μm	2.381
@ 1.55 μm	2.386
@ 1.064 μm	2.392
Abbé factor (1/nm)	55.3
(1/n) dn/dT (ppm/K)	4.04

#### UNCOATED NORMAL INCIDENCE REFLECTIVITY

@ 10.6 μm (%)	16.7
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#### ABSORPTION

	OPTICAL	LOW ABSORPTION
@ 10.6 μm (1/cm)	<0.05	<0.05
@ 1.064 μm (1/cm)	<0.1	<0.005

#### INTEGRATED FORWARD SCATTER (2.5 ≤ θ ≤ 87.5°)

@ 1.064 μm (%)	<0.7
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#### TRANSMISSION (1 mm THICK)

8-50 μm (%)	71.4
633 nm (%)	>70

#### BIREFRINGENCE

	OPTICAL	LOW BIREFRINGENCE
Stress birefringence (n <sub>e</sub> - n <sub>o</sub> )	Of order 1 × 10 <sup>-4</sup>	<5 × 10 <sup>-5</sup>

### THERMAL

Thermal conductivity (W/mK @ 300 K)	>2000
Thermal expansion (ppm/K @ 300 K)	1.0
Specific heat Cp and Cv (J/kgK @ 300 K)	520

### SIZES AVAILABLE

Sizes (mm)	Up to 8 × 8 × 2 mm
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## GOING BEYOND TODAY'S TECHNICAL BOUNDARIES

With the use of single crystal CVD diamond, new opportunities arise for the development of optical components for use in extreme situations where high light intensity combines with high thermal loads in aggressive and hazardous environments. Due to its biocompatibility single crystal CVD diamond is also ideal for use in the medical photonics industry.

## TAILOR-MADE SOLUTIONS

Element Six single crystal CVD diamond components can be engineered to feature the right combination of absorption and birefringence for your application. These CVD diamond components can then be processed into virtually any shape and even mounted to enable you to get the best performance out of your system.

Our specialized team of application engineers and processing technologists can design the right component for your application. This includes the windows, prisms and lenses, their processing and mounting, as well as partial or anti-reflective coatings. Mounts can be of simple flange design or made to customer specifications which facilitate special features such as water or air cooling if required.

## MODELING AND ANALYZING PROPOSED SOLUTIONS

Our engineers and technologists use the latest computer modelling systems to model and analyze every aspect of the thermal and mechanical properties of a proposed application. In this way the ultimate performance of a component can be accurately predicted before prototyping.

## ADVANTAGES OF SINGLE CRYSTAL CVD DIAMOND

- Extremely broad transmission spectrum from 220 nm up to >50 μm
- High thermal conductivity (>2000 W/mK)
- Sizes available up to 8 x 8 x 2 mm
- Path length >10 mm possible
- Biocompatible
- Scratch resistant
- Chemically inert and operates in corrosive environments
- Low scatter
- High Raman gain

## ELEMENT SIX

Element Six, part of the De Beers Group of Companies, designs, develops and produces synthetic diamond and other supermaterials, and operates worldwide with primary manufacturing facilities in China, Germany, Ireland, South Africa, the UK and US.

Element Six supermaterial solutions are used in applications such as cutting, grinding, drilling, shearing and polishing, while the extreme properties of synthetic diamond beyond hardness are opening up new applications in a wide array of industries such as optics, power transmission, water treatment, semiconductors and sensors.

If you would like to know more about Element Six please visit our website [www.e6.com/optical](http://www.e6.com/optical) or contact us at any of the addresses below.

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