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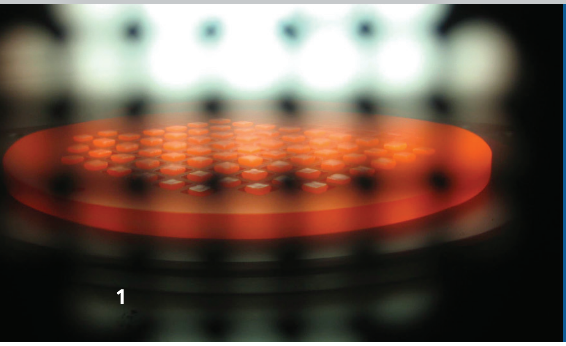
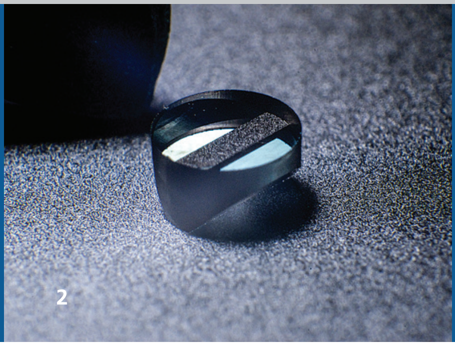
USA

FRAUNHOFER USA CENTER FOR COATINGS AND DIAMOND TECHNOLOGIES CCD





1. **SCD deposition on 70 samples simultaneously**

2. **Rounded ATR diamond**

3. **SCD plates**

SINGLE CRYSTAL DIAMOND

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IN COOPERATION WITH

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Overview

Single crystalline diamonds (SCD) have extraordinary physical properties, making diamond the material of choice for many challenging applications. Diamond is not only the hardest material, it also offers a unique combination of properties relevant to high power and high frequency electronic applications:

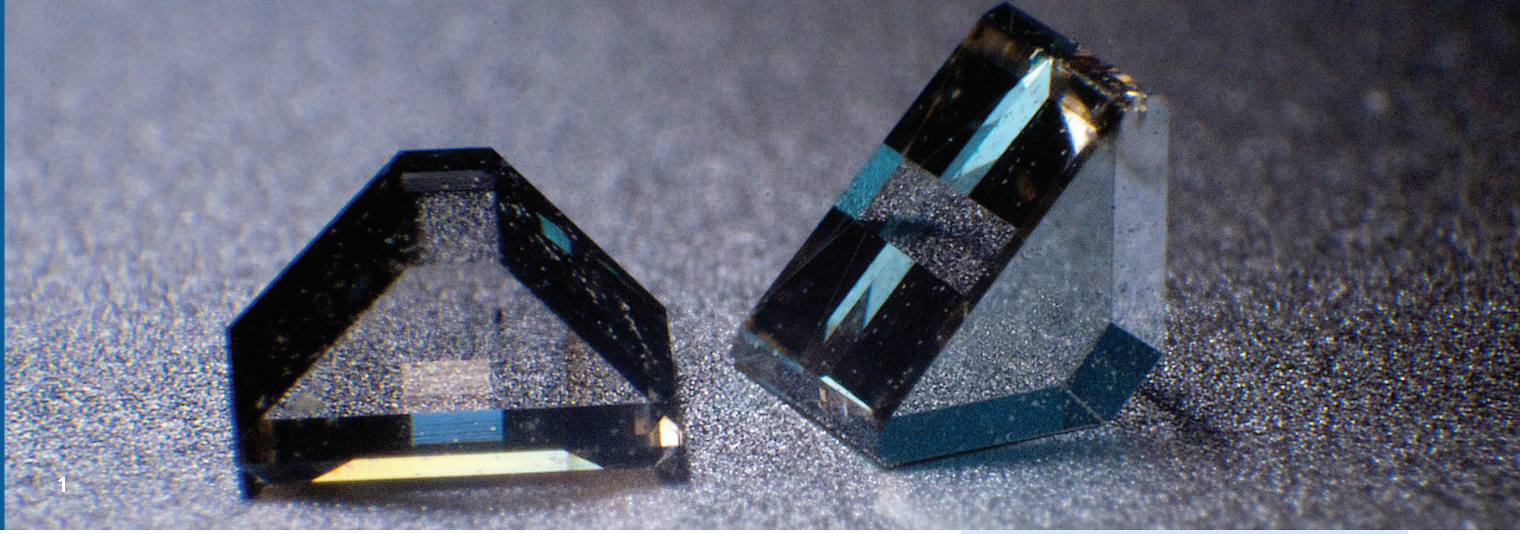
- Highest thermal conductivity of 2200 W/m·K
- Widest band gap of 5.45eV
- Largest electric breakdown field of 10^6 V/cm
- Highest saturation electron drift velocity of $2.7 \cdot 10^7$ cm/s

Diamond electronics can operate about 10 times more efficiently than SiC. This allows for a reduction in device cooling and increased safety. Diamond can be doped using boron (p-type) and phosphorus (n-type) during growth.

Single crystalline diamond and its doped variations can be produced using chemical vapor deposition technology. Similar to the development of silicon carbide and gallium nitride wafers it is expected that ever larger diamond plates will become available and thus further reduce the costs of the material for electronic devices and other application development.

Our Offer

Fraunhofer USA CCD offers the development of single crystalline diamond material tailored to customer specifications. Products are freestanding SCD plates of up to 8×8 mm^2 in size and crystals shaped for specific applications. Our in-house fabrication capabilities enable material development and prototype production of complex SCD products.



SCD Growth

Single crystal diamond is grown by in-house developed state-of-the-art microwave plasma assisted chemical vapor deposition technology. High process pressure synthesis at 380 Torr (0.5 atm) achieves more than 1 mm of homo-epitaxial diamond growth per day. When using 8×8 mm^2 seed crystals this rate produces more than 1 carat of diamond per day per seed. Post-processing includes laser cutting and mechanical polishing to obtain freestanding plates and shaped crystals.

A diamond synthesis process was developed to produce optical grade type IIa SCD material. The nitrogen content in the fabricated crystals are less than 100 ppb and there is little optical absorption for photon energies below the bandgap (wavelengths greater than 225 nm).

SCD Processing

In-house post diamond growth fabrication capabilities include wet chemical etching, plasma dry etching, mechanical polishing and laser cutting.

Grown SCD material is sliced off its seed crystal via laser cutting. After mechanical polishing, freestanding high quality crystals are obtained as a semi-finished product. These crystals can then be formed into diamond plates for wafer based applications or they can be shaped into specific geometries as requested by the customer (for example the attenuated total reflection spectroscopy crystals).

SCD Devices

Fraunhofer USA CCD has capabilities of manufacturing electronic SCD devices such as pn- and Schottky-barrier diodes. Device fabrication and characterization is carried out in our cleanroom facility.

SCD Products

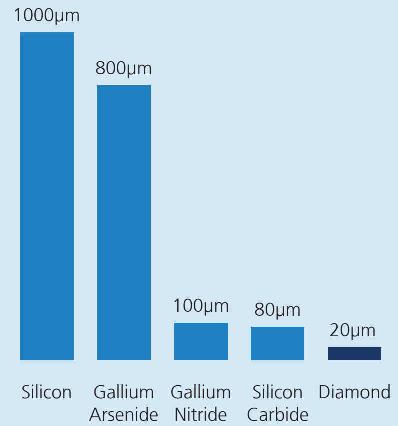
Optical grade intrinsic SCD diamond can be used for:

- Attenuated Total Reflection (ATR) crystals
- Raman laser crystals
- Raman probes
- Heat spreaders
- X-ray optical components
- Freestanding SCD plates (diamond wafers)
- Gemstones
- Optical Windows

Electronic grade intrinsic and doped single crystalline diamond can be used for:

- Radiation detectors
- Spin electronic devices
- High power high frequency electronic devices

Comparison of Intrinsic Material Thickness Needed to Hold-Off 10,000V



Property (relative to sillicon)	Si	GaAs	GaN	SiC	Diamond
Thermal Conductivity	1	0.3	0.9	3.1	13.5
Thermal Expansion Coefficient	1	1.6	2.2	1.6	0.03
Dielectric Constant	1	1.06	0.9	0.9	0.5
Electron Mobility	1	5.67	0.83	0.67	3.0
Hole Mobility	1	0.67	0.42	0.08	6.3
Saturated Carrier Velocity	1	1	2.2	2	>2.5

Property (relative to sillicon)	Si	GaAs	GaN	SiC	Diamond
Johnson Figure of Merit	1	11	790	410	5,800
Keyes Figure of Merit	1	0.45	1.6	5.1	31
Baliga Figure of Merit	1	28	400	290	12,500
Baliga High Frequency Figure of Merit	1	16	44	34	1,100

1. ATR crystal diamonds