elementsix™

DE BEERS GROUP

Electronics cooling

CVD diamond delivers a cool competitive advantage

High purity synthetic diamond is the most thermally conductive bulk material. In electronics, our CVD diamond brings a new dimension to thermal management, extending device lifetime, reducing device footprint as well as offering performance and efficiency gains. Where power, temperature and reliability are critical factors, CVD diamond transforms competitive advantage in electronic thermal management.

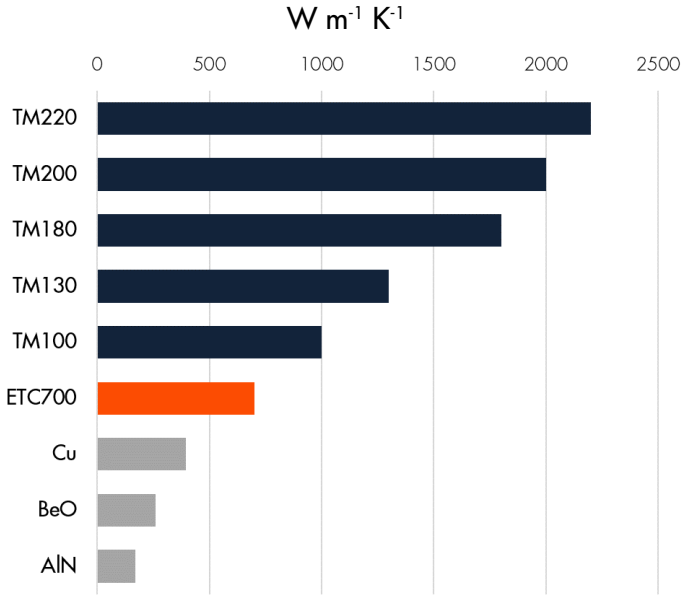
Increase performance, efficiency and device lifetime

- Leveraging synthetic diamond's unparalleled thermal properties allows semiconductor design engineers to address today's critical challenges, such as improved reliability and increased power density on a smaller footprint, thereby delivering world-leading competitive advantage to both device and system manufacturers alike
- Combining low weight, electrical insulation, mechanical strength, low toxicity and low dielectric constant with a room-temperature thermal conductivity up to 5 times higher than copper makes CVD diamond the optimal heat spreader for device and package designers
- Leveraging over 25 years of experience, Element Six engineers diamond properties to meet its customers' specific performance/cost requirements and custom cuts, metallizing diamond to help customers integrate singulated heat spreaders into their modules and systems
- CVD diamond enables dramatic increases in lifetime and power, with reduced operating costs for the latest semiconductor GaN devices

Transforming thermal management performance

Highest room-temperature thermal conductivity of any material

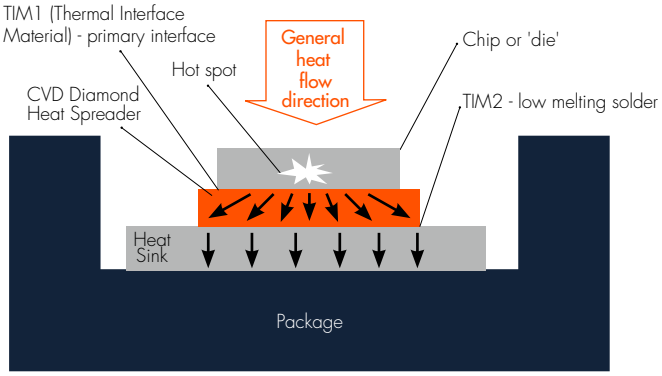
Heat is the single biggest cause of failure in electronics. Statistically, reducing the operating junction temperature by 10°C can double a device lifetime. CVD diamond outperforms today's common materials for thermal management, such as copper, silicon carbide, and aluminium nitride, by factors of 3 to 10 times.



Element Six's CVD diamond expertise enables smooth customer implementation

CVD diamond can be made with thicknesses from 250 to 1000 microns and in diameters up to 140 mm. Element Six's laser cutting and polishing capabilities provide our customers the geometry, surface flatness and low roughness that meet their specific requirements. Our metallization expertise gives our customers a functional material they can use in die bonding with low thermal barrier resistances.

Typical package geometry with CVD diamond mounted module



Typical applications

High-power RF devices

- Base station RF amplifiers
- Satellite RF uplink amplifiers
- Microwave amplifiers

High-power optoelectronics

- Laser diodes and laser diode arrays
- Optical planar IC modules
- High-brightness LEDs

High voltage power devices

- Automotive sub systems
- Aerospace sub systems
- Energy distribution
- DC/DC converters

Semiconductor equipment

- Characterization testing
- Die-attachment processes

Rapidly emerging technology applications

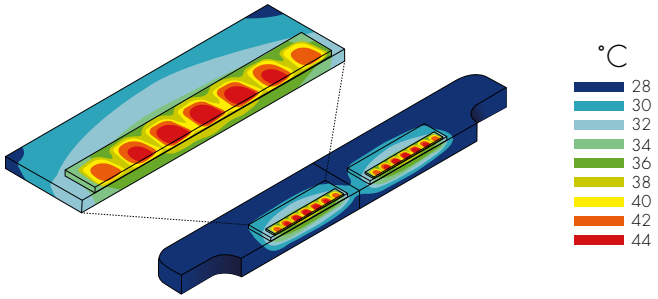
High-power RF and optoelectronics

Higher power at lower operating temperature

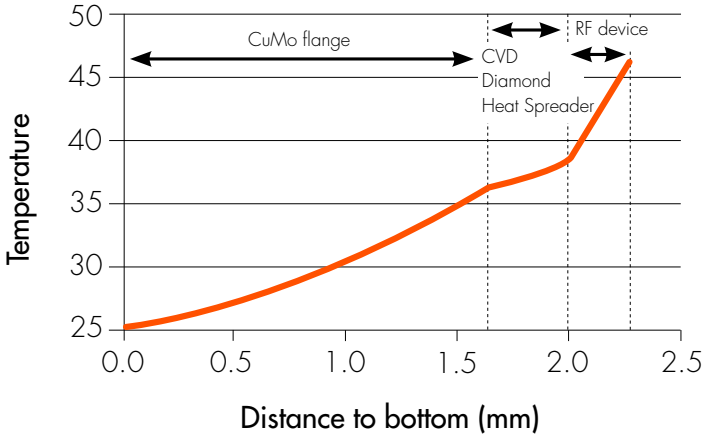
CVD diamond allows high-power RF and optoelectronic devices to:

- Run at higher power levels without increasing junction operating temperature
- Run at the same power level, but much cooler, thereby increasing lifetimes and reliability
- Wide optical transmission enables CVD diamond heat spreaders to operate within an optical path, such as in laser cavities, without optical performance degradation

CVD diamond heat spreader in RF package



Temperature drop across RF device using CVD diamond heat spreaders



High-voltage power devices

Smaller, faster, high-voltage power systems

CVD diamond delivers:

- Improved reliability and increased efficiency by lowering device operating temperature
- Reduced system weight and footprint
- Reduction or elimination of auxiliary cooling systems

Semiconductor assembly and test

Longer testing time and evenly attached die

CVD diamond enables extended stress testing and characterization of semiconductor devices by maintaining lower devices temperatures. CVD diamond also ensures heat is rapidly and evenly spread across the entire semiconductor area during die attachment, delivering strong and reliable contact.

Electrically conductive CVD diamond

Diafilm™ ETC700, delivers the exceptional heat dissipation of diamond combined with minimized resistive and RF losses, enabling smaller and more reliable high power devices without impeding electrical performance.

Compound semiconductor devices

Using Diafilm™ series heat spreaders, the performance of advanced devices, such as those based on GaN, SiC, InP and GaAS, can be enhanced and their lifetimes extended.

Collaboration in applications development

Our specialised team of application engineers and processing technologists will help you to design the right component for your application. Using the latest computer modelling system, the ultimate performance of a component can be accurately predicted.

Advantages of CVD diamond

- Highest room temperature thermal conductivity of any material
- Electrically insulating
- High mechanical strength
- Very low weight
- Chemical inertness and low toxicity
- Broad range of diamond bonding solutions
- Range of thicknesses across large areas available
- Low roughness with high flatness possible

CVD diamond properties

Property	TM100	TM150	TM180	TM200	TM220	ETC700
Thermal conductivity						
@ 300K (W m^{-1} K^{-1})	>1000	>1500	>1800	>2000	>2200*	~700*
@ 425K (W m^{-1} K^{-1})	>900	>1400	>1500	>1500	>1620	>500
Thermal expansion coefficient						
@ 300K (ppm K^{-1})	1.0 ± 0.1	1.0 ± 0.1	1.0 ± 0.1	1.0 ± 0.1	1.0 ± 0.1	1.0 ± 0.1
@ 1000K (ppm K^{-1})	4.4 ± 0.1	4.4 ± 0.1	4.4 ± 0.1	4.4 ± 0.1	4.4 ± 0.1	4.4 ± 0.1
Thermal diffusivity						
300K (cm^2 s^{-1})	>5.5	>8.3	>10.0	>11.1	>12.2	>3.9
Specific heat capacity						
300K (J kg^{-1} K^{-1})	520	520	520	520	520	520
Hardness						
GPa	81 ± 18	81 ± 18	81 ± 18	81 ± 18	81 ± 18	81 ± 18
Fracture toughness						
(MPa $m^{0.5}$)	5.3 - 7.0	5.3 - 7.0	5.3 - 7.0	5.3 - 7.0	5.3 - 7.0	8.5
Young's modulus						
(GPa)	1050	1050	1050	1050	1050	1050
Poisson's ratio	0.1	0.1	0.1	0.1	0.1	0.1
Density						
(10^3 kg m^{-3})	3.52	3.52	3.52	3.52	3.52	3.52
Resistivity						
Bulk Rv (Ω m)	10^{12}	10^{12}	10^{12}	10^{12}	10^{13}	0.05 - 0.07
Surface Rs (Ω m)	10^{10}	10^{10}	10^{10}	10^{10}	10^{11}	0.05 - 0.07

* Measured at 293K

For references and further information on these properties please download the Diamond Handbook.

Element Six is a global leader in the design, development and production of synthetic diamond and tungsten carbide supermaterials. Part of the De Beers Group, our primary manufacturing sites are located in the UK, Ireland, Germany, South Africa, and the US.

Since 1959, our focus has been on developing the diamond synthesis process to enable innovative synthetic diamond and tungsten carbide solutions. As well as being the planet's hardest material, diamond's extreme and diverse properties give it high tensile strength, chemical inertness, broad optical transmission and very high thermal conductivity.

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