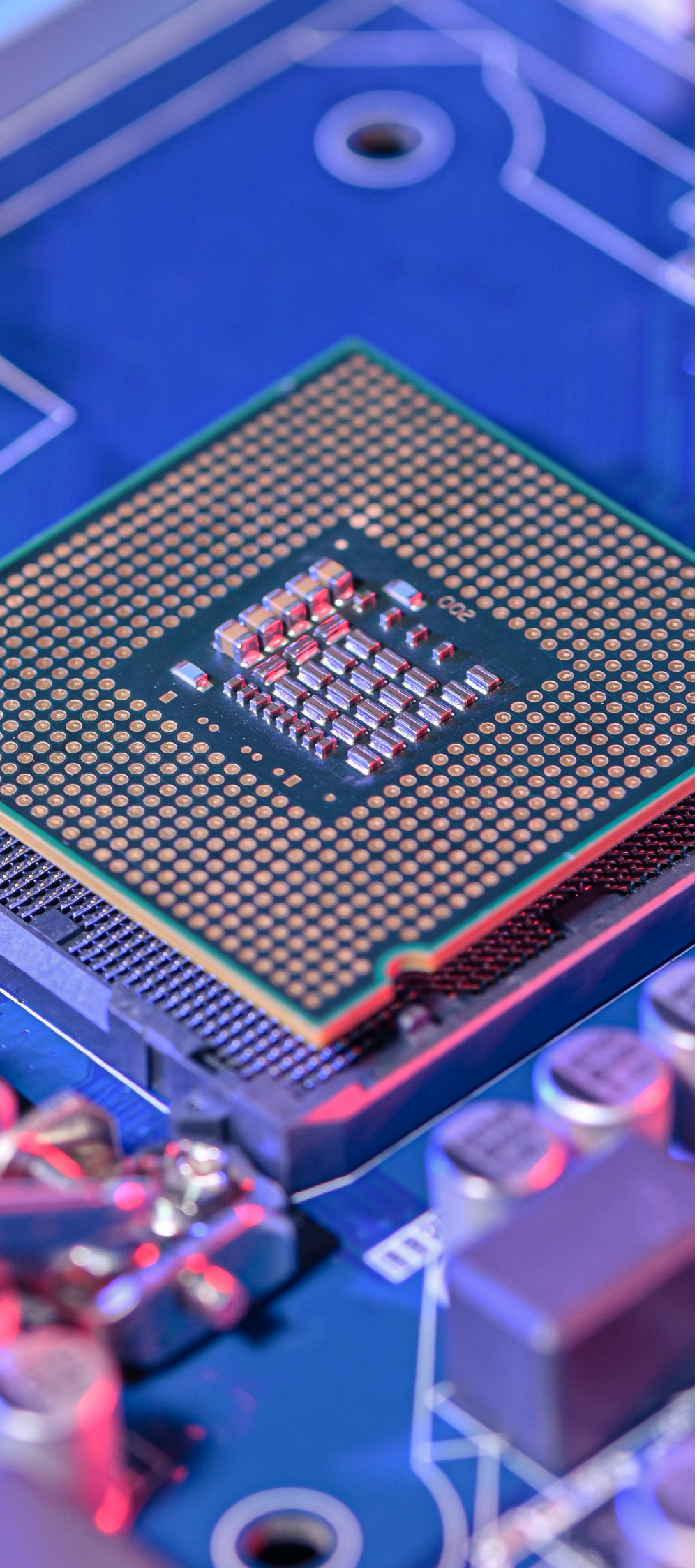


elementsix™

DE BEERS GROUP

Advanced solutions for the semiconductor industry

Advanced solutions for the semiconductor industry

Our world-leading range of high-quality chemical vapour deposition (CVD), grits & powders, and polycrystalline diamond (PCD) products provide solutions to customers across multiple stages of the semiconductor and consumer electronics value chains.

Semiconductors are critical enablers at the heart of a vast range of electronic devices and systems, including smart phones, servers and telecommunications infrastructures. Innovations in semiconductor design and manufacturing are driving new, disruptive technologies, such as 5G, the internet of things, artificial intelligence, electric vehicles, and advanced defence and security applications.

Our diamond-enabled thermal management solutions improve the reliability of mission-critical, high-power density RF amplifiers, and facilitate the testing and inspection of processed wafers and semiconductor chips. Our high-performance diamond grits, powders and wire drawing die are integral to the cutting and polishing of semiconductor wafers and the hard optical materials used in smart electronics. Device assembly and integration require precision machining of printed circuit boards and a variety of metal, glass and ceramic materials - our monocrystal and polycrystalline diamond ranges for precision machining tools provide the quality and reliability expected by the world-leading industrial manufacturers of consumer electronics.

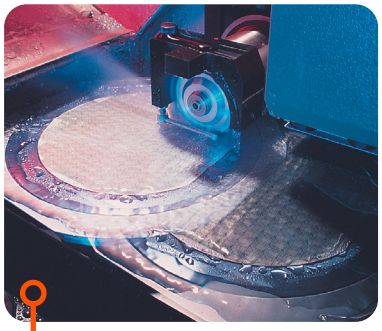
The semiconductor manufacturing value chain

Once a new semiconductor chip has been designed, it is mass produced using a highly sophisticated manufacturing process. Front-end manufacturing refers to the production of multiple copies of an integrated circuit (IC) on a semiconductor wafer. Back-end manufacturing entails dicing a wafer into individual die and packaging them into chips for incorporation into electronic devices and systems.

Element Six (E6) provides a comprehensive portfolio of high-quality synthetic diamond solutions, supporting the semiconductor and electronics manufacturing value chains from ingot to chip, and final electronic device production.



Wafer processing



Wafer dicing



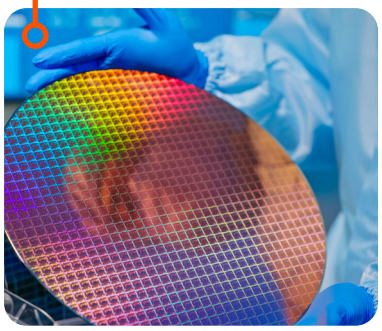
Machining

Front-end manufacturing

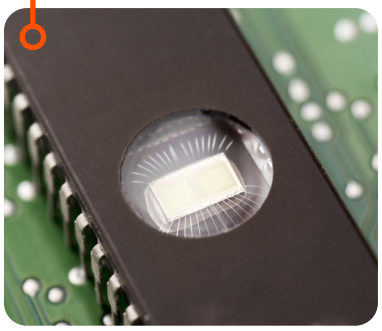
Back-end manufacturing

Electronic device/system processing

IC processing



Packaging, test & inspection



Glass scribing & milling

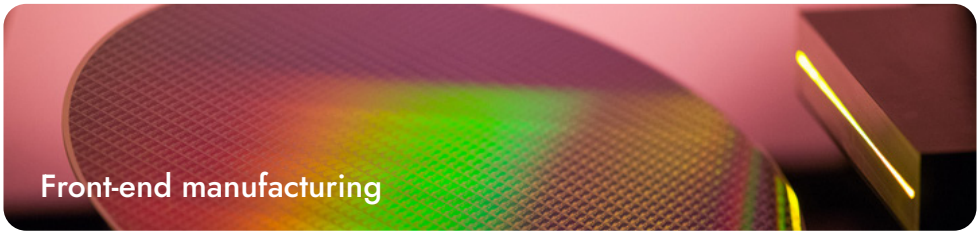


With our extensive innovation expertise, collaborative approach to development, and scale capabilities, we work with customers to provide tailored solutions, enabling semiconductor manufacturers to optimise their products and overcome their most demanding process challenges.



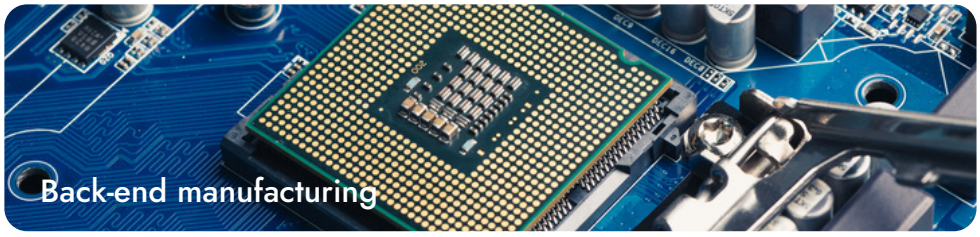
We put our customers first. Using our technological expertise and industrial leadership we deliver innovative solutions to achieve competitive advantage.

Contents



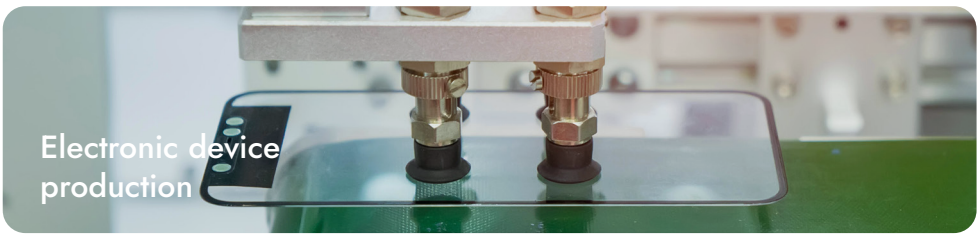
Manufacturing of semiconductor wafers and processing of integrated circuits

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Slicing of processed wafers into chips; device assembly, packaging and testing

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Production of electronic systems and devices

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Front-end manufacturing

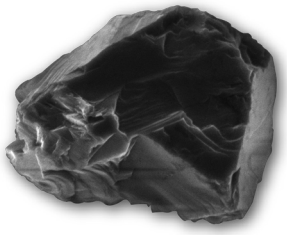
E6's comprehensive portfolio of Grit & Micron™ products provides solutions to the most challenging electronic materials processing requirements, from ingot to chip, including silicon, silicon carbide, and sapphire, while our diamond windows are enabling some of the most advanced lithography tools.

Micron+ MDA™ for diamond wire sawing

Product details

Product: Clad Micron+ MDA™ for electro-plated diamond wire sawing

Product type: Synthetic Micron+™ powder



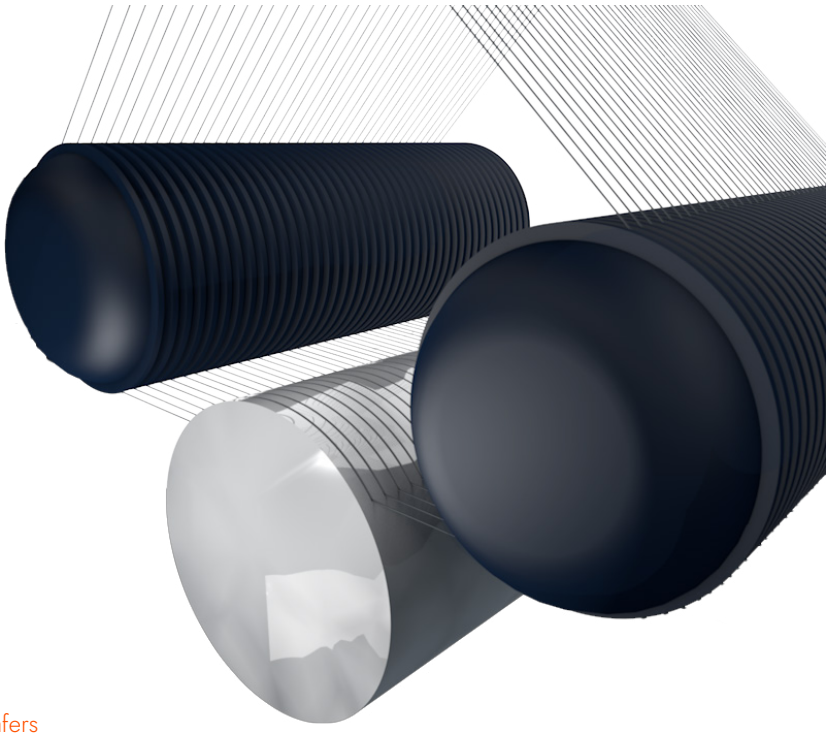
Micron+ MDA particle

Key properties

- High strength for high form accuracy and good surface quality
- Wide range of sizes to choose from, with most popular sizes ranging from 5 to 20 µm
- Coarser range (e.g. M3050) for cropping, squaring or peripheral grinding, and grinding orientation flats
- Customisable shape - blockier for longer life and superior surface finish
- Tight control of large particles to minimise likelihood of workpiece scratching
- Nickel clad material preferred to aid manufacturing and improve retention

Example applications

Micron+ MDA can be used as as the abrasive component in in wire saws to cut silicon, silicon carbide and sapphire, for microchips, solar cells and LEDs.



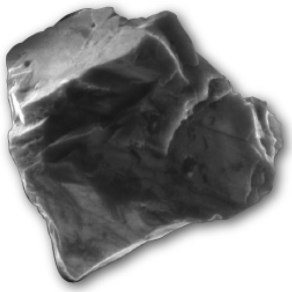
Diamond wire sawing of a silicon ingot into wafers

Micron+ MDA™, UFD™ and CDA™ for double disc, back and surface grinding

Product details

- Micron+ MDA for vitrified bond wheels
- Micron+ CDA™ for resin bond wheels
- Micron+ UFD™ for bespoke semiconductor processing requirements

Product type: Synthetic Micron powder



Micron+ CDA particle

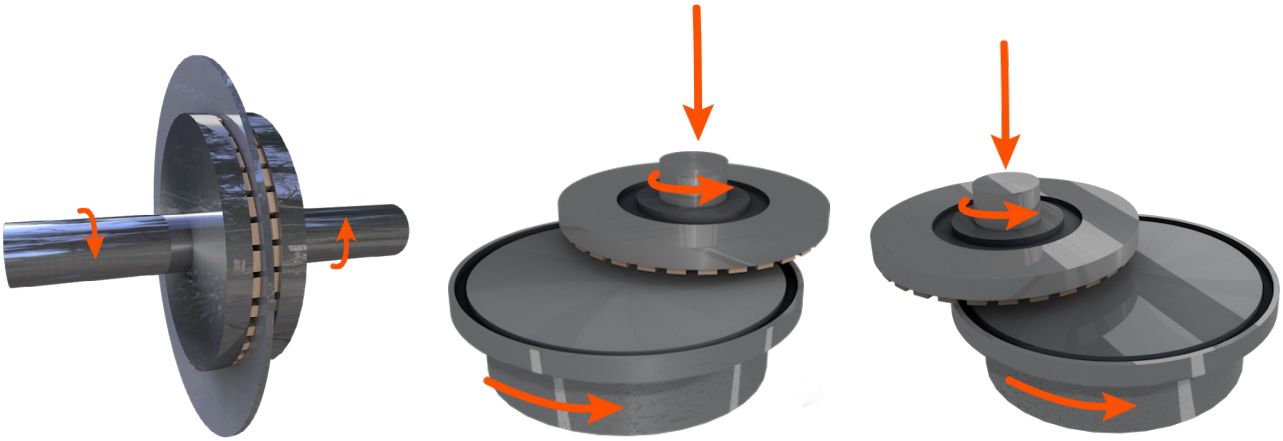
Key properties

- High strength for high form accuracy and good surface quality
- Controlled particle fracturing for free cutting behaviour
- Customisable shape - blockier for longer life and superior surface finish, or elongated for greater free cutting ability
- Wide range of sizes to choose from:
  - Rough grinding 30 – 80 µm (e.g. M4060 – M4080)
  - Finish grinding 0 – 3 µm (e.g. M0.1, M0.25, M0.5, etc.)
  - Bespoke size distributions 0 – 3 µm (e.g UFD products)
- Tight control of large particles to minimise likelihood of workpiece scratching particularly in finishing operations
- High surface purity to aid tool manufacturing processes and reduce risk of workpiece contamination
- Clad materials available for CDA powder for improved particle retention

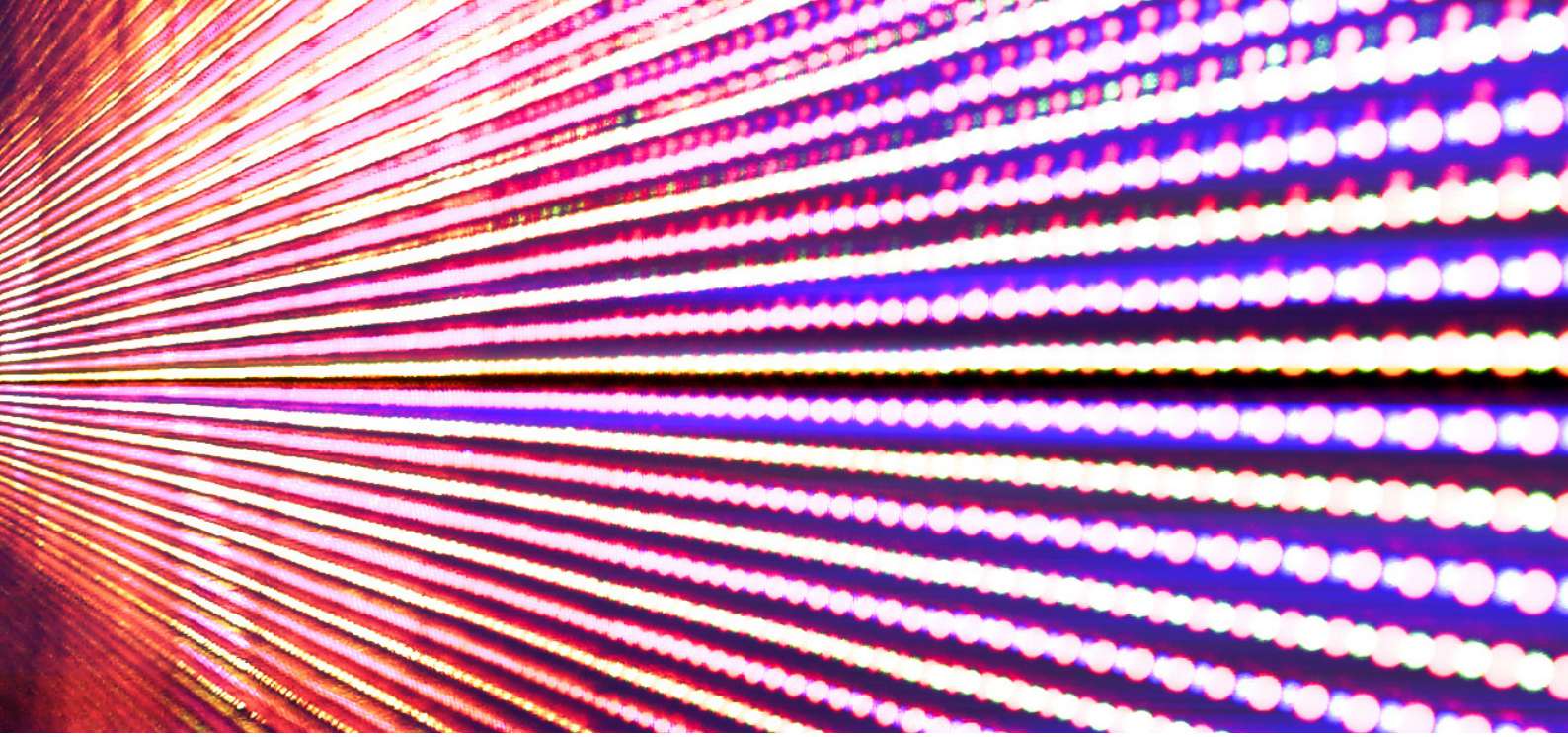
Example applications

Micron powder is used in the production and processing of wafers (such as silicon, silicon carbide and sapphire) for electronic microchips.

Sliced wafers are brought to a desired thickness by back grinding, double disc grinding, and then smoothed out by surface grinding.



Double disc grinding | Back grinding | Surface grinding



Metal bond diamond for CMP pad conditioning

Product details

Product: PremaDia™

Product type: Synthesised metal bond diamond grit

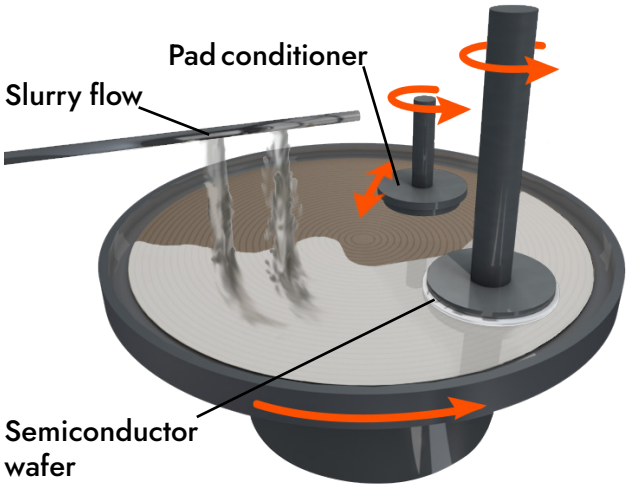
Key properties

- Offering customised mechanical and thermal grit properties in a wide size range
- Tight shape and size distribution, to ensure protrusion uniformity and consistent pad removal rate
- As well as having a tight shape distribution, the actual shape target (e.g. more blocky/irregular), can be controlled to suit the application
- Very high impact strength
- Absence of multiplets and weak particles
- Highly controlled surface purity

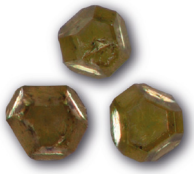
Example applications

CMP is a nano-polishing process to smooth and flatten the surface of wafers. Pad conditioning is critical to maintain consistent wafer planarity.

Diamond grit can be used for CMP pad conditioning for silicon, silicon carbide, gallium nitride and sapphire wafer polishing.



CMP pad conditioning



E6 synthetic diamond grit close-up



Wire drawing with Monodie™

Product details

Product: Monodie™ MD 111

Product type: Single crystal synthetic diamond

Key properties

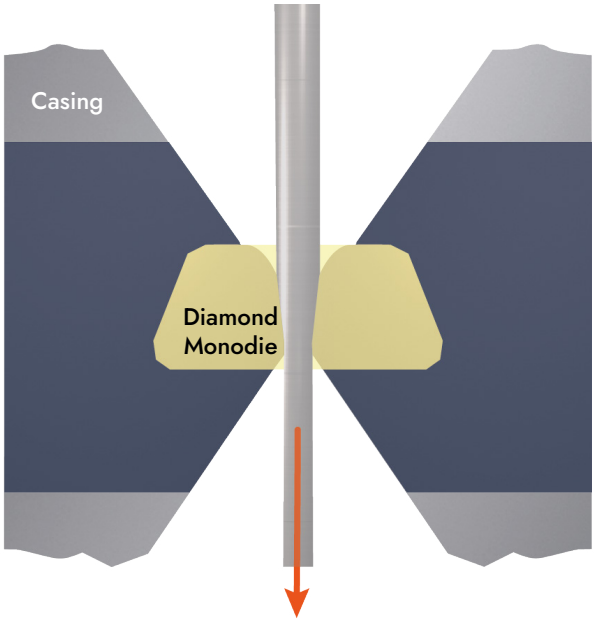
- The higher abrasion resistance of Monodie provides extended die life, consistent roundness, superior surface finish and uniform stress in the finished drawn wire
- Lowest inclusion density ensures both higher manufacturing yields for die manufacturers and higher reliability for end users
- Wide range of sizes to choose from: 0.5 to 1.8 mm in 0.1 mm steps
- High processing capability on material and dimensional attributes (AQL <1%)

Example applications

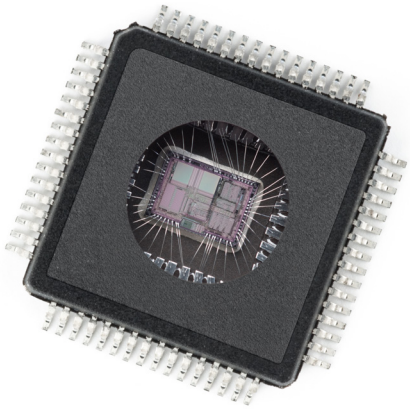
Producing high tensile strength wire used for blocking and slicing of wafers and solar panels, and bonding wire for electrical interconnections, such as copper and gold.



E6 Monodie single crystals



Wire drawing



Diamond windows for extreme ultraviolet (EUV) lithography

Product details

Product: Dialfilm™ OP

Product type: CVD optical grade



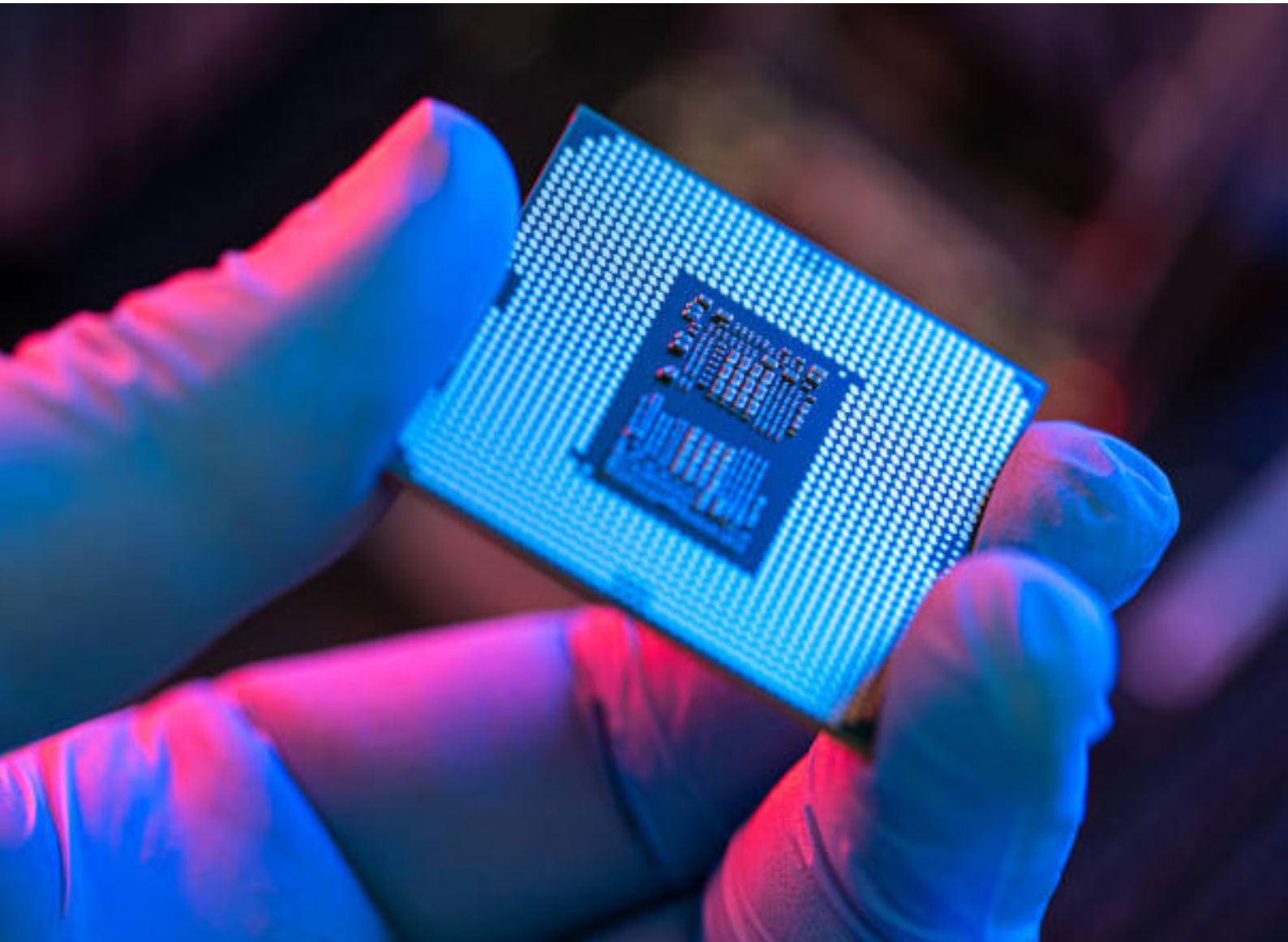
E6 optical window

Key properties

- Diamond combines the highest thermal conductivity with high transparency in the infrared optical range, making it the ideal window material for high power infrared lasers:
  - Thermal conductivity >2200 W m^{-1} K^{-1} at room temperature
  - Low optical absorption coefficient <0.07 cm^{-1} at the CO_2 laser wavelength of 10.6 µm
  - Low thermo-optic coefficient $dn/dT = 9.6 \times 10^{-6}$ K^{-1} ensures minimal laser beam distortion

Example applications

E6 optical windows can be used for high power CO_2 lasers, that form part of extreme ultraviolet (EUV) lithography tools. Typically used for manufacturing advanced silicon microchips for smart electronic technologies (smartphones, cars etc.).



Diamox™ electrochemical cells for easy and effective destruction of PFAS fluorocarbons in wastewater

Product details

Product: Diamox™

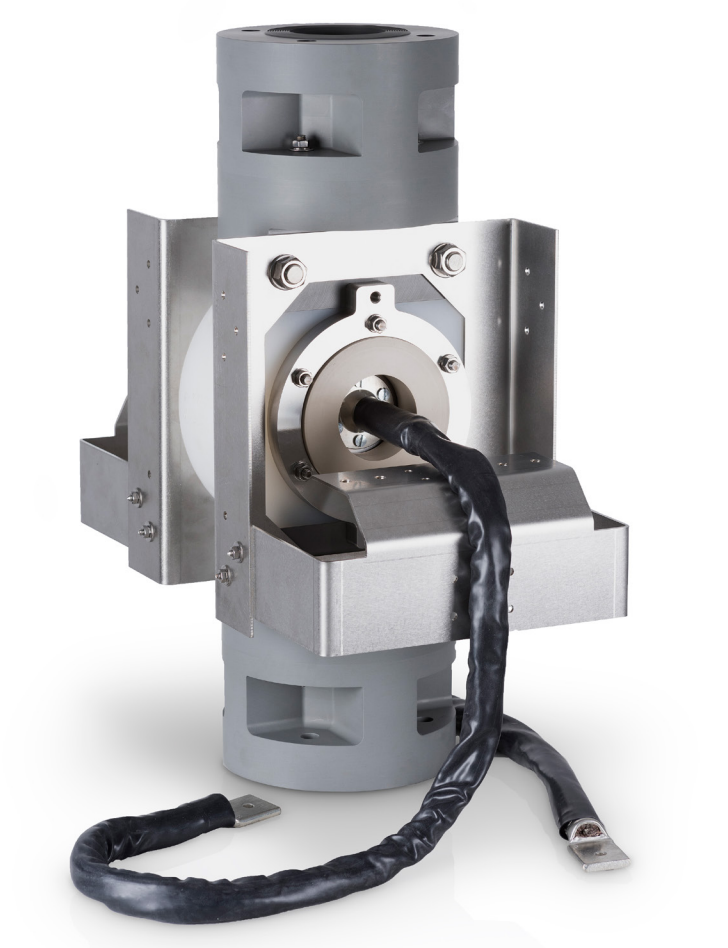
Product type: Electrochemical oxidation reactor

Key properties

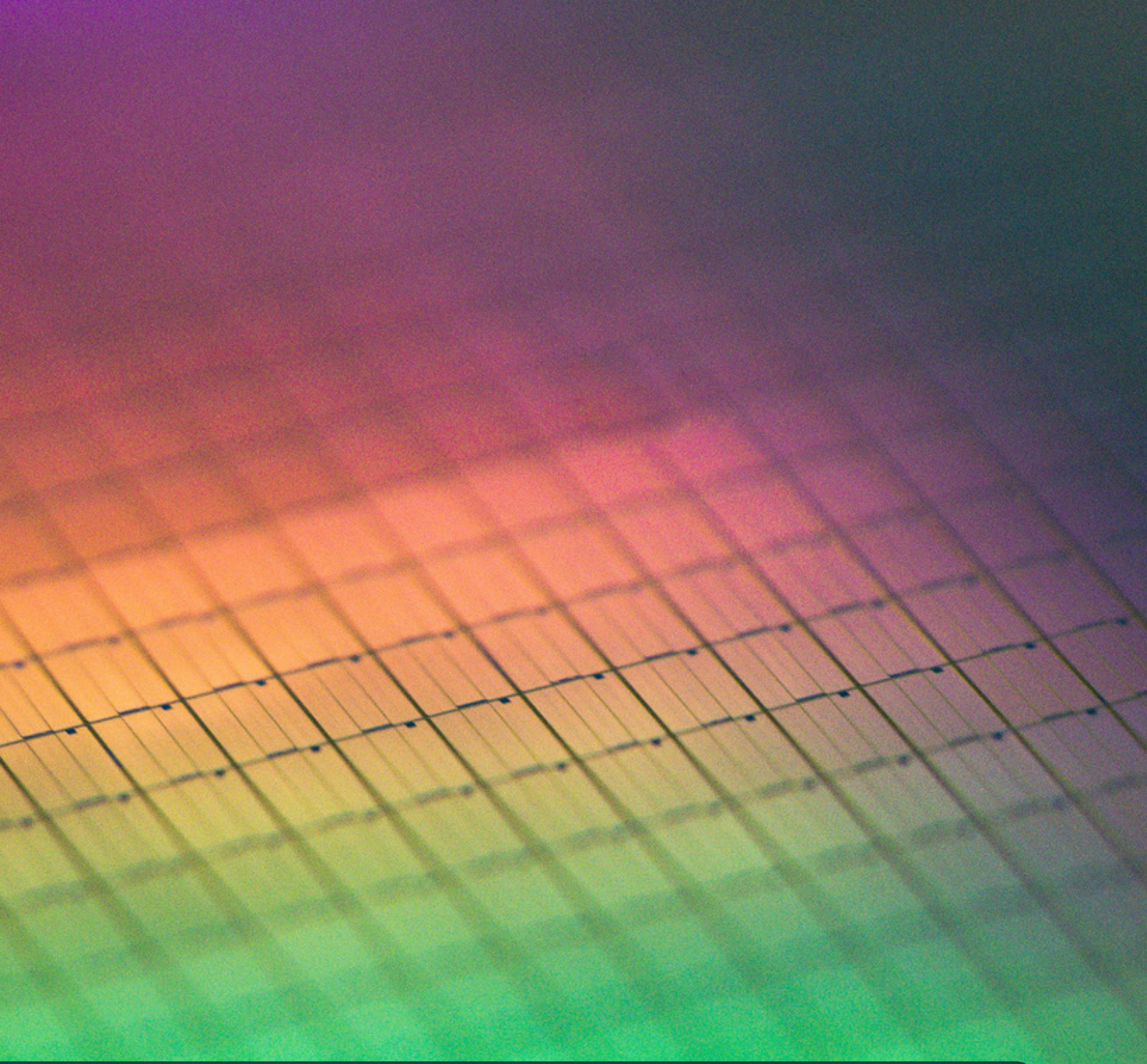
- Electrochemical oxidation cell based on Electrochemical Processing Grade (Diafilm EP) boron doped diamond (BDD) solid electrodes
- Effective destruction of perfluoroalkyl and polyfluoroalkyl substances (PFAS) - known as "forever chemicals" - by direct oxidation
- C-F bonds oxidised in preference to H_20
- Long-term electrochemical stability of the electrodes
- Compact and easy to implement
- Proven performance in a variety of industries and recalcitrant waste streams

Example applications

Destruction of PFAS-contaminated wastewaters resulting from semiconductor fabrication processes.



E6 Diamox assembly



With a wide range of synthetic diamond solutions, over 80 years of technical expertise, scale capabilities, and a collaborative approach to material development, E6 is uniquely equipped to enable semiconductor manufacturers to optimise their products and overcome their most demanding technical challenges.

Back-end manufacturing

Following front-end processing, wafers are diced into individual segments with high precision using diamond dicing blades, before being packaged into individual devices. E6's high quality Micron™ powders provide the consistency and accuracy required for the most demanding wafer dicing processes. Moreover, our diamond heat spreaders cool hot devices effectively, allowing design engineers to take performance and power density to the next level.

Micron+ MDA™ and UFD™ for wafer dicing

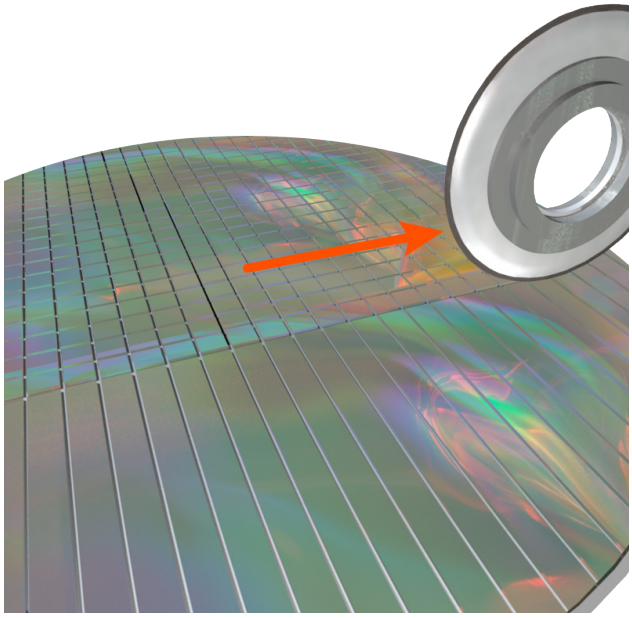
Product details

Product: Micron+ MDA and UFD for electroplated or bonded dicing wheels

Product type: Synthetic Micron powder

Key properties

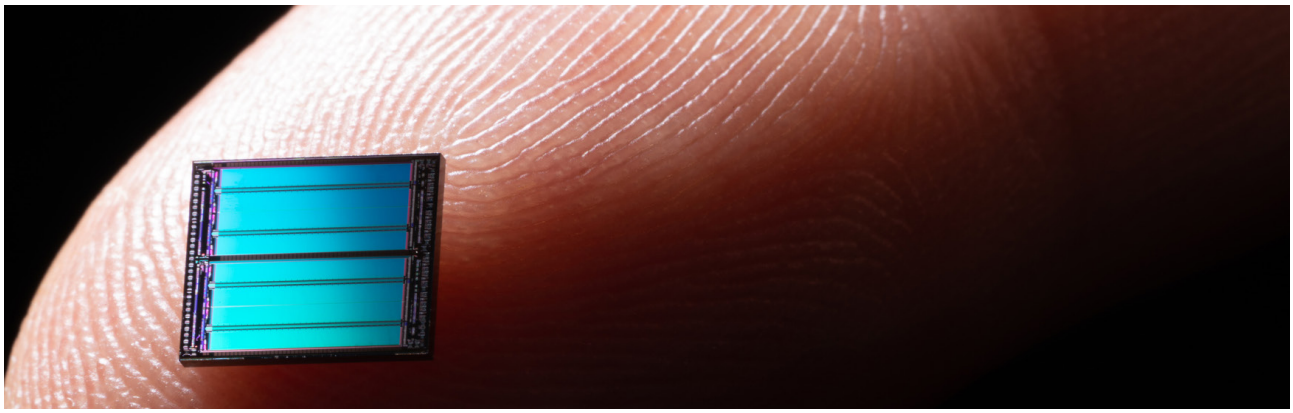
- High strength for high form accuracy and good surface quality
- Customisable shape - blockier for longer life and superior surface finish, and elongated for more free cutting ability
- Wide range of sizes to choose from, with most popular size ranging between 2 - 10 µm (e.g. M36)
- Bespoke size distributions for specific application requirements (UFD products)
- Tight control of large particles to minimize likelihood of workpiece chipping
- High surface purity



Wafer dicing

Example applications

E6's Micron+ MDA can be used to dice silicon, silicon carbide, gallium nitride and sapphire, which are materials employed in producing microchips for electronics and LEDs. Micron UFD can be used for polishing, grinding and dicing semiconductor materials such as silicon, silicon carbide and gallium nitride.



Diamond transmission windows for high power X-ray targets

Product details

Product: Diafilm TM, typically TM180 to TM220

Product type: CVD thermal grade

Key properties

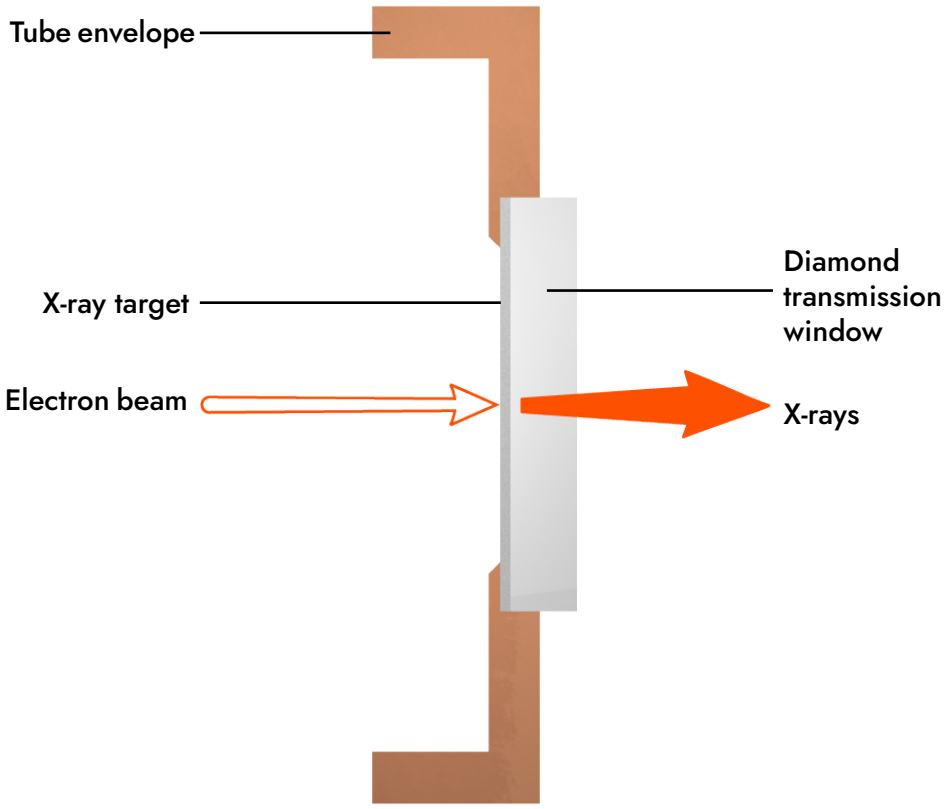
- Diamond has the highest thermal conductivity of any material, which makes it the most efficient heat spreader
  - >1800 W m^{-1} K^{-1} for TM180 grade
  - >2000 W m^{-1} K^{-1} for TM200 grade
  - >2200 W m^{-1} K^{-1} for TM220 grade
- Electrically insulating
- Parts can be provided metallised to customer's requirements
- Sizes up to multiple square centimetres possible

Example applications

Extensive testing and inspection is carried out throughout the semiconductor manufacturing process. Achieving high throughput or high resolution can require the use of high powered tools and instruments, resulting in hot spots on the X-ray target in the tool. An example is in X-ray inspection instruments such as X-ray photoelectron spectroscopy (XPS) or X-ray flourescence (XRF) tools. Where high resolution or high intensity X-rays are required, diamond's high thermal conductivity and low X-ray absorption coefficient make it an ideal substrate solution for X-ray targets.



E6 polycrystalline thermal grade wafer



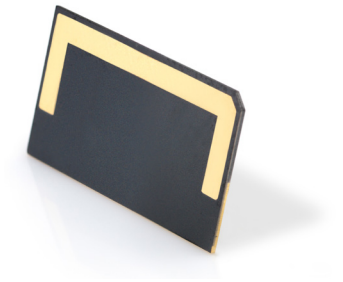
X-ray inspection tool

Diamond heat spreaders for cooling high performance, high power chips

Product details

Product: Diafilm TM

Product type: CVD thermal grade



E6 heat spreader with metallisation

Key properties

- Diamond has the highest thermal conductivity of any material, which makes it the most efficient heat spreader
- Thermal grades available with room temperature thermal conductivity from 1000 W m^{-1} K^{-1} (TM100 grade) to 2200 W m^{-1} K^{-1} (TM220 grade)
- Electrically insulating
- Parts can be provided metallised to customer's requirements (typically Ti/Pt/Au)
- Sizes up to multiple square centimetres possible

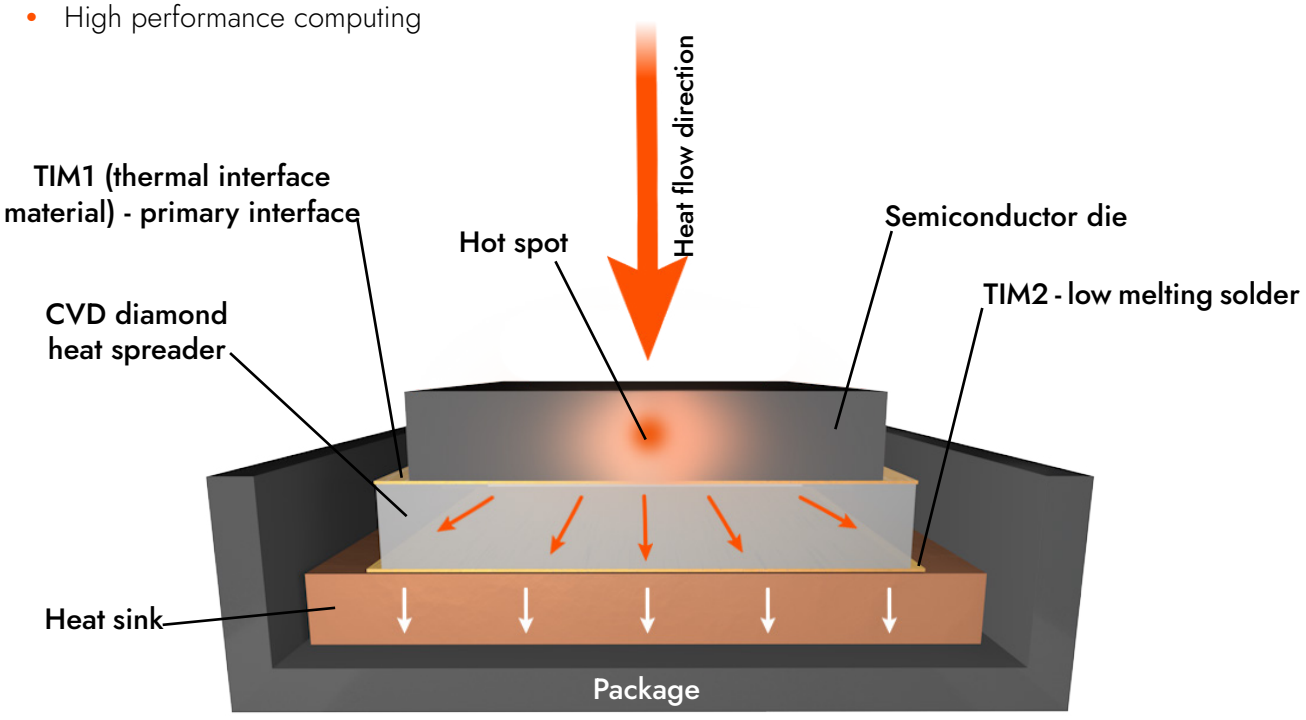
Example applications

Diafilm TM is used in reducing device temperature in high power density RF and microwave amplifier chips based on gallium nitride (GaN), enhancing performance and reliability. Applications include:

- Defence (such as electronic warfare)
- Satellite communications
- RF/microwave base stations

Diafilm TM is also used in reducing hot spots in high-end silicon processors, ASICs and FPGAs for applications such as:

- Telecommunications
- Artificial intelligence
- High performance computing



Typical package geometry with a CVD diamond mounted module

Micron+ MDA™, UFD™ and PDA™ for thermal applications

Product details

Product: Micron+ MDA, UFD and PDA™ mesh products

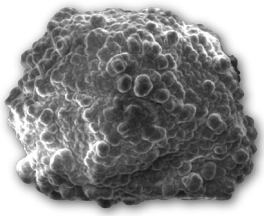
Product type: Synthetic Micron powder and PremaDia

Key properties

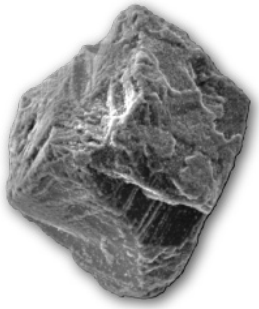
- Customisable shape - blockier or irregular shape distributions available for optimised particle flow and packing properties
- Wide range of sizes to choose from:
  - M0.1 to M4060 micron sizes for Micron+ MDA
  - 500600 to 6080 mesh sizes for PDA range
  - Bespoke size distributions 0 - 3 µm (UFD products)
- Range of coatings and claddings can be selected for optimisation of thermal properties and matrix compatibility
- Control of surface purity
- Typical matrices include polymeric and metallic compounds

Example applications

Thermal interface materials for applications including power electronics, energy and telecommunications.



Cu clad Micron

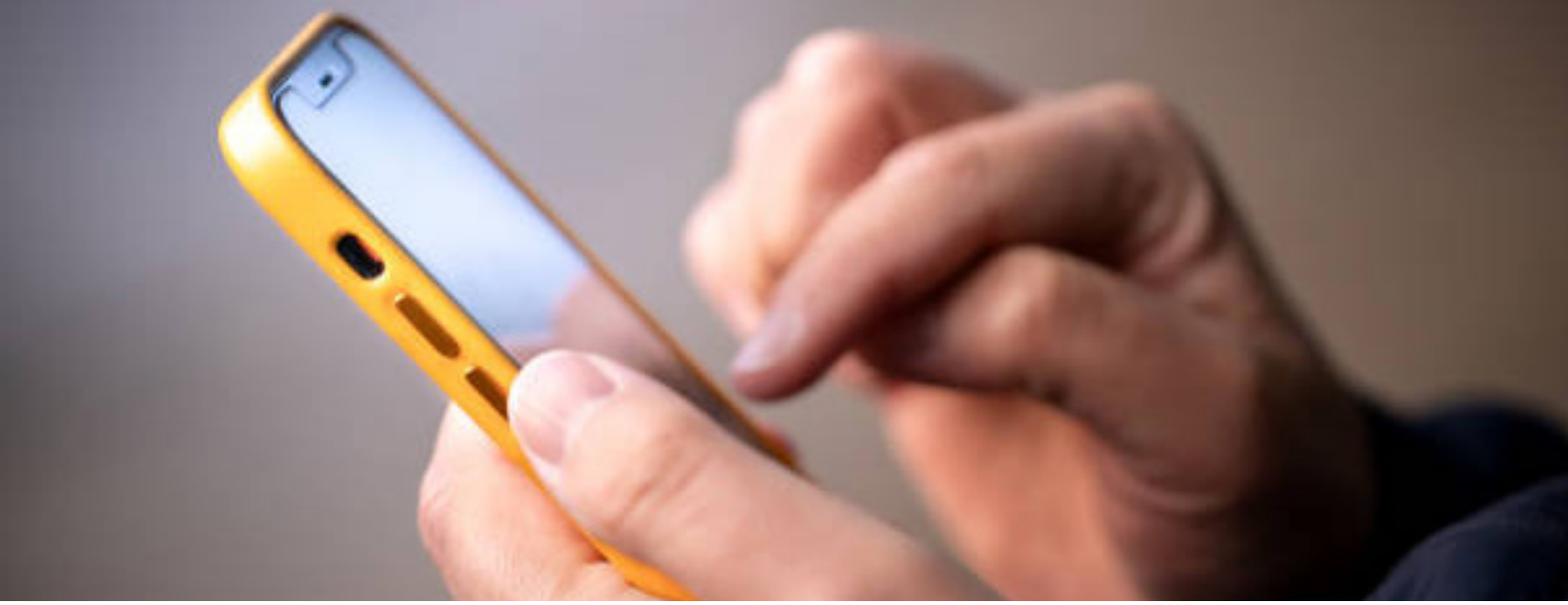


TiC coated Micron



E6 PDA grit





Electronic device production

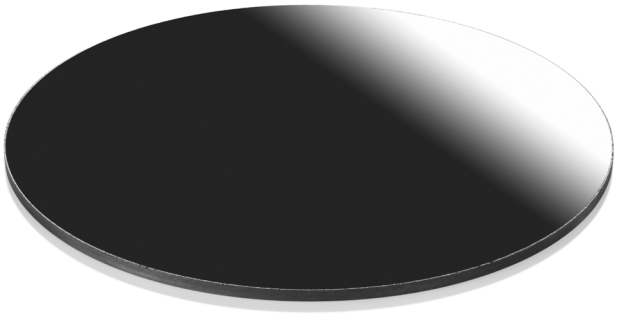
Consumer electronics manufacturing requires precision tooling for hard-to-machine materials, including printed circuit boards, metals, and novel ceramics. Our sintered polycrystalline diamond (PCD) range delivers the quality and reliability expected by world-leading industry manufacturers.

Large form machining of metal and glass parts for smart electronic devices

Product details

Product: PCD for large form machining of metal and glass for electronic devices

Product type: Coarse grade PCD



E6 PCD disc

Key properties

- Multi-modal coarse grade PCD
- High abrasion resistance for extended tool life
- A range of thicknesses of the diamond layer and overall height available
  - >1.5 mm thick diamond layer is possible
- Available in diameters up to 70 mm of usable area
- Available as a full disc or segments

Example applications

CTM302 can be used for form milling of brittle materials, such as glass and ceramics, milling of aluminium chassis parts and drilling small diameter holes. This type machining is adopted in the manufacturing of consumer electronic devices such as smart phones, watches, laptops and tablets.

Multiple tool processing methods are available to achieve the desired tool geometry, including:

- Mechanical grinding
- Electro-discharge machining (EDM)
- Laser ablation

Small form machining and hole drilling of metal and glass components

Product details

Product: PCD for small form and hole drilling of metal and glass

Product type: Extra thick layer PCD



A3DP Planar

Key properties

- 5 micron grain PCD
- Thick layer PCD provides flexibility for tool design
- 2 mm and 4 mm thick PCD layers available
- Ideal for drilling and small diameter milling tools
- Available as cut segments at specific diameters

Example applications

Typical applications include form milling of brittle materials, such as glass and ceramics, milling of aluminium chassis parts, and drilling of small diameter microphone and charging port holes for phones, watches, laptops and tablets.



Glass scribing and segmentation of electronic devices and TVs

Product details

Product: PCD glass scribing for smart electronic devices and TVs

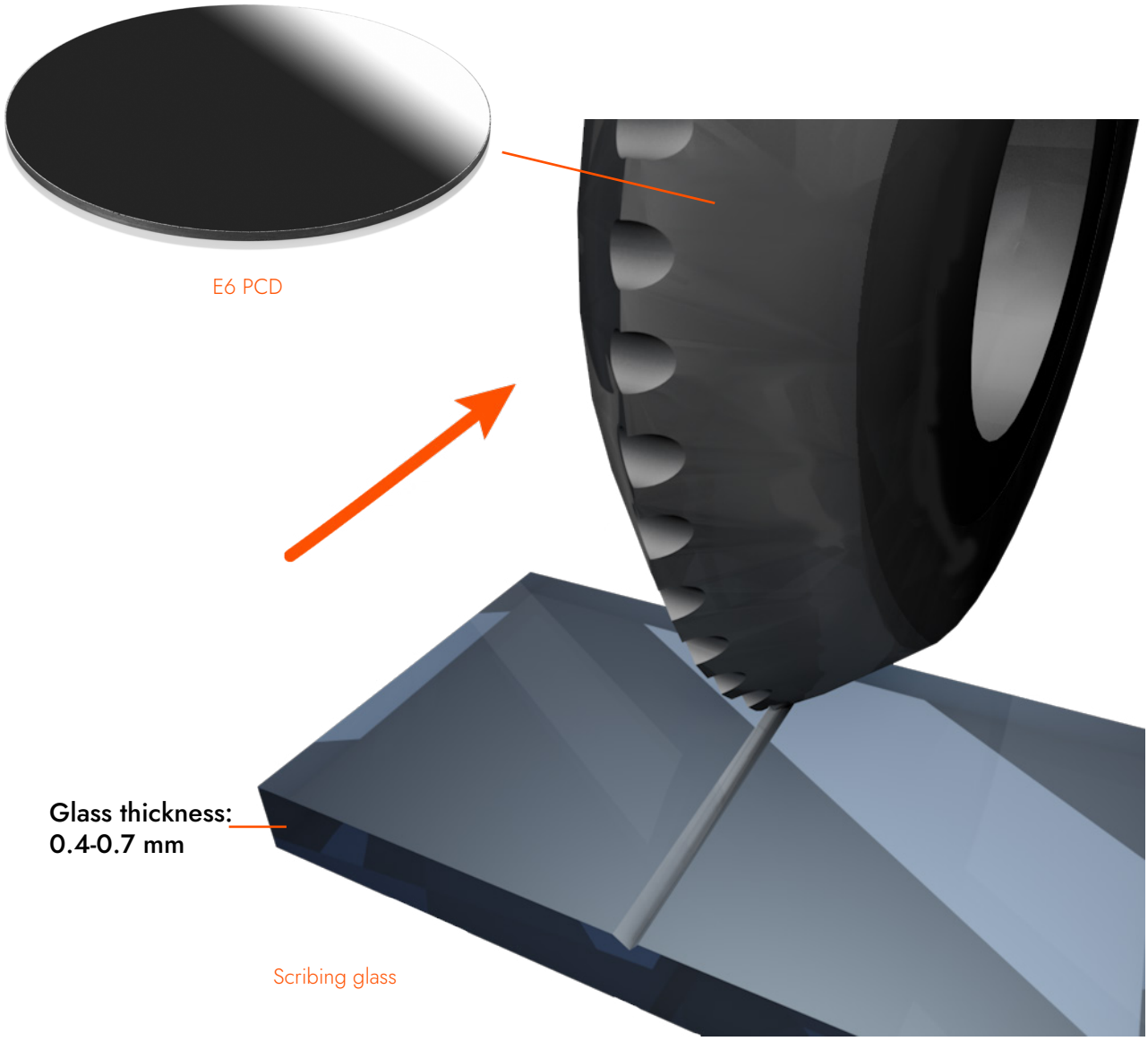
Product type: Super-fine grain PCD

Key properties

- Sub-micron grain size for an ultra-fine tool edge
- Tight tolerance discs supplied to meet application requirements
- Offered as 0.8 mm free-standing PCD discs

Example applications

There are multiple designs of PCD scribers for different thicknesses and types of tempered glass, which operate with a combination of micro-chipping and abrasion wear modes. Typical end-markets include: cover glass for LCD and OLED smart phone screens, tablets and TVs.



Element Six (E6), part of the De Beers Group, designs, develops and produces synthetic diamond and other supermaterials, and operates worldwide with primary facilities in Germany, Ireland, South Africa, the UK and US.

E6 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.

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