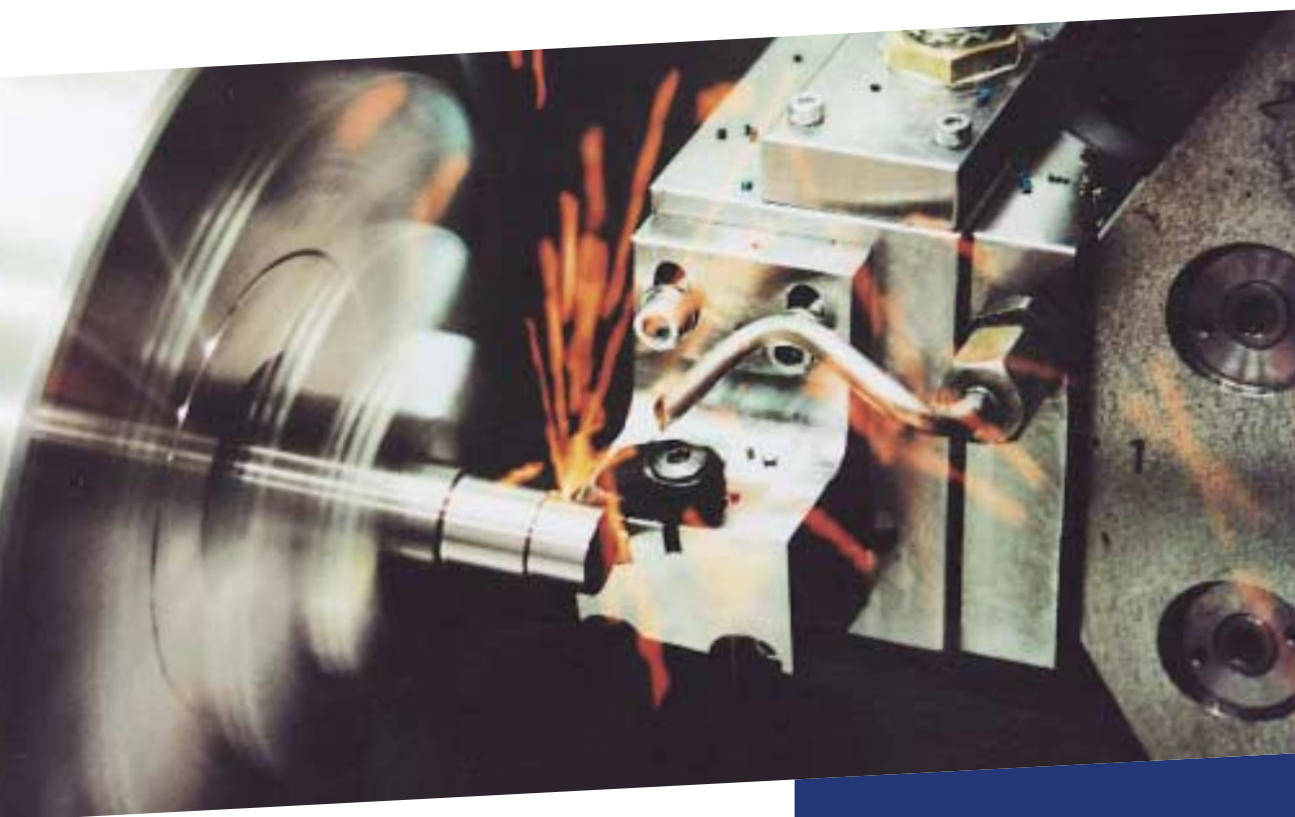


AN INTRODUCTION TO

Cutting Tool Materials



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As the drive towards higher productivity and cutting speeds increases, the case for using diamond tooling of all types continues to rise.



Diamond and PCBN tooling is undoubtedly a key factor in achieving the necessary economic goals of the industries of today.

WITH GREAT PRECISION

Cutting

As the market for diamond and cubic boron nitride tooling continues to develop, so too do the technologies of the raw material supplier. Such have been the advances in the last forty years that natural diamond is no longer alone in the growing range of ultrahard materials now available to the toolmaker.

Following the introduction of synthetic diamond grit in the 1950s, the 1970s yielded a second product, polycrystalline diamond cutting tool material – PCD. PCD, such as Syndite, is a synthesised intergrown mass of randomly orientated diamond crystals bonded to a tungsten carbide substrate. The introduction of this cutting tool material opened up the field of machining abrasive non-ferrous materials with defined cutting edge tools, for example turning and milling.

Another polycrystalline cutting tool material is polycrystalline cubic boron nitride (PCBN), which was developed soon after PCD for machining hard ferrous materials, such as hardened steels and grey cast iron. The introduction of PCBN cutting tool materials such as Amborite has resulted in a range of technical and economical advantages, particularly when compared with grinding.

Today, more options are available to the markets due to the arrival of the next generation of cutting tool materials. Large synthetic single-crystal materials and a range of product developed out of the Chemical Vapour Deposition (CVD) process are available for specialised applications.

A complete range of cutting tool materials ensures that a solution to every ultrahard machining requirement is available from Element Six.

Syndite

AN EXTENSIVE RANGE

Syndite can be regarded as a composite material which combines the hardness, abrasion resistance and thermal conductivity of diamond with the toughness of tungsten carbide. These properties are best utilised in cutting tools for machining a wide variety of abrasive materials, as well as in wear part applications, where they greatly contribute to improved life of the tool or wear part and offer additional technological advantages, such as process reliability and low frictional behaviour.

The extensive Syndite product range covers blanks of various sizes and shapes for the tipping of cutting tools and wear parts.



HOW IT WORKS

Syndite PCD is produced by sintering together micron-sized diamond particles at ultra-high pressure and temperature in the presence of a metallic catalyst. The presence of the metal in the PCD structure, together with the tungsten carbide substrate, confer a degree of toughness and electrical conductivity not found in single crystal diamond products.

Syndite is produced in six standard grades. These six grades are designated CTB 002, CTC 002, CTB 010, CTB 025, CTH 025 and CTM 302 where the numbers refer to the average dimensions in microns of the starting diamond material. The designation CTB refers to standard PCD products, whereas CTC, CTH and CTM refer to modified PCD grades, which are described later. Generally, the finer the diamond grain size, the better the cutting edge and/or surface finish produced, provided that appropriate fabrication techniques are used. Also, as a general rule, the coarser the particle size, the greater the wear resistance, which is also reflected in relative machinability.

This product range enables the toolmaker to select the most appropriate PCD material to meet the requirements of a given application. However, Syndite CTB 010 may, in the majority of cases, be considered the general-purpose grade.

PARAMETERS

Syndite is intended for use as a brazeable cutting tip in all types of standard inserts and single or multi-edge rotary tools, and as a full-face clamp-type insert. For optimum performance with regard to machining quality and tool life, particularly under conditions of interrupted or intermittent cutting, the tooling system should be as rigid as possible.

For the majority of cutting operations, ie. on non-ferrous metals or composite materials, neutral or positive rake geometry is used. This should be designed with the requirements of the particular application and the inherent properties of PCD in mind. Polishing the PCD top face may contribute to improved cutting edge quality and better chip flow characteristics or, in the case of wear part components for example, reduced friction. Coolant is normally used with Syndite tools. However, dry cutting can also be employed where necessary. Because of PCD's extreme wear resistance, the life of Syndite tools under test conditions can be realistically assessed only on very difficult-to-machine (i.e. highly abrasive) materials. For example, Syndite and tungsten carbide in turning a heavily glassfibre reinforced plastic, which although not strictly a representative application, allows direct comparison of the two tool materials on the basis of the volume of material removed by each, with Syndite having the advantage over tungsten carbide by several orders of magnitude.

TYPICAL SYNDITE WORKING PARAMETERS FOR MACHINING DIFFERENT WORKPIECE MATERIALS

WORKPIECE MATERIAL	CUTTING SPEED (m/min)	FEED RATE (mm/rev)	DEPTH OF CUT (mm)
TURNING & BORING			
Aluminium alloys, copper, brass and their alloys	300 - 1000	0.05 - 0.5	up to 10.0
Sintered tungsten carbide	10 - 30	0.1 - 0.2	up to 2.0
Green tungsten carbide	50 - 200	0.1 - 0.5	up to 5.0
Glass - and carbon-fibre-reinforced plastics	100 - 600	0.05 - 0.5	up to 5.0
Green ceramics	100 - 600	up to 0.2	up to 2.0
Reconstituted and fibre-reinforced plastics	50 - 150	0.1 - 0.5	up to 3.0
MILLING, SAWING & ROUTING			
Aluminium alloys	500 - 3000	0.1 - 0.5*	up to 5.0
Chipboard, fibreboard and plastics	2000 - 3000	0.1 - 0.5*	up to 15.0
			*mm/tooth

THE SYNDITE PRODUCT RANGE

Element Six will provide quotations for cut products which are available in all grades. Individual pieces are cut to the highest quality standards and more complex shapes are also available, although minimum order quantities may apply.

SYNDITE CTC 002

Syndite CTC 002 has a 2 micron average grain size. This grade features a modified microstructure by which the subsequent cutting edge is less susceptible to edge chipping. This makes it highly suited to the machining of wood composites, for example the panel sawing of chipboard where the tool cutting action and the workpiece material characteristics tend to make some PCD grades chip. Grade CTC 002 is highly suited to this application.

SYNDITE CTB 002

Syndite CTB 002 has a 2 micron average grain size. It is available in a range of PCD layers and overall thicknesses. Manufactured with fine grain diamond particles, it is suitable for the production of precision tools to provide high workpiece surface finish requirements. As well as the standard PCD layer thickness, this grade is available in thin diamond layer format.

SYNDITE CTB 010

Syndite CTB 010 has a 10 micron average grain size. It is available in a range of PCD layers and overall thicknesses. Being the general purpose grade, this includes standard, thin and thick PCD layers. This allows the manufacture of a wide range of general, precision and roughing tools as well as wear parts. Grade CTB 010 has the best combination of tool fabrication and application performance characteristics.

All Syndite PCD discs are available with a lapped or polished surface and are available in a 74 mm diameter disc or in cut segments.

SYNDITE CTC 002 - ROUND

Element Six Product No.	R743-36005	R742-36005	R741-36005
Dia(mm)	74	74	74
Thick (mm)	3.2	2.0	1.6
Angle °	360	360	360
PCD (mm)	0.5	0.5	0.5

SYNDITE CTB 002 - ROUND

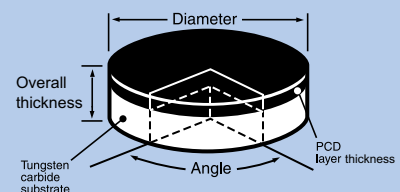
Also available in a 0.3 mm PCD layer thickness

Element Six Product No.	R743-36005	R742-36005	R741-36005
Dia(mm)	74	74	74
Thick (mm)	3.2	2.0	1.6
Angle °	360	360	360
PCD (mm)	0.5	0.5	0.5

SYNDITE CTB 010 - ROUND

Also available in a 0.3 mm PCD layer thickness

Element Six Product No.	R743-36005	R742-36005	R741-36005
Dia (mm)	74	74	74
Thick (mm)	3.2	2.0	1.6
Angle °	360	360	360
PCD (mm)	0.5	0.5	0.5



SYNDITE CTB 025

Syndite CTB 025 has a 25 micron average grain size. This coarse grained PCD is highly wear resistant and is particularly suited to abrasive machining applications where tool life is of prime importance. CTB 025 is well suited to high speed machining and dry machining conditions i.e. where abrasive wear increases significantly.

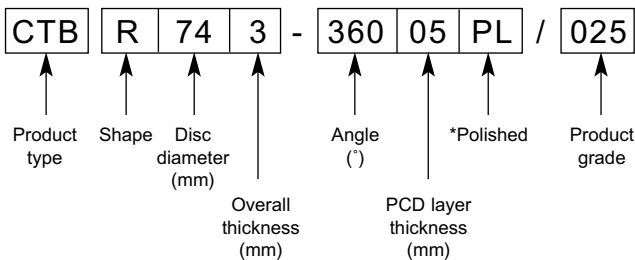
SYNDITE CTH 025

Syndite CTH 025 has a 25 micron average grain size. This grade is manufactured using diamond synthesis conditions specially developed to produce optimum wear resistance in abrasive machining applications. As this is achieved without increasing diamond grain size there are no negative effects of using this material when it comes to tool processing (grinding/EDM) and edge quality considerations.

SYNDITE CTM 302

Syndite CTM 302 extends the range of Syndite products to include a product with a new unique combination of wear resistance, edge strength and quality. It contains a carefully selected mix of micron selected particles of diamond (between 30 and 2µm). The combination of these particle sizes and a specifically developed high pressure sintering process, produces a structure of extreme abrasion resistance, toughness and good edge quality.

For further information on the availability of different diamond layers and thicknesses please contact one of our sales offices. Element Six has devised the following product code system to aid customers when placing orders for Syndite products:-



* only include when polished product is required.

SYNDITE CTB 025 - ROUND

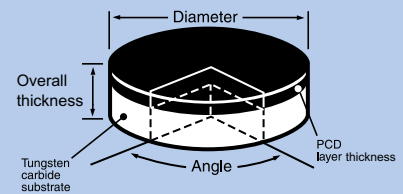
Element Six Product No.	R743-36005	R742-36005	R741-36005
Dia (mm)	74	74	74
Thick(mm)	3.2	2.0	1.6
Angle °	360	360	360
PCD (mm)	0.5	0.5	0.5

SYNDITE CTH 025 - ROUND

Element Six Product No.	R743-36005	R742-36005	R741-36005
Dia (mm)	74	74	74
Thick (mm)	3.2	2.0	1.6
Angle °	360	360	360
PCD (mm)	0.5	0.5	0.5

SYNDITE CTM 302 - ROUND

Element Six Product No.	R743-36005	R742-36005	R741-36005
Dia (mm)	74	74	74
Thick (mm)	3.2	2.0	1.6
Angle °	360	360	360
PCD (mm)	0.5	0.5	0.5



APPLICATIONS

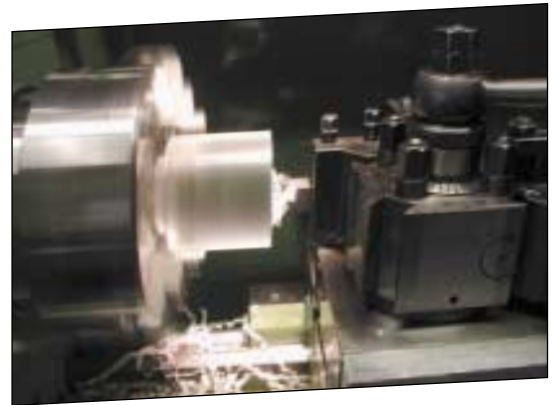
With the development of larger diameter Syndite discs, the use of diamond tools has expanded mostly into volume production industries, in particular automotive and woodworking, as a high-performance replacement for conventional cutting tool materials. As a consistent, engineered and cost-effective product available in edge lengths of up to 74 mm, the growth in its use in various industries have been rapid. Examples of typical workpiece materials are as follows :-

- Chipboard, fibreboard, particle board and hard natural woods
- Metal matrix composites
- Aluminium alloys
- Copper, brass, bronze, magnesium alloy
- Ceramics, fibre glass, carbon fibre
- Plastic, rubber
- Pre-sintered (green) and sintered tungsten carbide
- Mineral material

Due to its high abrasion resistance, PCD is also ideal for use in wear part applications (both ferrous and non ferrous contact surfaces).

Industry has found that tools and wear parts tipped with Syndite outperform conventional alternatives, such as tungsten carbide by between thirty and many hundred times, depending on conditions. This proves that Syndite is economical for any one or more of the following reasons:-

- Increased productivity
- Improved workpiece quality
- Increased process reliability



Machining of an acrylic component with a Syndite PCD tipped turning tool.



Syndite PCD tipped combination tools for finishing machining.



Machining of a MMC brake disc with Syndite PCD.

Amborite

A COMPREHENSIVE RANGE

Amborite comprises a range of PCBN products that utilise excellent hardness, good toughness and thermal stability. These properties make Amborite highly suited to machining a wide range of cast

irons and hardened steels. Machining with Amborite products offers the capability of improved tool life, faster machining speeds and better component tolerance. The extensive Amborite range covers both solid and tungsten carbide backed blanks of various shapes and sizes suitable for practically every type of cutting tool.



HOW IT WORKS

The effectiveness of the Amborite PCBN range in machining hardened steel components in the range 45 to 65 HRC is due to the exploitation of PCBN's high hot-hardness and chemical stability at elevated temperatures through the deliberate generation of heat in the cutting zone, which in turn softens the workpiece material. The self-induced heat generated at the cutting zone is in the region of 700 - 800°C and is enough to reduce the hardness of the material in contact with the cutting tool. This heat-induced soft cutting means that the PCBN is not in contact with the workpiece in its hardened state, thus giving PCBN greater tool life compared with other cutting tool materials.

Amborite products are also very effective in the machining of much softer, but very abrasive grey cast and sintered irons. Here, PCBN's high hardness and abrasion resistance (second only to PCD/diamond) is exploited. Amborite is produced in five standard grades, designated as AMB90, DBW85, DBA80, DBC50 and DBN45. The numbers refer to the volume of cBN material contained within each grade, expressed as a percentage.

PARAMETERS

Amborite AMB90 being a solid product, is intended for use in negative rake clamp-type tool holding arrangements. The other products in the Amborite range are tungsten carbide backed and can be brazed easily to other tungsten carbide surfaces to form a tipped tool arrangement. Alternatively like AMB90 these grades can be used as full top inserts in the solid clamp-type tool holding arrangement.

For the majority of PCBN applications a chamfered and honed cutting edge should be employed. This serves to strengthen the cutting edge and avoid premature tool failure. Tool edge condition selection and application are an integral part of the tool manufacturing process. In many cases the performance level of the tool is strongly influenced by the edge selection and preparation process. Machining operation and parameters, workpiece material and grade of PCBN are all important factors in considering edge preparation

The high PCBN Amborite grades AMB90, DBW85 and DBA80 are generally used for roughing and semi-finishing of hardened steels and irons, and for all machining operations on grey cast irons. The low PCBN Amborite grades, DBC50 and DBN45 are used for finish machining operations where the depth of cut is less than 0.5 mm. This is explained by the fact that the greater thermal conductivity of the high PCBN grades is beneficial in higher stock removal machining, but the situation is reversed in finish machining, where the low heat generation means that materials with lower cBN content, and, therefore with reduced thermal conductivity are more advantageous in terms of wear resistance.

TYPICAL AMBORITE WORKING PARAMETERS FOR MACHINING DIFFERENT WORKPIECE MATERIALS

WORKPIECE MATERIAL	OPERATION		PRODUCT	CUTTING SPEED (m/min)	FEED RATE (mm/rev)	DEPTH OF CUT (mm)
	Rough	Finish				
Hardened steel	✓		AMB90/DBW85/DBA80	60 - 200	0.1 - 0.3	up to 3.0
		✓	DBC50/DBN45	90 - 200	up to 0.2	up to 0.5
Grey cast iron	✓		AMB90/DBW85/DBA80	400 - 2500	0.1 - 0.8	up to 3.0
		✓	AMB90/DBW85/DBA80/DBC50	400 - 2000	0.1 - 0.6	up to 1.0
Hard iron	✓	✓	AMB90/DBW85/DBA80	40 - 150	0.1 - 1.0	up to 5.0
Hard facing alloys	✓		AMB90/DBW85/DBA80	50 - 200	0.2 - 0.4	up to 3.0
		✓	DBC50/DBN45	50 - 200	up to 0.2	up to 0.5
Sintered iron	✓	✓	DBC50/DBW85	100 - 300	0.1 - 0.3	up to 1.0

THE AMBORITE PRODUCT RANGE

AMBORITE AMB90 010

Amborite AMB90 is a high (approx. 90 vol. %) cBN content PCBN material with a relatively coarse grain structure. This material possesses high thermal conductivity and has proved particularly effective in the machining of hard ferrous materials at medium to high stock removal rates. Amborite AMB90 is a solid PCBN material, without a tungsten carbide backing and with an aluminium ceramic-based binder phase, making it particularly well suited to meet the thermal requirements of such machining operations.

AMBORITE DBW85 002

Amborite DBW85 is available with a layer of PCBN supported by a tungsten carbide substrate. It consists of 85% cBN by volume with a tungsten cobalt and aluminium based binder. The cBN grain size before synthesis averages 2 microns. DBW85 is a versatile PCBN grade making it suitable for all types of machining operations.

AMBORITE DBA80 006

Amborite DBA80 is a medium-grain PCBN material containing approx. 80% by volume cBN, and has a titanium/aluminium-based binder phase and a tungsten carbide backing, thereby offering full flexibility for optimised tool design.

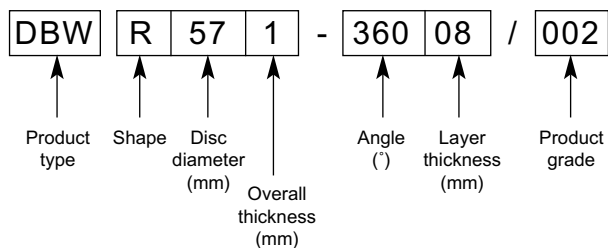
AMBORITE DBC50 002

Amborite DBC50 is a fine-grain PCBN material containing approx. 50% by volume cBN in a titanium carbide based binder phase. It has improved edge stability in hard ferrous machining under continuous fine cutting conditions with the resulting benefits of longer tool life and improved workpiece quality.

AMBORITE DBN45 001

Amborite DBN45 is available with a layer of PCBN supported by a tungsten carbide substrate. It consists of 45% cBN by volume with a titanium nitride ceramic binder. The cBN grain size before synthesis averages less than 1 micron. DBN45 has an extremely tough structure making it particularly suited to hard ferrous machining under interrupted fine cutting conditions. Its sub-micron grain size enables the generation of extremely fine surface finishes.

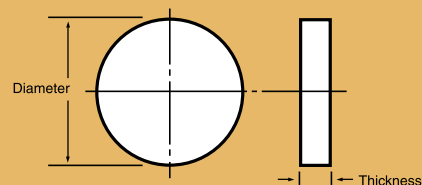
Element Six has devised the following product code system to aid customers when placing orders for Amborite products:-



AMBORITE AMB90 - ROUND

(R Series)

Element Six Product No.	R1013-360	R1014-360	R1016-360
Dia (mm)	101.6	101.6	101.6
Thick (mm)	3.2	4.8	6.4
Angle °	360	360	360



AMBORITE DBW85 - ROUND

(R Series)

Element Six Product No.	R571-36008	R572-36008	R573-36008	R574-36008
Dia (mm)	57	57	57	57
Thick (mm)	1.6	2.4	3.2	4.8
Angle °	360	360	360	360
PCBN (mm)	0.8	0.8	0.8	0.8

AMBORITE DBA80 - ROUND

(R Series)

Element Six Product No.	R571-36008	R572-36008	R573-36008	R574-36008
Dia (mm)	57	57	57	57
Thick (mm)	1.6	2.4	3.2	4.8
Angle °	360	360	360	360
PCBN (mm)	0.8	0.8	0.8	0.8

AMBORITE DBC50 - ROUND

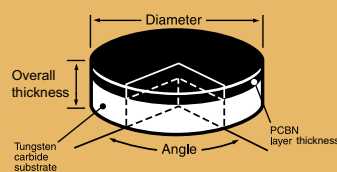
(R Series)

Element Six Product No.	R571-36008	R572-36008	R573-36008	R574-36008
Dia (mm)	57	57	57	57
Thick (mm)	1.6	2.4	3.2	4.8
Angle °	360	360	360	360
PCBN (mm)	0.8	0.8	0.8	0.8

AMBORITE DBN45 - ROUND

(R Series)

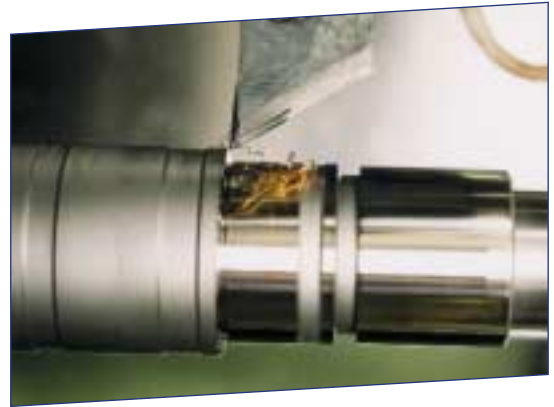
Element Six Product No.	R571-36008	R572-36008	R573-36008	R574-36008
Dia (mm)	57	57	57	57
Thick (mm)	1.6	2.4	3.2	4.8
Angle °	360	360	360	360
PCBN (mm)	0.8	0.8	0.8 </tr	



APPLICATIONS

Amorite (PCBN) is widely used to machine a wide variety of hard and/or abrasive ferrous workpiece materials. PCBN is chemically inert up to high temperatures and unlike PCD, therefore, has a relatively low chemical reaction with iron in ferrous workpiece materials. Typical components machined with PCBN are brake discs, engine blocks, engine cylinder liners, brake drums, flywheels, valve seats/guides, machine parts, gears, mould and die parts etc. Examples of typical workpiece materials are as follows :-

- Hot/cold worked tool steel (45 - 65 HRc)
- Case hardened steel (45 - 65 HRc)
- High speed steel (45 - 65 HRc)
- Bearing steel (45 - 65 HRc)
- Sintered iron (> 30 HRc)
- Hard facing alloys (> 35 HRc)
- Grey cast irons (200 - 280 HBN)



Hard turning a fuel pump barrel with Amorite DBN45.



Surface turning a hardened axle drive bevel wheel with PCBN.

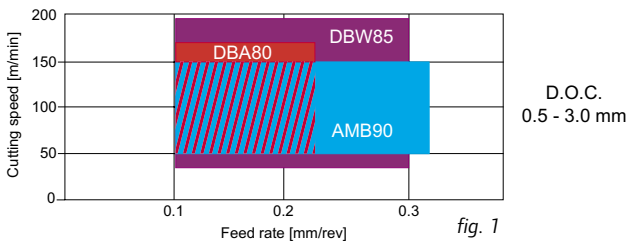


fig. 1

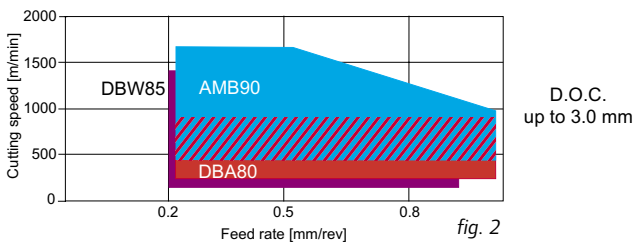


fig. 2

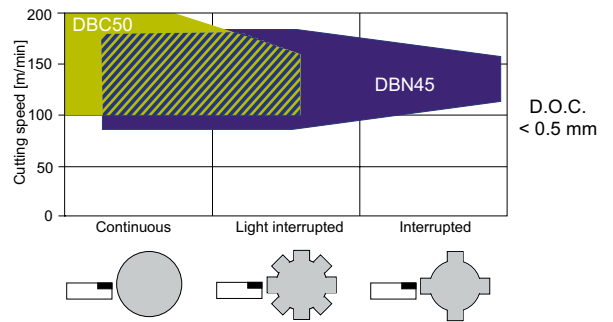
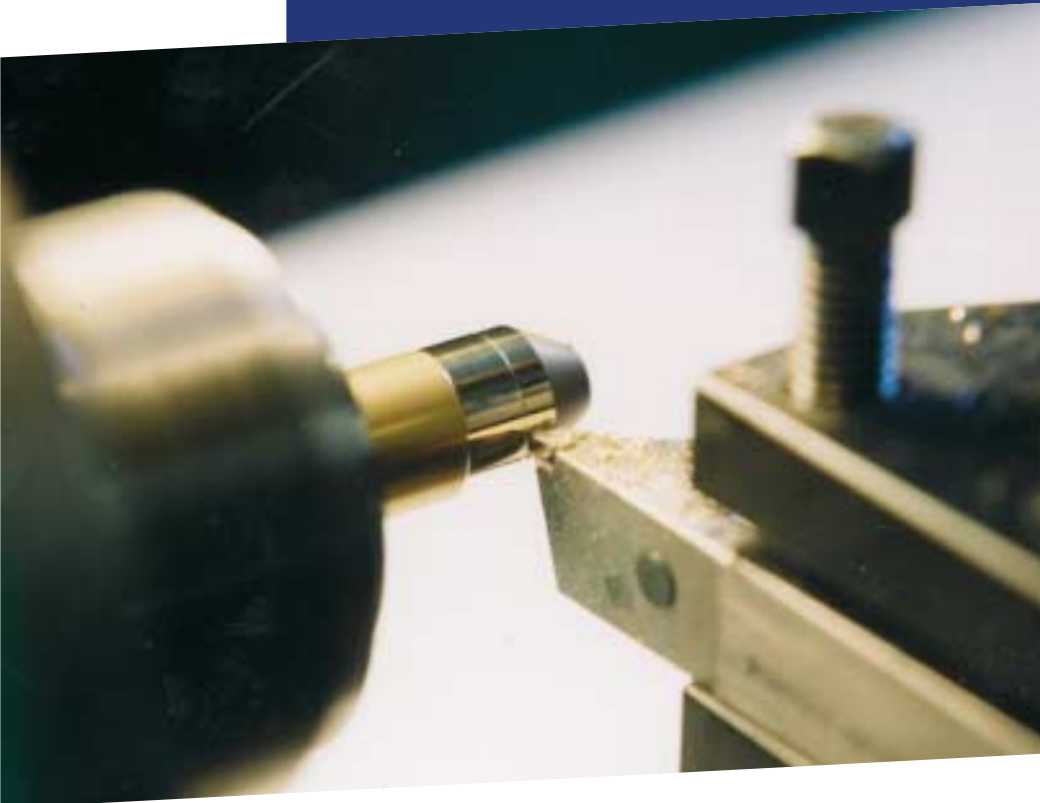


fig. 3

fig. 1 Machining hardened steel.

fig. 2 Machining grey cast iron (200-280HBN).

fig. 3 Finishing machining hardened steel (> 45 HRc). Typical of cutting conditions.



SINGLE CRYSTAL DIAMOND

Mono

The Mono range consists of a series of products, all of which are derived from high quality single crystal diamonds synthesised under tightly controlled growth conditions and subject to high standards of quality control with regard to dimensions and physical characteristics. Mono products are used for cutting tools for non-ferrous and non-metallic materials, dressers for wheel dressing, a variety of speciality knives, burnishing tools, wear parts, and wire drawing dies.

HOW IT WORKS

Element Six produces single crystal diamond products for use in a wide range of cutting tool, drawing die and wear part applications. The Mono range of products is produced using advanced synthesis processes and must pass high standards of quality control before entering their product lines.

As with all monocrystalline products from Element Six, Monodress is produced using advanced synthesis technology. The size of the monocrystal starting material is such that dresser logs of up to 7 mm length and 1.5 mm thickness can be produced, in square or rectangular cross section, and with 4 point faces on all sides.

Mono products are Type Ib diamond with excellent heat conducting characteristics (four times that of copper), and are free from metal inclusions within the critical working zone. These properties are similar to those generally found in natural diamond, ensuring rapid removal of heat from the cutting point of a cutting tool or the drawing zone of a wire drawing die. This contributes greatly to consistency of tool performance. They are oriented with respect to

diamond's crystallographic planes and are thermally stable in excess of 1000°C in a protected non-oxidising environment.

The product range offers a wide choice of geometries, edge lengths and cross-sectional areas to give the diamond tool and die maker unprecedented options plus the opportunity to manufacture tools for a broad range of applications.

PARAMETERS

The application areas of Monodite are cutting tools, surgical knives, fibre optic cleaving knives, microtome knives, heat sinks, lead bonding tools, EDM wire guides, burnishing tools, and wear parts. In cutting tool applications Monodite can be used for the machining of same materials that are machined with natural diamond, using similar machining parameters.

TYPICAL MONODITE WORKING PARAMETERS FOR MACHINING DIFFERENT WORKPIECE MATERIALS

WORKPIECE MATERIAL	CUTTING SPEED (m/min)	FEED RATE (mm/rev)	DEPTH OF CUT (mm)
Fluorosilicone acrylate/silicone acrylate soft contact lenses	100 - 200	0.4	0.1 - 1.5
Oxygen free copper <i>(10% oil additive coolant)</i>	200 - 880	0.05	0.1
9ct. gold bracelet	10,000 rpm <i>(spindle speed)</i>	-	-
9ct. gold stud earring	15,000 rpm <i>(spindle speed)</i>	-	-
PMMA hard contact lenses	100 - 200	0.04	0.1 - 1.5

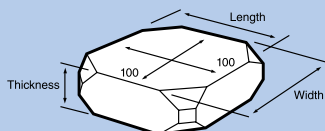
TYPICAL MONODRESS WORKING PARAMETERS

WORKPIECE MATERIAL	CUTTING SPEED (m/min)	FEED/LEAD (mm/rev)	DEPTH OF CUT (mm)
Aluminium oxide grinding wheel specification WA 80 KV	25 - 35	0.05 - 0.2	0.01 - 0.15
Silicon carbide grinding wheel specification GC 46 LV	25 - 35	0.05 - 0.2	0.01 - 0.15

Below is a selection of standard products available from Element Six, for more information on the complete Mono range please contact one of our sales offices.

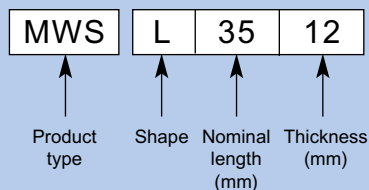
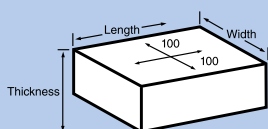
MONOPLATE MWS

Element Six Product No.	MWS 2510	MWS 2512	MWS 3010	MWS 3012	MWS 3510	MWS 3512
Length (mm)	2.5	2.5	3.0	3.0	3.5	3.5
Width (mm)	2.5	2.5	3.0	3.0	3.5	3.5
Thick (mm)	1.0	1.2	1.0	1.2	1.0	1.2



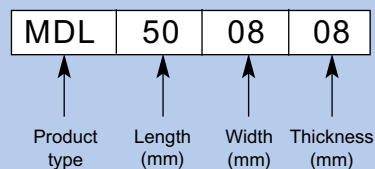
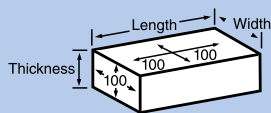
MONODITE MT

Element Six Product No.	MTL 503012	MTL 403015	MTL 403012	MTL 303015	MTL 303012	MTL 252512
Length (mm)	5.0	4.0	4.0	3.0	3.0	2.5
Width (mm)	3.0	3.0	3.0	3.0	3.0	2.5
Thick (mm)	1.2	1.5	1.2	1.5	1.5	1.5



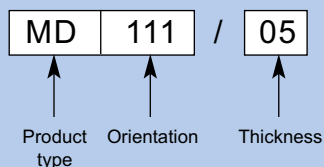
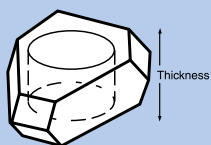
MONODRESS MDL

Element Six Product No.	MDL 251212	MDL 300808	MDL 400606	MDL 400808	MDL 500606	MDL 500808
Length (mm)	2.5	3.0	4.0	4.0	5.0	5.0
Width (mm)	1.2	0.8	0.6	0.8	0.6	0.8
Thick (mm)	1.2	0.8	0.6	0.8	0.6	0.8



MONODIE MD111

Element Six Product No.	MD 111/10	MD 111/9	MD 111/8	MD 111/7	MD 111/6	MD 111/5
Orientation	111	111	111	111	111	111
Thickness	1.0	0.9	0.8	0.7	0.6	0.5



THE MONO PRODUCT RANGE

MONODITE

The Monodite family includes the Monoplate tool blank range, incorporating the MWS, MXP and MSP plates, and the highly engineered Monodite MT products. The MWS and MXP plates are available with edge lengths from 2.0 mm to 5.5 mm, with thickness from 0.8 mm to 1.5 mm. Larger edge lengths are provided by the MSP plates with typical dimensions from 6.0 mm to 10.0 mm, and with thickness up to 2.0 mm. The highly engineered Monodite MT product is available in a wide variety of shapes and sizes.

Monoplate MWS

A diamond plate defined by an inscribed circle of ~80% of the usable four-point length. Available in lengths up to 5.5 mm.

Monoplate MXP

A diamond plate defined by an inscribed square of ~75% of the usable four-point length. Available in lengths up to 5 mm.

Monoplate MSP

Large sawn plates in the 6 mm to 10 mm length range, available as individual units according to specific requirements.

Monodite MT

A highly engineered and tightly specified product. Available in standard formats and can be produced to meet specific customer requirements.

MONODRESS

The Monodress logs provide the toolmaker with exceptional ease of fabrication, by virtue of the fact that the 4 point faces are easily defined and located with their grinding directions as shown.

Monodress MDL

A specially engineered product for dressing and parting tool applications. Available as uniform cross-section logs in a standard size range. Monodress MDL has outstanding thermal properties and very high thermal oxidation resistance. It is ideal for secure mounting when using traditional non-ferrous metal sintering. Alternatively, the synthetic single crystal diamond dressers can be brazed onto a dresser body using an active braze alloy in a non-oxidising environment.

MONODIE

Monodie MD111 die blanks can be used for drawing ferrous, non-ferrous, precious and refractory metals. The blanks also possess excellent thermal conductivity and, in a non-oxidising environment, are thermally stable at temperatures up to 1100°C.

APPLICATIONS

The wide range of synthetic single-crystal diamond in the Mono product range has been developed to meet the exacting requirements of many different industries. In particular, Monodite, which has excellent wear resistance and consistent properties, has found application in fine finishing applications such as: hard and soft contact lens machining; fly-cutting thermal imaging components; turning aluminium surfaces to the exceptional surface finish required for optical components and the compact disc industry; plus milling and engraving jewellery products. The wide variety of applications of this material reflect its versatility. Mono products are also used for dressing tools, high-pressure anvils, fibre-optic cleaving knives, lead-bonding tools, nozzles and EDM wire guides. The long edges available from Monodite also lend themselves to applications such as heat sinks and surgical blades.



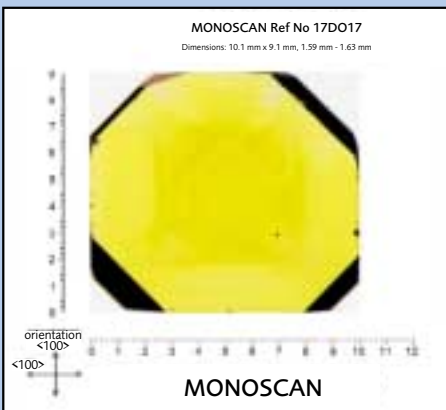
Single-crystal diamond saw teeth used for cutting laminate flooring panels.

MONOSCAN

To enable the diamond toolmaker to determine which Monoplate MSPs are available, a catalogue of Monoscans has been developed. The catalogue of high resolution images - referred to as Monoscans - is of currently held stock so that the most suitable Monoplate MSP can be selected for any application. Each specific catalogue has an expiry date and updates are issued periodically to ensure that the catalogue accurately lists the available stock.

The catalogue of all Monoplate MSP products which are currently available for sale can be viewed on the internet at www.mono-online.net. On this website it is possible to reserve specific plates and mark up the cut pattern required to provide material suitable for long edge length Mono cutting tools.

A Monoscan is a high resolution scanned visual image of a Monoplate. This digital colour image shows the internal and external features of the Monoplate with internal features as small as 10 microns being clearly visible.



An example Monoscan from the mono-online website.



Dressing of a grinding wheel with Monodress.

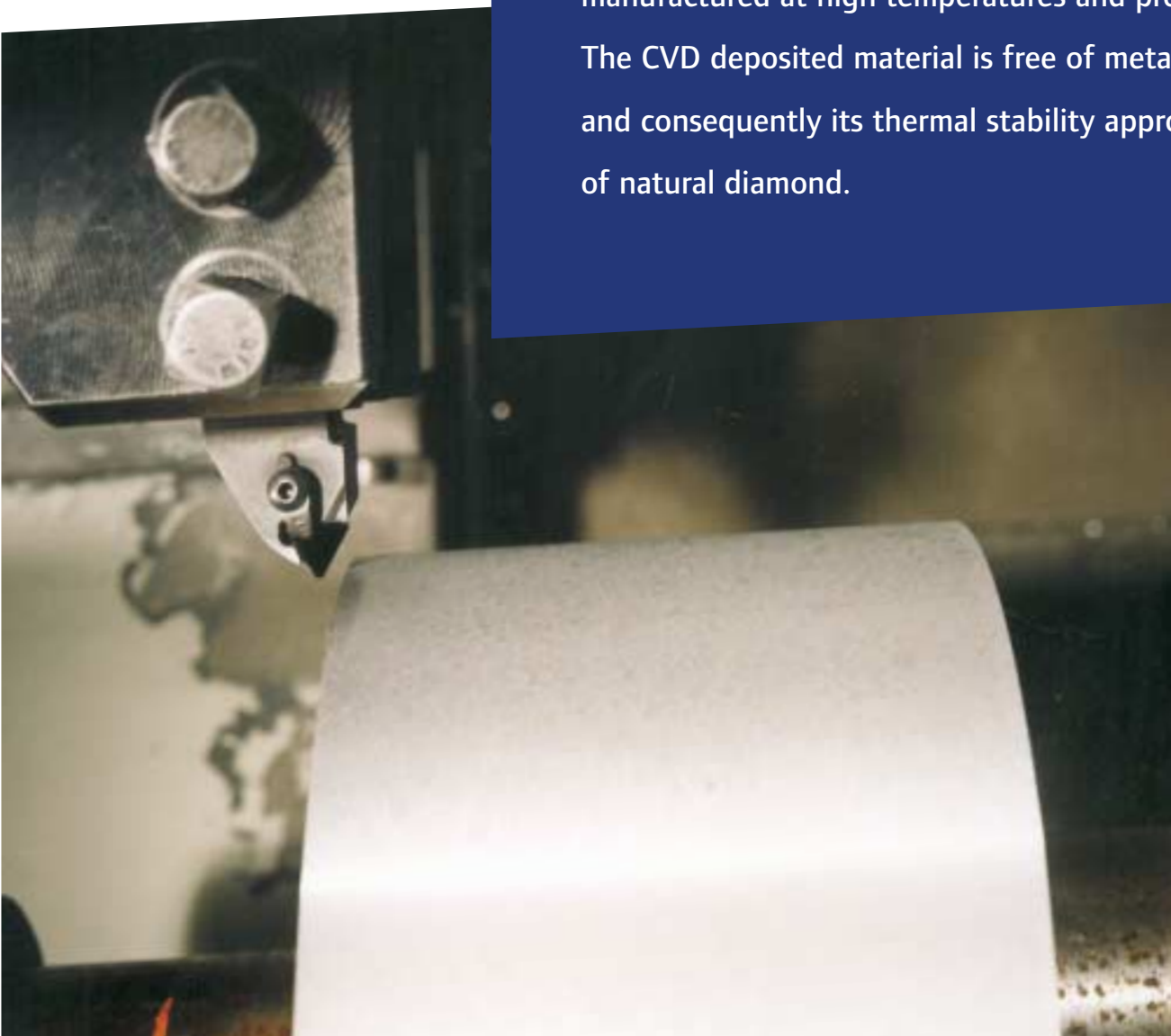


Cutting of an internal thread with a Monodite diamond tool for a component used in dentistry.

ENGINEERED FOR MECHANICAL APPLICATIONS

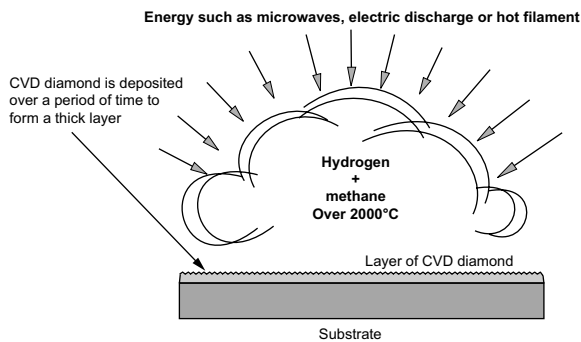
CVD Diamond

Chemical Vapour Deposition (CVD) diamond is synthesised at relatively low pressure whereas PCD and PCBN and synthetic single-crystal diamond are manufactured at high temperatures and pressures. The CVD deposited material is free of metal catalyst and consequently its thermal stability approaches that of natural diamond.



HOW IT WORKS

Chemical Vapour Deposition (or CVD) is the scientific term for a thin film growing process first developed over forty years ago. The technique generally involves forming a material from a hot reactive gas mix which condenses onto a controlled surface (or substrate). In contrast to high pressure and high temperature crystal synthesis, the CVD technique is generally - though not always - performed at below atmospheric pressure and used to grow microns-thick coatings onto surfaces of a few square centimetres. Development of CVD diamond technology over the last decade has led to the growth of millimetres-thick, self-supporting layers over larger areas, most often used to grow high purity semiconductor device structures. The CVD technique is nowadays frequently used in industry to grow high purity polycrystalline diamond raw materials previously only synthesised as thin films in research laboratory processes. Element Six has adapted and developed this technology for the production of diamond films.



A schematic of the CVD diamond process.

PROPERTIES

In most respects, CVD diamond has the extreme chemical and physical properties of natural and high pressure high temperature (HPHT) synthetic diamond. It is essentially pure carbon with no binder phase. However, formed as intergrown diamond microcrystallites, CVD diamond is a truly polycrystalline material. As is the case with many materials grown with thin-film technology, the grains in this CVD diamond grow from small nuclei which intergrow as they become larger and as the layer becomes thicker giving it a columnar structure.

CVD diamond is chemically inert, has outstanding thermal conductivity and excellent abrasion resistance. Depending on the synthesis process used, CVD diamond can be engineered to give a range of diamond material properties which enable new technologies and new opportunities for research and industry. The table below illustrates some of the generic thermal and mechanical properties of CVD diamond compared with single crystal diamond and Syndite.

Each individual grade has been designed to meet the needs of a particular application area and exploit one or more of diamond's unique properties. Each product range optimises combinations of material properties desired by both research and industry .

CVDITE

Cvdite is a CVD diamond range which has been specially developed for cutting tool and wear part applications. This range, comprising of two grades, has been designed to complement the existing Syndite and Monodite ranges.

COMPARISONS BETWEEN CVDITE, SINGLE CRYSTAL DIAMOND AND SYNDITE

PROPERTY	CVDITE	SINGLE CRYSTAL DIAMOND	SYNDITE
Density (x10 ³ kg/m ³)	3.52	3.52	4.12
Hardness (GPa)	85 - 100	50 - 100	50
Fracture toughness (MPam exp 0.5)	5.5 - 8.5	3.4	8.81
Young's modulus (GPa)	1000 - 1100	1000 - 1100	776
Poisson's ratio	0.07	0.07	0.07
Tensile strength (MPa)	450 - 1100 (Growth - Nucleation)	1050 - 3000 (Orientation dependent)	1260
Transverse rupture strength (GPa)	1.3	2.9	1.2
Compressive strength (GPa)	9.0	9.0	7.60
Thermal conductivity at 20°C (W/mK)	500 - 2200	600 - 2200	560
Thermal conductivity at 200°C (W/mK)	500 - 1100	600 - 1100	200
Thermal diffusivity (cm ² /s)	2.8 - 11.6	5.5 - 11.6	2.7
Thermal expansion coef.			
300K	1.21	1.21	4.2
500K	3.84	3.84	-
1000K	4.45	4.45	6.3

THE CVD DIAMOND PRODUCT RANGE

Cvdite CDM and CDE

These new materials, which have both good fracture strength and toughness, have been engineered for mechanical applications such as the machining of highly abrasive non-ferrous material, plastics, wood-based materials and wear-part applications. These products do not contain a metallic binder phase or catalyst and therefore have extremely high thermal stability.

Cvdite CDE is specially synthesised to make it electrically conductive and therefore EDM-cuttable, whereas Cvdite CDM is a near perfect electrical insulator and is not processable using EDM techniques. The electrical conductivity of Cvdite CDE provides an opportunity for diamond tool fabricators to process this material with existing equipment suitable for PCD processing. The standard surface finish condition of Cvdite CDE is polished.

Cvdite CDM has very high thermal conductivity and excellent thermal oxidation resistance, making it suitable for both high-speed and dry machining of highly abrasive composites - a growing trend within the cutting tool industry. The standard surface finish is polished.

Cvdite blanks are available ex-stock in the shapes and sizes detailed in these tables. Other shapes and sizes may be available on request according to blank size and availability.

CVDRESS

A free-standing CVD diamond grade specifically designed for dressing and truing of grinding wheels. Supplied predominantly as "logs", these integrate well into traditional dresser manufacturing techniques with the advantage of long, uniform wear lengths where dressing ability is not orientation dependent.

Cvdress CDD

Cvdress CDD dresser blanks have outstanding thermal properties and very high thermal oxidation resistance. They are ideal for secure mounting when using traditional non-ferrous metal sintering. Alternatively, the CVD diamond dressers can be brazed onto a dresser body using an active braze alloy in a non-oxidising environment. Using PCD grinding techniques, the dressers can be shaped in-situ to make cone, chisel and radius shapes.

Cvdress CDM NP

This option is intended for the manufacture of dressers and is specified by the addition of "NP" to the product codes. Cvdite CDM unpolished material provides a very cost effective solution for the manufacture of rotary dressing tools, where a large number of dressing elements are required and the optimum wear resistance is not a requirement.

CVDITE CDM/CDE - RECTANGLE

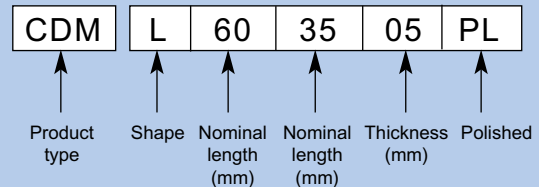
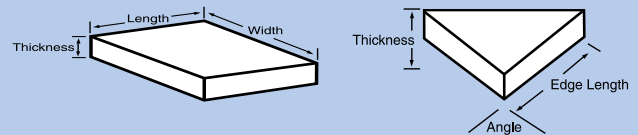
(L Series) Also available in other formats and sizes

Element Six Product No.	CDM/CDE L603505PL	CDM/CDE L604305PL	CDM/CDE L605205PL
Length (mm)	6.0	6.0	6.0
Width (mm)	3.5	4.3	5.2
Thick (mm)	0.5	0.5	0.5

CVDITE CDM/CDE - TRIANGLE

(T Series) Also available in other formats and sizes

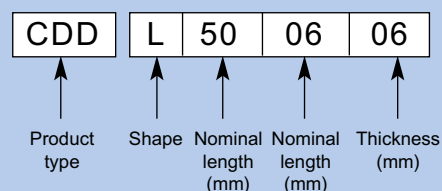
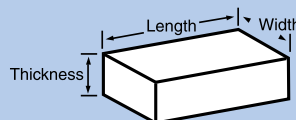
Element Six Product No.	CDM/CDE T5005-60PL	CDM/CDE T5005-90PL	CDM/CDE T7005-60PL	CDM/CDE T7005-90PL
Edge (mm)	5.0	5.0	7.0	7.0
Angle °	60	90	60	90
Thick (mm)	0.5	0.5	0.5	0.5



CVDRESS CDD - LOGS

(L Series)

Element Six Product No.	CDD L200808	CDD L400808	CDD L500404	CDD L500606	CDD L500808
Length (mm)	2.0	4.0	5.0	5.0	5.0
Width (mm)	0.8	0.8	0.4	0.6	0.8
Thick (mm)	0.8	0.8	0.4	0.6	0.8



APPLICATIONS

Various CVD deposition processes allow the synthesis of diamond with a wide range of grain sizes and morphologies suitable for specific applications. The choice of crystal grain size and deposition technique can be tailored. The properties for a tool are wide-ranging and it is probable that more than one variant of CVD is needed to cater for all applications.

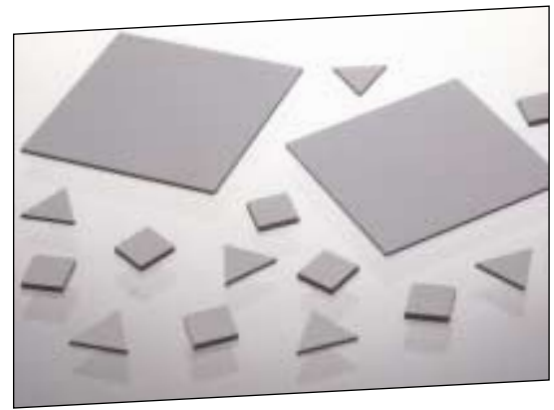
CVD cutting tool products will expand the PCD range of machining applications, which include the machining of highly abrasive workpiece materials where the purity of the diamond, and hence increased abrasion resistance and thermal stability, may be utilised.

Cvdite is generally recommended for machining non-ferrous materials where high abrasion resistance is required. Although highly abrasion resistant and hard, it is less tougher than PCD and is not recommended for use in interrupted or intermittent cutting, since optimum performance is limited by potential edge-chipping. Typical examples of workpiece materials which can be manufactured by CVD are those machined with PCD, which include:

- Metal matrix composites
- Aluminium alloys
- Glass-reinforced plastics and carbon fibre-based materials
- Plastics and rubbers
- Graphite

Due to its high abrasion resistance and low coefficient of sliding friction, the Cvdite range is also ideal for use in lubricated or dry wear part applications.

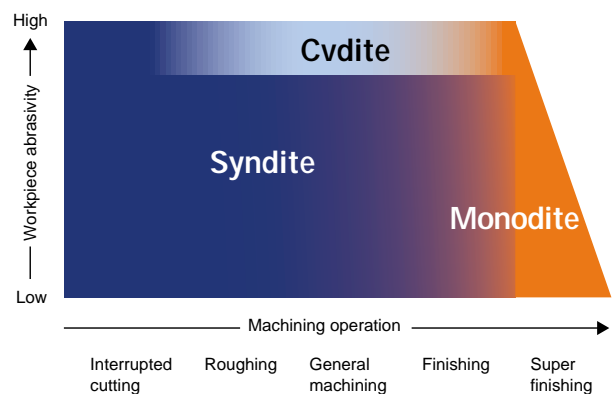
Cvdite extends the range of diamond cutting tool materials available from Element Six. The diagram to the right gives an indication as to where Cvdite may be evaluated in relation to machining operation and workpiece material for diamond cutting tools not PCBN.



Cvdite CDM.



Cvdress CDD.





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Further literature available from Element Six

This publication is one of a series on Element Six PCD, PCBN, single crystal and CVD diamond products and their applications. For details of availability and to obtain other publications in the series, please contact your local supplier of Element Six products, or any Element Six office.

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