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CVD diamond tools — Categorization

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Foreword

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This document was prepared by Technical Committee ISO/TC 29, *Small tools*, Subcommittee SC 9, *Tools with defined cutting edges, holding tools, cutting items, adaptive items and interfaces*.

Any feedback or questions on this document should be directed to the user's national standards body. A complete listing of these bodies can be found at www.iso.org/members.html.

CVD diamond tools — Categorization

1 Scope

This document deals with diamond tools whose cutting edges are made of CVD diamond, either as a solid single piece or as a coating. The tool specifications are differentiated into CVD diamond-coated tools (CVD diamond thin-film coatings) and tools with a CVD diamond cutting insert.

According to ISO 513, CVD diamond tools can be classified under "hard coatings of hard metal and ceramic" and "binder-free polycrystalline diamond". In order to differentiate the CVD diamond tools from tools with monocrystalline synthetic or natural diamond (MCD or monocrystalline diamond) or with sintered diamond with a binder phase (PCD or polycrystalline diamond), the structure and characteristics of MCD and PCD tools with binder phase are also briefly described.

2 Normative references

There are no normative references in this document.

3 Terms and definitions

For the purposes of this document, the following terms and definitions apply.

ISO and IEC maintain terminological databases for use in standardization at the following addresses:

— ISO Online browsing platform: available at https://www.iso.org/obp

— IEC Electropedia: available at http://www.electropedia.org/

3.1
active brazing
process of joining diamond to a metallic substrate by means of a brazing alloy

Note 1 to entry: The brazing alloy contains so-called active elements (titanium, for example) which form unsaturated carbides with the carbon atoms of the diamond and in this way bond the diamond to the braze material. Brazing of this kind is carried out in a vacuum or in shielding gas atmosphere.

3.2
chemical vapour deposition
CVD
process for manufacturing diamond in most cases at low-pressure and deposition temperatures of 600 °C to 1 000 °C

Note 1 to entry: Polycrystalline, binder-free diamond coatings and even monocrystals can be produced.

3.3
high-pressure high-temperature synthesis
HPHT synthesis
method of manufacturing diamond at a pressure of approximately 6 GPa and temperatures, *T*, between 1 400 °C and 1 800 °C

Note 1 to entry: It is only possible to manufacture monocrystals by HPHT synthesis.

3.4
monocrystalline diamond
MCD
cutting material made of diamond in natural or synthetic modification [from *HPHT synthesis* (3.3)]

3.5
polycrystalline diamond
PCD
diamond-cutting material which is manufactured by a two-stage high-pressure high-temperature sintering process [*HPHT synthesis* (3.3)]

Note 1 to entry: The diamond crystallites which are produced in different crystallite sizes in the first step (through HPHT synthesis) are sintered into a cobalt matrix in the second step.

3.6
blank
diamond crystallites which are produced in different crystallite sizes in the first step are sintered into a cobalt matrix in the second step

Note 1 to entry: Due to the conditions of synthesis, the blank is a cylindrical disk with a thickness, s_D, of 300 µm to 2 000 µm.

3.7
cutting insert
platelet made of super-hard cutting material which is brazed onto a *tool holder* (3.9) and is used as a cutting part

3.8
cemented carbide
substrate material that consists of a hard metal phase and a binder phase for use as *CVD* (3.2) diamond coated thin film cutting tools

Note 1 to entry: Monotungsten carbide (WC) as hard metal combined with cobalt (Co) as a binder phase are commonly referred to as WC-Co. Cemented carbides may also consist of three phases: the Monotungsten carbide phase (WC) as the alpha phase, the binder phase (Co, Ni, etc.) as the beta phase and any other individual or combined carbide (TiC, Ta, NbC, etc.) as the gamma-phase.

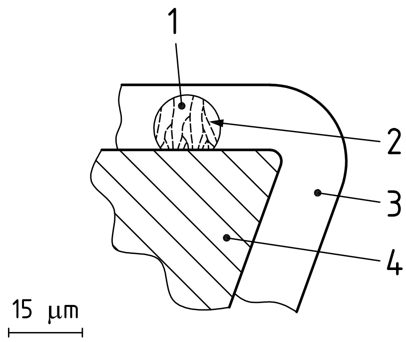
3.9
tool holder
disposable insert or tool shank of which a corner has been ground away and a super-hard *cutting insert* (3.7) brazed on

4 Classification of CVD diamond tools

4.1 CVD diamond-coated tools

Tools made of CVD diamond can be subdivided into two types: CVD diamond coated tools (CVD diamond thin-film tools) in which a coating with thickness, s_D, normally between 1 µm and 40 µm is directly deposited on the tool body, reproducing its shape, and tools with a CVD diamond cutting insert. Figure 1 shows the structure of a CVD diamond coating. An example of a CVD diamond coated tool is shown in Figure 2.

The manufacturing process of the synthesis CVD diamond is represented in Annex A.



Key

1 diamond grain
2 grain boundary
3 CVD diamond film
4 tool substrate

Figure 1 — Structure of CVD diamond coating

Figure 2 — Example of CVD diamond-coated tool

CVD diamond coating modifications are displayed in Annex B.

4.2 CVD diamond thick film tools

CVD diamond thick film tools consist of a self-supporting, polycrystalline diamond layer normally between 20 µm and 2 000 µm thick, which is deposited and then cut into geometric sections, as shown in Figure 3. Like PCD, they are then, in a further operation, brazed as cutting inserts onto a tool holder (Figure 4). The key difference to PCD blanks is that no binder is necessary.

Key

1 diamond grains

2 grain boundary

a Polished side of substrate.

Figure 3 — Structure of CVD diamond thick film

Structure and characteristics of MCD and PCD tools are represented in Annex C.

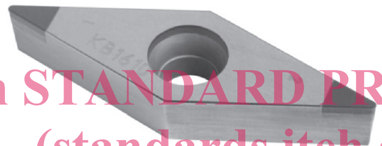


Figure 4 — Example of CVD diamond thick film tool

Since 2005, low-pressure synthesis (CVD process) has also been used for synthesizing monocrystalline CVD diamond (CVD-MCD). This diamond modification has applications in electronics and optics and as well as in machining technology, as shown in Figure 3.

4.3 Classification of CVD diamond tools

Table 1 shows a common example of classification of CVD diamond tools.

NOTE The use of CVD diamond tools is not limited to the examples given in Table 1.

Table 1 — Classification of CVD diamond tools

	Classification of CVD diamond tools	
	CVD diamond-coated tools	**CVD diamond thick film tools**
Thickness, s_D (µm)	1 to 40	20 to 2 000
Substrate material	WC-Co cemented carbide with cobalt with a maximum mass fraction of 12 %. Amongst ceramic substrates, silicon-based ceramics.	Silicon has established itself as a disposable substrate, and molybdenum as a reusable substrate. In addition, titanium or copper alloys are possible substrate materials.
Carrier material		CVD diamond brazable material
Applicable tools	Drills, tapping tools and shank cutters, microtools, large-diameter tools, indexable inserts for turning and milling operations, sinusoidal.	Disposable inserts for turning, drilling and milling as well as in rotating-shaft tools
Post-treatment (Final processing)	The aim of post-treatment is to give the tool the cutting edge radius required for the cutting or chip-removal application or to create a friction-minimized surface on the normally raw growth side of the diamond film.	As a rule, the high quality requirements can only be satisfied by the mechanical processes of grinding, lapping and polishing as the final processing step.[a]

[a] For a long time a characteristic feature of these diamond tools included the production with only two-dimensional cutting-edge geometries. At present they can also be produced with complex or 3-dimensional cutting-edge geometries. An additional geometric modification of diamond cutting parts can be obtained by laser cutting or, in the case of electrically conductive CVD diamond, by electrical discharge machining (EDM) in order to create cutting-edge contours or chip grooves. EDM is made possible by doping with boron during the deposition process.

Manufacture of CVD diamond-coated tools is listed in Annex D.

Annex A
(informative)

Manufacturing processes — Synthesis of CVD diamond

CVD techniques allow diamond to be deposited directly onto a series of materials and base geometries. Particularly in the field of machining, where higher performance and improved cost effectiveness in processing new, difficult to machine materials are always demanded, a series of CVD diamond tools has been developed and become commercially available.

Polycrystalline CVD diamond from gas phases is usually manufactured in the low pressure range between 1 hPa and 100 hPa. Either a plasma or a thermal activation of the gas phase is required. Processes which are in industrial use for the deposition of CVD diamond thin film are the hot-filament CVD process and the high-current arc plasma CVD process. For CVD diamond thick film, plasma processes with microwave or direct current (DC) excitation are typically employed.

In hot-filament CVD diamond deposition (HFCVD) the gas phase is activated by filaments of tungsten, tantalum or another refractory metal at filament temperatures of approximately 2 000 °C to 2 800 °C. In plasma-assisted CVD methods (PACVD), microwave plasmas (MW PACVD) or direct-current plasmas (DC PACVD) are usually employed for gas-phase activation. The gas phase to be activated consists for the most part of hydrogen plus an admixture of methane or another hydrocarbon as a source of carbon. This admixture falls within the range of a volume fraction of 0,5 % to 5 %.

Diamond deposition rates depend on the one hand on the activation process the associated CVD process parameters and on the other hand on the materials and geometries to be coated. In the field of CVD diamond tools, deposition rates range from values of around 0,3 µm/h up to some 10 µm/h in the fabrication of CVD diamond thick film by plasma-activated methods.

Electrical conductivity – and thus the electrical discharge machining of CVD diamonds – can be achieved by doping: boron is incorporated during diamond deposition. Doping can have various effects on the behaviour of CVD diamonds used as a cutting material, however.

Annex B
(informative)

CVD diamond coating modifications

As a way of improving performance of CVD diamond coatings, according to VDI 2840, CVD coating technology offers the possibility of various diamond coating modifications. The different modifications have differing material properties and can, as such, determine the properties of the cutting tool. Free-standing CVD diamond thick-film has microcrystalline film morphology whereas CVD diamond thin-film systems are classified into microcrystalline, nanocrystalline and multilayer systems.

Microcrystalline films have grains with a columnar structure, having fewer grain boundaries which means that the highest CVD diamond thin-film quality and resistance to abrasive wear can be obtained. Due to the smaller size of the crystallites, nanocrystalline diamond films have a larger number of grain boundaries (see Figure B.1). Figure B.2 shows the fracture face of a nanocrystalline diamond film. These coatings are characterized by low surface roughness, good frictional properties and high resistance to adhesive wear, and are eminently suitable for post-deposition processing. Resistance to cracking is also improved since the high number of grain boundaries makes it more difficult for cracks to propagate.

Figure B.1 — Cutting edge with CVD diamond coating (example)

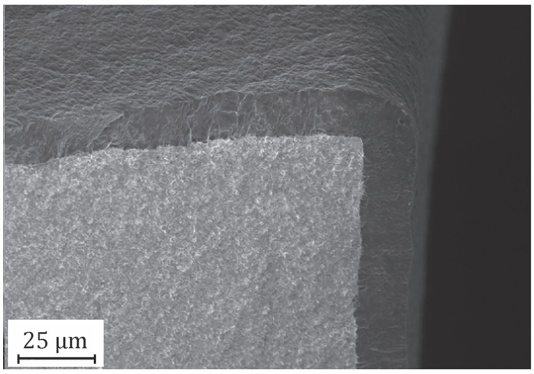


Figure B.2 — Carbide substrate and diamond coating (example)

If the process conditions for depositing microcrystalline and nanocrystalline diamond films are alternated during the coating process a diamond multilayer coating with an almost identical surface quality as is obtained with pure nanocrystalline diamond films results (see Figure B.3). Adhesion and cracking resistance is further improved since any cracks which do occur will propagate along the individual film layers and thus not reach the interface, the connection of substrate and coating.

