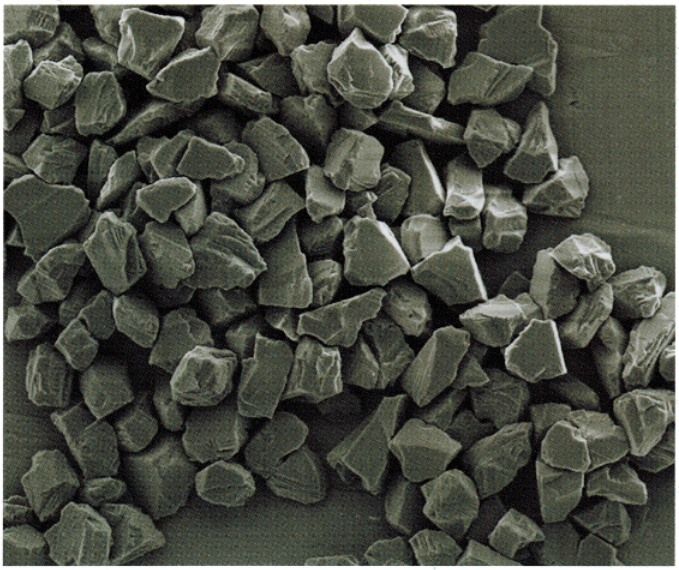
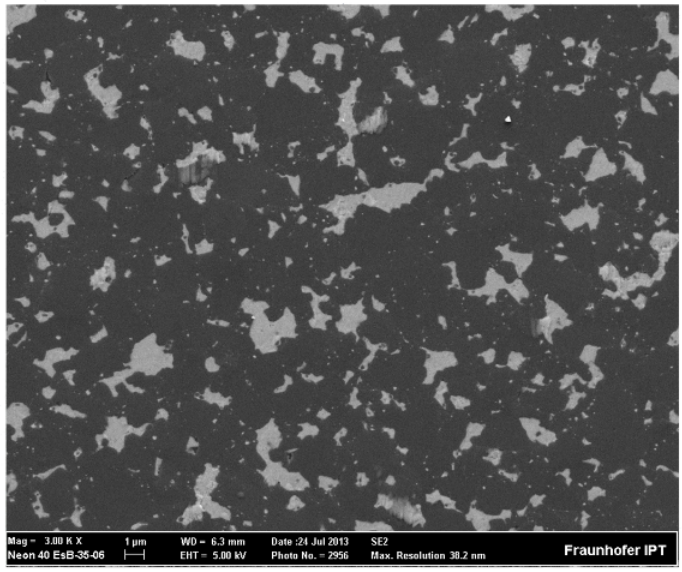
Wire drawing dies with MANT® type polycrystalline diamonds

Tungsten carbide supported PCD are barely susceptible to tension fissures. The material is mostly used for drawing stainless steel wire in diameters around 1 mm and up. REDIES develops and manufactures the material and tools.



Picture 1: SEM-micrograph of synthetic diamond powder 5µm for MANT® PCD



Picture 2: SEM-micrograph of the surface of drawing die with PCD MANT®

REDIES is a manufacturer of wire drawing dies and specialty tools made using diamond and carbide materials for drawing wire and tubes and has production plants in Germany (Aachen), Italy (Giussano, near Mailand) and the Czech Republic (Vamberk). Development and acquisition of the raw materials mono-crystalline (natural) and polycrystalline diamonds (PCD) and also pressure sintering those into stainless steel casings is done at the central facility in Aachen. At RWTH Aachen University and the university-related Fraunhofer institutes we have optimal access to facilities for analysis and inspection.

While also using PCD blanks from brands like COMPAX® and SUMIDIA®, REDIES has been developing its own products: MANT® branded PCD blanks. During the analysis of broken PCD a connection has been found between inhomogeneity inside the PCD and structural defects on the inner surface after cutting the drawing die geometry using laser and ultrasonic methods (detailed here: www.mant.de). Chemical purity and grain homogeneity of the diamond powder and catalyst metals are the main points in selecting the raw materials for MANT PCD which is made in a high-pressure liquid phase sinter process.

Only blocky diamond grains of a very narrow granularity always the same grit is used from the manufacturer VAN MOPPES in Geneva. To establish this constant quality, samples are regularly being examined using SEM-micrography. Picture 1 shows a typical diamond powder sample for the "bread-and-butter" product MANT PCD 5 micron.

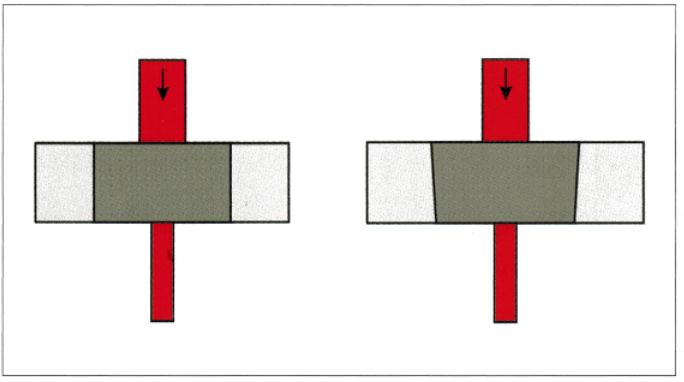
The cubic, blocky structure of the diamond powder results in a dense interlacing of the particles after sintering at ca. 50,000 bar and temperature of above 1,000 °C. During this process, carbon from the grain's boundaries goes into solution in the liquefied cobalt and, after a change in the thermodynamic state, is being deposited in a cubical crystal structure. Bonds are formed, connecting formerly singular diamond crystals. This is shown in Picture 2.

The diamond structure is visible as dark, the remaining cobalt islets as light areas. The degree of bridging between the grains defines the tensile strength and hardness – resistance against wear - of the PCD body and is in the end essential for the drawing die's durability.

Needle-like crystals and a high content of finer grains, are detrimental for the saturation of the diamond cake with the liquefied cobalt, which leads to defects in the microstructure. Diamond powder containing such crystals, lower in price, are not used in the manufacture of PCD MANT.

Diamond in micron	non-ferous material	ferous material	other material
1	Cu + Al uncoated fine wire Cu Sn- + Ni-coated	welding wire Cu-coated INOX fine wire	Mg-alloys
5	Cu, Al up to ca. 4mm	all steels up to ca. 2mm	brass-alloys
25	Cu, Al coarse wire	high-alloyed tool steels + HSS steels up to 5.5 mm	
40			warm drawing of Tungsten + Molybdenum

Table 3: Typical use cases for MANT®-drawing-dies
Pictures by Redies



Picture 4: Comparison of tungsten-carbide supported PCD with cylindrical and conical TC rings

There are around 40 types of MANT Products for usage in drawing dies, self-supported or tungsten-carbide supported. An overview on the main use cases can be seen in table (3).
After making the PCD body, there still is a metallic content of around 6-8 weight-% inside the interlaced diamond structure.

Thermostable PCD

Up to a process temperature of around 600°C this does not pose a problem. Above this temperature however, the differing expansion of the materials leads to a destruction of bridges between grains. If Ni-base-alloys are used during sintering at around 1,000°C and / or if the surface temperature rises due to high-speed drawing of hard wire, thermostable PCD are used.
Thermal stability in PCD means that the metallic content is mostly removed in a time-intensive acid treatment. There are thermostable versions of self-supported PCD blanks from all major brands as well as from MANT.
Tungsten-carbide supported PCD are less sensitive towards tension fissures than self-supported and are used in many applications, such as drawing steel wire of diameters from 1mm upwards, to drawing wire rod. A peculiarity of MANT PCD: the conical PCD body is pressed into a fittingly conical Tungsten Carbide ring which helps absorb axial drawing forces and thus lowers the risk of breaking.
In another development-step, these **two properties have been combined**. In our plant in Aachen, Germany, an economic chemical-physical process was developed in order to leach the metal contents out of the PCD. Subsequently the PCD is cut into cylinders before pressing into the TC ring. By this process thermostable, tungsten-carbide supported MANT PCD are made in sizes **D15** (for wire diameters from 0.8 to 1.5mm) and **D18** (for wire diameters from 1.0 to 2.0mm) which are subsequently sintered at 1,000°C using a Ni-base-alloy in stainless steel casings. Then conventional die making follows (laser drilling, ultrasonic grinding and polishing).

MANT MTD-15-005-TS – as they are called – have been tested high-speed-drawing welding rod for a year now with excellent lifetime. The characteristics:

- Constant surface finish over a long lifetime by utilizing only narrow grainsizes for producing MANT PCD
- High lifetime due to a high density of bridging in the PCD
- Highest protection against breaks due to a conical PCD-body / TC-ring contact area
- Thermostable PCD-property for protection against thermal tensions during wire drawing

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