Low-pressure diamond: from the unbelievable to technical products

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Received: 20 January 2021 / Accepted: 17 February 2021 / Published online: 16 March 2021
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Abstract
The idea to grow diamond from the gas phase was born in the 1950s but it took about 30 years until first diamond layers directly grown from the gas phase on substrates were shown in Japan by Matsumoto and co-workers. During the first years of research the function of atomic hydrogen, various growth methods and process parameters were investigated. Research was primarily focused on applications for wear-resistant tools. For this topic the interactions of substrates like hardmetals and ceramics, with diamond deposition gas atmosphere, were investigated. Beside its superior hardness, diamond exhibits the highest heat conductivity, high transparency, high chemical inertness and suitable semiconducting properties. The various requirements for the areas of application of diamond required a division of diamond research into corresponding sub-areas. The hot-filament method is used mainly for wear applications, because it is highly suited to coat complex geometries, but the diamond contains some impurities. Another method is the microwave plasma system which allows the growth of pure diamond used for optical windows and applications requiring high thermal conductivity. Other research areas investigated include doped diamond for microelectronic or electrochemical applications (e.g. waste water treatment); ballas (polycrystalline, spherical diamond), NCD (nanocrystalline diamond) and UNCD (ultra-nanocrystalline diamond) for wear applications. It should be noted that CVD (chemical vapour deposition) diamond synthesis has reached the stage of industrial production and several companies are selling different diamond products. This work is intended to convey to the reader that CVD diamond is an industrially manufactured product that can be used in many ways. With correspondingly low costs for this diamond, new innovative applications appear possible.

Keywords Diamond · CVD

History
Diamond synthesis was a miracle of nature for hundreds of years until scientists at GE (General Electric Company) succeeded in high-temperature high-pressure (HPHT) synthesis of diamond in 1954 [1]. This synthesis follows the rules of thermodynamics, and process parameters of diamond growth are located in the region of diamond stability.

However the research on diamond synthesis within the region of its thermodynamic metastability started nearly simultaneously, with patent applications in Russia and the USA [2, 3]. In Russia, Deryagin and Spitsyn [4, 5] investigated the growth of diamond from the gas phase on diamond seed crystals. With this method it was possible to increase the size of diamonds up to the onset of graphite growth, but it was necessary to use a cyclic process to remove graphite and non-diamond carbon. For the etching step, oxidising acids or hydrogen were used at increased pressure and temperature. At this time, Angus and co-workers investigated the use of atomic hydrogen (at.H) for etching graphite [6].

In principle the requirements for low-pressure diamond growth were known at this time. In Russia, Deryagin, Spitsyn and several co-workers investigated the epitaxial diamond growth on diamond also with etching graphite by atomic hydrogen [7–14]. All of these papers describe the diamond growth very vaguely, possibly for reasons of confidentiality.

Also during the late 1970s the deposition of carbon coatings by PVD (physical vapour deposition) was investigated. Because some of these coatings showed high
hardness, Weissmantel called these coatings “diamond-like carbon” (DLC) [15–19]. This name immediately became accepted for amorphous carbon coatings.

The situation changed when Japanese researchers from NIRIM (National Institute for Research in Inorganic Materials, Tsukuba) published the low-pressure diamond deposition, using the hot-filament method, in detail in 1982 [20, 21]. Shortly after, papers about the characterisation of the diamonds and other deposition methods were published [22, 23].

Since it is impossible from a thermodynamic point of view to produce diamond under low-pressure conditions, it was unbelievable for chemists at the time that such a process is possible. Because Prof. B. Lux (1930–2013) [24] from TU Wien ignored thermodynamic prejudices and believed in the Japanese publications in 1984, low-pressure diamond research started in Austria. In July 1985, the first diamond crystals were grown in Vienna (Fig. 1) [25–27]. Their presence was confirmed by Raman measurements.

In Japan many research groups in companies but also at universities investigated various aspects of this new method of diamond growth. Outside of Japan, research on CVD diamond started a little later.

**Atomic hydrogen: the secret of low-pressure diamond growth**

For low-pressure diamond deposition, at.H is needed. The unbelievable fact was that from a thermodynamic point of view, it is impossible to grow diamond at low pressure. However in reality, atomic hydrogen is necessary for diamond growth and drives non-equilibrium reactions already resulting in diamond.

A filament bulb was used to illustrate how easy diamond deposition is (Fig. 2a). During the first years, the actual effect and contribution of atomic hydrogen was not clear, but Badzian et al. [28, 29] showed a plausible concept (Fig. 2b). During pyrolysis of carbon, the deposition of diamond is thermodynamically preferred, because it is metastable. However, in reality, graphite is formed owing to the Ostwald–Vollmer law [30], because graphite has a lower density than diamond. The etching of the layered $sp^2$ graphite crystal structure by atomic hydrogen is much faster than the etching of $sp^3$ diamond. By combination of pyrolysis and etching with atomic hydrogen, diamond can be grown directly. Atomic hydrogen has to be generated and transported to a substrate surface without recombination (Fig. 2c) [31].

Thermodynamic equilibrium calculations can be used to calculate the amount of at.H achievable at selected conditions of gas activation, but not to describe diamond
growth. During gas activation of hydrogen and carbon-containing gas mixtures, many $\text{C}_x\text{H}_y$ compounds can be formed theoretically [32–35]. Kinetic calculations, considering the non-equilibrium system and continuous addition of atomic hydrogen, show the complexity of the chemical reactions (Fig. 3) [36, 37]. Later computer simulations were used to try to explain diamond growth and the role of at.H [38].
Finally, diamond morphology and quality are defined by the amount of at.H and its relation to carbon (Fig. 4). Diamond morphology changes from well-faceted octahedric (111) over cubic (100) to un-faceted ballas morphology with decreasing at.H to C ratio (Fig. 4a) [39, 40]. The term ballas for half-spherical and polycrystalline diamond deposits was first used by Bichler et al. [25, 27], but later cauliflower-like [41], ball-shape [42] etc. were used by some authors.

The relationships between deposition conditions, amount of at.H and diamond morphology are shown in Fig. 4b [43–47].

Methods to generate atomic hydrogen for diamond growth

Low-pressure diamond deposition is a CVD process, using hydrocarbons and at.H for diamond growth. The at.H can be produced by high temperatures or gas plasma (Fig. 5). These methods offer the possibility of growing polycrystalline diamond layers in large size and thickness on different substrate materials.

The first method described by Matsumoto et al. was the hot-filament method [20], also used by Bichler et al. at TU Wien [25]. Microwave activation was introduced by Kamo et al. shortly after (Fig. 5b) [23]. Several other methods followed, e.g. plasma jets, glow discharges and the acetylene torch. Some schematic drawings are shown in Fig. 6.

The hot-filament method (Fig. 6a) works by thermal decomposition of H2 to obtain at.H, and allows for an easy design and up-scaling of reactors [47, 48]. For filament materials, W or Ta can be used, allowing filament temperatures up to 2500 °C [49–51]. Inhomogeneous diamond deposits, caused by deviation of substrate temperature and at.H concentrations, can be prevented by arranging several filaments in optimal positions (Fig. 7a) [48]. An advantage of the hot-filament method is that the substrate surface temperature can easily be regulated by additional heating, and no active substrate cooling is necessary. However diamond deposition rates are relatively low (about 1 µm/h) compared with other methods. As a result of impurities in the diamonds caused by the filament materials, this method is primarily used for diamond coatings on wear parts [52, 53]. Several companies sell hot-filament equipment [54–56].

The acetylene torch (Fig. 6b) also uses high temperatures to generate at.H and is very simple. However, as a result of the small size of the flame and problems with acetylene purity, this method has not gained high importance [57, 58].

Microwave plasma diamond deposition (Fig. 6c) with “ball”-shaped plasma is convenient to handle and highly pure diamond can be deposited. Enlarging the deposition areas is difficult, and as a result of the ball-shaped plasma, the diamond quality is inhomogeneous between centre and border of the discharge (Fig. 7b) [43, 44, 59]. An advantage of this method is that microwave power can easily be increased resulting in higher diamond growth rates (greater than 10 µm/h). The possibility to deposit diamond with high purity is the main advantage of this method [60]. Today, several companies sell microwave equipment for diamond deposition [61, 62].

Balzers (now Oerlikon) introduced a high density/low voltage arc discharge reactor as an industrial process for coating tool materials [63, 64]. This method produces high concentrations of at.H and therefore allows the coating of a large number of inserts under quite controlled conditions [65].

DC- and arc-plasma jets permit high speed diamond growth on relatively large surfaces, comparable with microwave and hot-filament methods. As the substrates are typically located near the arc, controlled cooling is needed to regulate the substrate surface temperature, which can be a serious problem for mass production applications [66–69].

The DC-glow discharge method (Fig. 6c) allows far higher diamond growth rates, but there are some problems like scale-up, substrate geometry and reproducibility [70–72].

The advantages and disadvantages of the primary processes for hydrogen activation are summarized in the Table 1 [73].

Process parameters and substrate interactions for diamond growth

As already described, the diamond quality is largely influenced by the ratio of at.H to carbon as well as the substrate surface temperature. Furthermore, there is a large overlap of influences on diamond growth caused by other process parameters such as doping elements and substrate materials. These aspects will be presented separately.

Diamond deposition parameters

The main parameter which has to be optimized to grow diamond is the correct gas phase composition in terms of the C/H/O ratio compared to the at.H produced [74] (Fig. 8).

Diamond nucleation and growth are the key parameters for diamond deposition, and there are always interactions between the diamond layer, the substrate, and the gas phase.
The diamond layer formation can be subdivided into three steps: (1) diamond nucleation, (2) growth of individual diamond aggregates which grow together and (3) diamond layer growth (Fig. 9) [27, 75].

If the growth conditions for diamond growth are fulfilled, the final diamond quality is linked to the amount of at.H and the diamond growth rate. High-quality diamond with low defect density requires low diamond nucleation rates and low growth rates. By increasing the growth rate, the defect density in the diamond crystals increases [40]. The defects are mainly micro twins which are preferably formed in (111) growth sectors. If the defect density becomes too high, the diamond surface is not faceted anymore and is then called ballas diamond [76] (Fig. 4).
Different diamond facets can be grown by changing the growth conditions, resulting in different layer morphologies [77]. The layer morphology is additionally influenced by texture formation during layer growth [78] (Fig. 10).

By reducing the amount of at.H compared to C, diamond nucleation is increased and fine-grained diamond coatings are formed. In the case of extreme changes in process parameters, nanocrystalline diamond (NCD) [79, 80] and ultrananocrystalline diamond (UNCD) [81, 82] films are formed. In these coatings the diamond crystals are in the nanometre range and are surrounded by amorphous carbon-containing grain boundaries. As a result of the high number of grain boundaries, the content of the diamond phase is reduced and it is hard to distinguish between diamond (crystalline) and amorphous carbon [83]. As a result of the higher amount of $sp^2$ carbon and increased etching by at.H, the layer growth rates are low.

Finally, all process parameters interact and lead to different diamond coatings. An example for the interactions of temperature and gas pressure on diamond growth is shown in Fig. 11 [84]. The gas pressure should be low enough to form high amounts of at.H but also high enough to achieve reasonable diamond growth rates [31, 46]. The substrate surface temperature should be below 1000 °C to prevent a transformation of already grown diamond into graphite. However, below 600 °C, the diamond deposition becomes extremely slow [85].

Following the general concept of Bachmann [74], oxygen has no negative influence on diamond growth. This was confirmed by the use of acetone as precursor [86] (Fig. 12) and CO addition to the gas source [87].
Impurities and diamond doping

A challenge in this research area is the production of p-type and n-type semiconducting diamond. In the past, boron [88–90], nitrogen [78, 91–93], phosphorus [94–96], lithium [97, 98] and also sulfur [99–101] additions to the diamond deposition process were investigated (Fig. 13a).

Boron addition during low-pressure diamond deposition has been used for quite a long time [90, 102, 103], as small boron concentrations increase diamond growth rates and improve crystallinity. Later on boron-doped diamond became interesting for semiconducting technology (p-type) [104] and for electrodes in electrochemistry [105]. The deposition methods usually attain gas activation by microwave plasma or a hot filament. In case of the hot-filament method, the reactions of the metallic filament materials with boron (formation of borides) have to be taken into account [106].

For boron concentrations in the gas phase below 500 ppm B/C, independent of the boron source and the deposition method used, an improved diamond quality is commonly found [107, 108]. Slightly increased diamond crystal sizes are observed and the crystal habitus becomes better pronounced.

B concentrations between 1000 and 5000 ppm B/C decrease the diamond growth rates to values comparable to undoped layers. Diamond morphology remains fairly
Fig. 10  Correlation between visible diamond crystal size and layer thickness

Fig. 11  Example for the influence of the process parameters temperature and pressure on the diamond deposition with otherwise constant deposition parameters (modified from [57, 84])
constant with steadily decreasing crystal size. Optical microscopy and scanning electron microscopy (SEM) [88] of polished diamond samples visualise the inhomogenities in boron distribution. Boron is incorporated up to 3 at.% in the (111) and less than 0.3 at.% in the (100) grown sectors (Fig. 14) [109, 110].

The n-type doping of diamond received great interest, and addition of traces of P, N, S and Li was investigated. Any addition of impurities to the diamond deposition process influences diamond growth rate, morphology, as well as quality and properties of the deposited diamond [111].

Considering only steric and energetic factors, an introduction of phosphorus into the diamond lattice seems unlikely since the covalent radius of phosphorus is larger than that of carbon [112]. Even small amounts of phosphorus in the gas phase inhibit well-faceted diamond growth [94]. Nevertheless, some reports on the formation of n-type CVD diamond films using phosphorus-containing doping sources are found in the literature [95, 96, 113].

The influence of nitrogen was studied early, due to leakages or residues in the reaction gases (commonly found in H₂ and CH₄). Small contaminations of nitrogen influence the diamond growth and crystal orientation drastically [93, 114, 115]. The outstanding electrical [91, 116] and thermal [117] properties of diamond layers are changed by small and medium nitrogen additions.

Research of sulfur-doped diamond [118, 119] was driven by the hunt for an n-type semiconducting diamond [120, 121], but in the end the results were not promising.

An interesting result was obtained when B and N were added simultaneously (Fig. 15) [122]. In this case diamond and graphite were deposited side by side, which contradicts the principle of low-pressure diamond growth that at.H etches away all the sp² carbon.

**Influence of substrate materials on diamond growth**

The interactions between substrates and diamond deposition are rather complex because diamond nucleation and growth can be influenced (Fig. 16).

Most important are reactions between the substrate and the carbon and atomic hydrogen in the gas phase. A subdivision into inert substrates, substrates forming carbides or showing carbon solubility, and substrates being attacked by atomic hydrogen can be made.

- Inert substrates: diamond [123], c-BN [124], SiAlON [27, 44], Cu, Au [125]
- Carbide-forming substrates: refractory metals (e.g. Mo, W, Ta [126–128]), but also Si [129, 130]
- Metals with carbon solubility: ferrous metals (Fe, Co, Ni [131, 132], Ni₃Ge [133]) and precious metals (e.g. Pt, Pd [125, 134])
Some examples for diamond growth on various substrates are shown in Fig. 17.

One field of interest was the diamond deposition on silicon because carbide formation is negligible and there is the possibility for epitaxial diamond nucleation to grow large area single crystalline diamonds [138, 139]. Epitaxy on Si is not perfect and many investigations with epitaxial intermediate layers were necessary to reach the goal. In 2017 Schreck [140] reported a single crystalline diamond plate with a diameter of about 92 mm.

Another important substrate material is hardmetal (WC–Co) [141], which is used for tool applications. When using WC–Co, problems are mainly caused by the Co binder [142], as the Co interacts during the diamond deposition in different ways [143, 144]. Cobalt catalyses the deposition of $sp^2$-non-diamond carbon, and it also has a relative high vapour pressure influencing the gas phase above the
substrate [145]. The $sp^2$-carbon (graphitic) has a negative influence on the adhesion of the diamond coatings.

The effects of Co during diamond deposition can be described as follows (Fig. 18):

Fig. 14 Example of the inhomogeneous incorporation of boron in different crystal faces. In SEM images, crystal surfaces containing boron appear darker because the electrons from SEM are diverted and there is no charging (modified from [88, 109])

Fig. 15 Simultaneous addition of boron and nitrogen during diamond deposition, resulting in mixtures of diamond and graphite (modified from [122])
Co migration takes place at the substrate surface, and Co droplets are formed [143, 146, 147].

During the deposition process, carbon and parts of already deposited diamond diffuse into the hardmetal, because the Co binder phase has solubility for carbon [148]. For the diamond coating to adhere well to hardmetal tools, it is necessary to saturate the cobalt binder with carbon before the diamond is deposited [148].

With increasing contents of Co and carbides like TiC in the hardmetal alloy, the thermal expansion coefficient increases, and as a result of the lower thermal expansion coefficient of diamond, compressive stress occurs in the diamond coating during cooling from deposition temperature. This is one reason for the reduced coating adhesion on the substrate [135].

To overcome the problems concerning Co it is necessary to reduce its surface mobility or surface concentration (Fig. 19).

⇒ Etching of Co by various acids.

Selective etching of the Co binder phase with various acids offers a wide range of different pre-treatment methods. The thickness of the etched zone is important because remaining porosity in the hardmetal results in reduced layer adhesion [149, 150].

⇒ Etching of WC and Co.

Etching of WC/Co composites can be achieved by a well-tailored two-step etching treatment, where a Murakami solution ($K_3[Fe(CN)]_6$ in KOH) is used to attack the WC first, and in a second step the remaining Co sponge is dissolved by Caro’s acid ($H_2SO_4$ with $H_2O_2$) [151, 152]. Diamond nucleation is favoured by the rough, etched surface resulting in a good layer adhesion.

⇒ Thick intermediate layers.

Intermediate layers should cover the substrate and encapsulate the Co. The material selection for such interlayers is difficult, because they must be stable during diamond deposition and diamond nucleation should be fast enough for rapid layer formation. Additionally, the interlayers should have a low thermal expansion coefficient to reduce stress at the interface [153, 154]. Various CVD and PVD coatings were tested as intermediate layers, but these experiments were not successful because of insufficient diamond nucleation on the intermediate layers and poor diamond adhesion.

⇒ Thin layers formed by surface reactions with Co.

Different methods were used to form stable Co compounds at the hardmetal surface. A simple heat treatment with B or Si was very effective, as can be seen in Fig. 19. SEM pictures show well-faceted diamond, Raman confirmed higher quality of the deposited diamond, and no Co droplets on the coating surface are visible [144].

To find more simple methods for the surface treatments various other procedures were investigated [155–158].

Nowadays variations of Murakami/Caro etching are the most frequently used pre-treatment for hardmetal tools.

Carbon substrates need tricky deposition conditions in order to coat them with diamond, because graphite is attacked by at.H [159, 160]. Carbon substrates can be used for electrode materials owing to their electrical conductivity and better corrosion resistivity compared with metals.

Steel substrates are also of interest for diamond deposition, because high speed steels (HSS) are widely used in tool industry. As a result of the high carbon solubility in iron at the typical diamond deposition temperatures (greater than 750 °C), direct deposition on steel is not possible [153, 161, 162]. Additionally, the thermal expansion coefficient of steel is high, causing problems with compressive stress in coatings after cooling down from deposition temperatures. Nevertheless, several PVD coatings were tested as intermediate layers for diamond deposition [161]. These experiments were not successful and no commercial products of diamond-coated steel tools are currently available.

Finally, the chemical properties of the substrate influence the diamond growth as do the surface roughness and
Fig. 17  Diamond deposition on various substrates
remaining particles from surface preparation (Fig. 20). On a rough surface, there are more active spots allowing the nucleation of diamond. Very often diamond is used for grinding the substrates, but also seeding with nano-diamond is often used. In this case it is not diamond nucleation but diamond growth on the seed crystals. Changes in diamond nucleation rates or seeding results in different diamond growth rates as can be seen in Fig. 9 [45, 127].

Analytical characterisation of diamond

When CVD diamond research started, Raman measurements were necessary for a clear identification of diamond [26]. The Raman peak at 1332 cm$^{-1}$ is characteristic for the diamond crystal lattice. The better the crystallinity of the diamond crystal, the higher this peak is. In case of crystal defects or impurities, the peak intensity decreases [40]. Additionally, different types of $sp^2$ carbon can be detected.

The availability of new Raman equipment with different laser wavelengths makes the situation more complicated because the wavelength of the laser influences the position and intensity of the different peaks (Fig. 21a, b) [40, 163–165].

CVD diamond coatings have been investigated by almost all available analytical methods [76, 88, 109, 166–170], the discussion and interpretation of which are impossible in this paper.

Only one example for cathodoluminescence is shown in Fig. 21c, and different coloured diamond aggregates can be seen side by side [171].

![Fig. 18](https://example.com/fig18.png) Interactions of the Co binder phase in the hardmetal during diamond deposition. a Schematic representation (modified from [142]), b Co droplets on the diamond surface (modified from [145]), c diffusion of C into a substoichiometric hardmetal substrate (modified from [145])

![Fig. 19](https://example.com/fig19.png) Hardmetal surface treatments prior to diamond deposition: a comparison of etching, intermediate layer and surface treatment (modified from [142]), b surface treatment with B and Si e diamond morphologies after the surface treatments (modified from [144])
Applications for diamond, focusing on CVD diamond

The excellent properties of diamond, including its extreme hardness, wear resistance, thermal conductivity and transparency predestine low-pressure diamond to become the ideal material for coatings on wear parts, heat-spreaders, and optical windows. The electrical conductivity of boron-doped diamond allows for electrochemical applications Fig. 22.

The dream of diamond-based microelectronics has unfortunately not come true, because of difficulties with p-doping of diamond [172].

Superconductivity [173, 174] and quantum dots light sources [175] have also been observed as special properties of diamond.

Diamond coatings for wear parts

The high hardness and wear resistance qualify diamond coatings for tool applications, which were developed quickly. Diamond-coated hardmetal tools have similar properties to PCD (poly-crystalline diamond sintered at high pressure), but the production costs of CVD diamond are significantly lower [53, 176]. For CVD diamond applications, two different application paths are possible [177–180]:

(a) Applications for free-standing diamond layers.

Free-standing diamond layers are binder-free (100% diamond), and their wear resistance can be higher than that of PCD. Several production steps are necessary from the diamond deposition to the final part. At first, a thick diamond layer is deposited on dummy substrates (e.g. Si, Mo etc.) before the layer is removed from the substrate and laser-cut to the final shape. Finally, the diamond sheets are bonded to the wear parts and finished by grinding.

(b) In situ diamond coatings on tools.

For most wear applications the diamond is deposited directly on the substrate. A very intensively investigated application is the diamond deposition on hardmetal (WC–Co) substrates (Fig. 22a) [177].

A comparison between commercially produced CVD diamond-coated tools and uncoated ones for the processing of various materials has been reported by several companies (e.g. Oerlikon Balzers [65, 181], Boehlerit [182], CemeCon [183]).

In this context, there were also extensive studies on the friction and wear of diamond layers [184, 185].

Diamond coatings with high heat conductivity

Diamond’s highest thermal conductivity (at room temperature) and good electrical insulation make it a desirable packaging material for semiconductors.

High-quality diamond layers are achieved by carefully selecting the diamond deposition parameters. Defects and impurities dramatically decrease the heat conductivity. The processing of heat spreaders requires flat layers with a uniform thickness (Fig. 22b) [92, 186, 187].
Diamond coatings for electrochemical applications

Boron-doped diamond exhibits electrical conductivity and a large electrochemical window. A high overpotential prohibits the decomposition of water, and because of this other chemical reactions are possible [188–190]. A typical application is in industrial wastewater treatment [105]. It was shown that organic carbon can be completely converted to carbon dioxide without the formation of by-products (Fig. 22d) [191, 192].

Optically clean and single crystalline diamond

Diamond’s unique multispectral transparency combined with its mechanical strength, chemical inertness and
abrasion resistance makes it a desirable material for optical windows (Fig. 22c).

Examples for the usage of CVD diamond windows are: X-ray detector windows for SEM and X-ray tubes [193, 194], mid-infrared attenuated total reflectance (ATR) spectroscopy [195] or optical diamond lenses [196].

Growth of single crystalline diamond requires a single crystalline seed crystal and growth rates are usually low to avoid defects and impurities in the diamonds [197]. CVD grown and polished gemstones up to several carats in weight are available and used in jewellery [198, 199].

If you consider the initial scepticism about CVD diamond deposition, the economic production of diamond single crystals for jewellery is certainly a high point of diamond research.

Knowledge on CVD diamond deposition is disappearing

It should not be possible for published knowledge to get lost, so why does this happen?

About 40 years ago scientists invented the low-pressure diamond deposition, and they found the most important deposition parameters and developed the theories for CVD diamond growth. These scientists are mostly retired and no longer working.

The large hype around diamond deposition was in the 1990s where many universities, research centres and companies were interested in new diamond applications. Over time, large companies took over the development of diamond products, start-ups were created for smaller areas of application and, as a result of a lack of funding, university research decreased. With university research, however, university teaching also disappeared.

Some long-established scientists can still understand the fascination of diamond synthesis at the time, but today this fascination has given way to indifference.

CVD diamond is manufactured in “black box” plants, the parameters are set, and it is not necessary to understand the chemical reactions at the plant. These are the circumstances in which the knowledge and secrets of CVD diamond deposition are lost.

An admittedly additional difficulty is that in the 1990s, the scientific work was not and is not digitally available, which of course means an increased effort for its procurement.

There is hope that this manuscript will be a useful summary of the history of CVD diamond deposition and that the essential secrets of diamond deposition will not be forgotten.
Funding Open access funding provided by TU Wien (TUW).

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