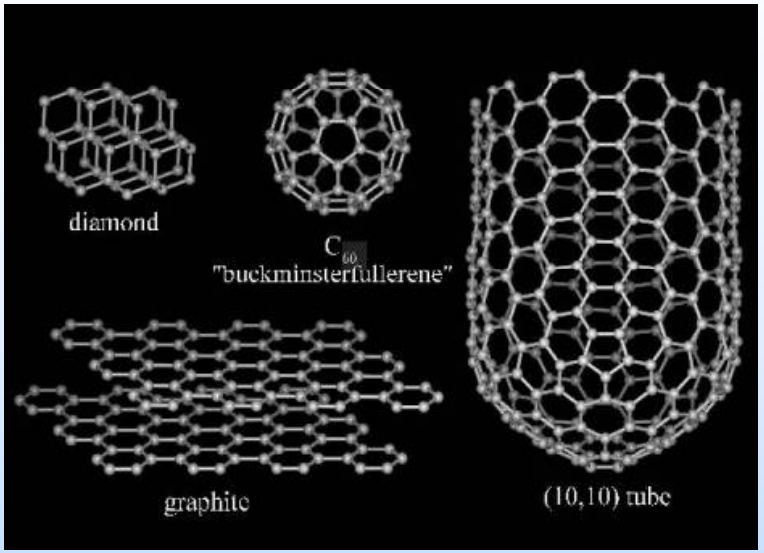
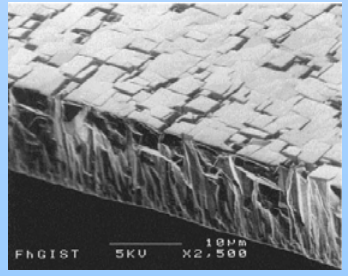
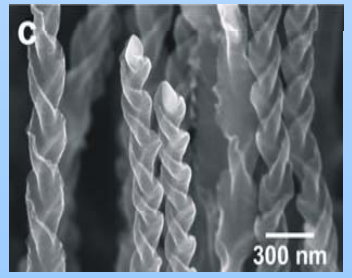
Contents

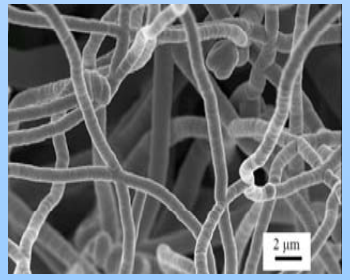
Content

- CVD-diamond films
- Graded nano-crystalline composite coatings
- a-C:H and Me-C:H films





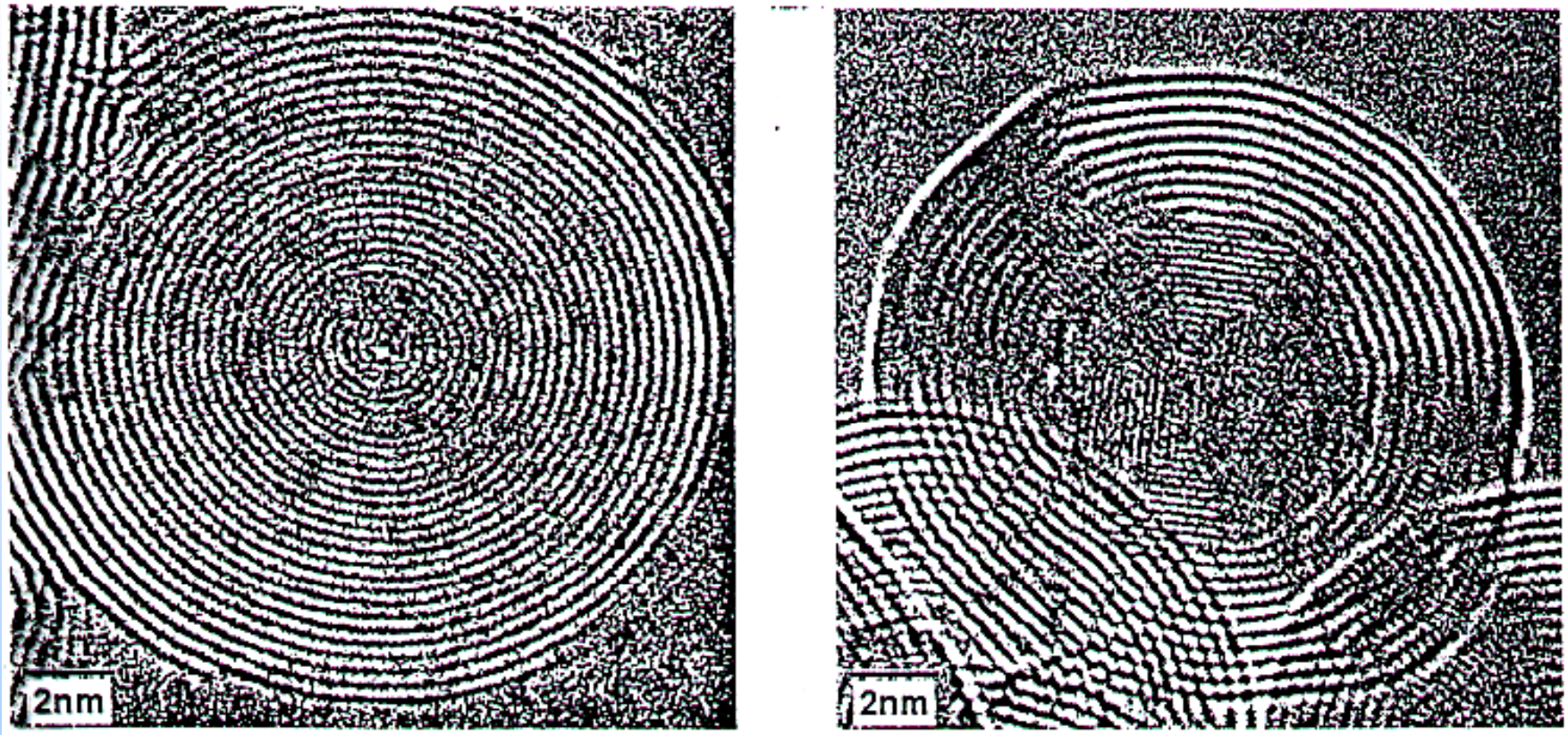




Intrinsic properties of diamond and applications

Hardness (Hv)	100 GPa	Cutting tools and machine part coating
Chemical resistance	Against all chemicals	Electrodes for the chemical Industry
Thermo-conductivity λ	20 W/cmK	Isolating heat sinks for Laser diode
Breakthrough field strength E_s	10^7 V/cm	
Transparency	UV-, VIS u. IR	Optic window for UV- bis –IR range
Refraction index n	2,42	
Absorption edge	200 nm	
Band gap E_g	5,45 eV	High temperature semiconductor and sensor materials (bis 600 °C, for Si 120 °C)
Carrier mobility µ, *Electron*	2200 cm^2/Vs	
Hole	1600 cm^2/Vs	

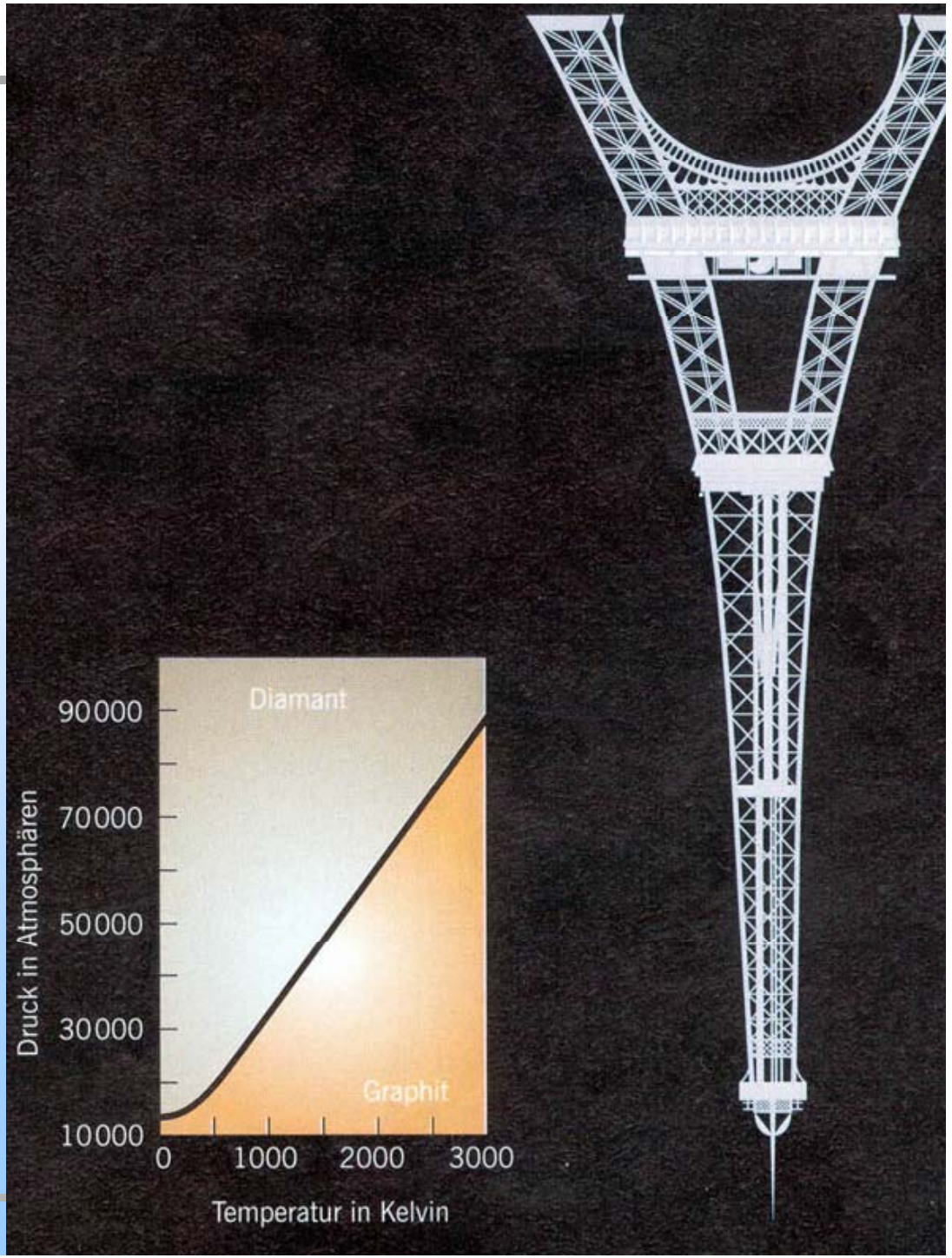
Low pressure diamond growth



Spherical, Graphite

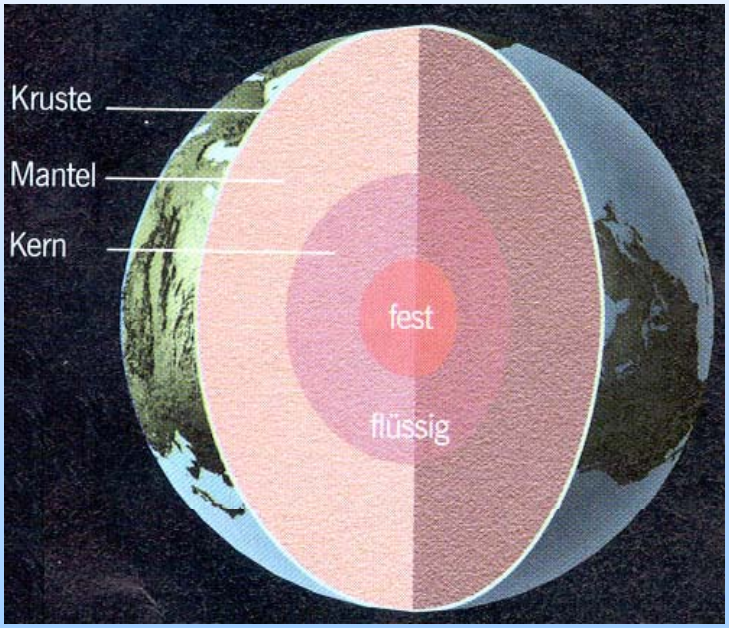
Graphite with diamond core.
Created by electron irradiation
at 1000 K

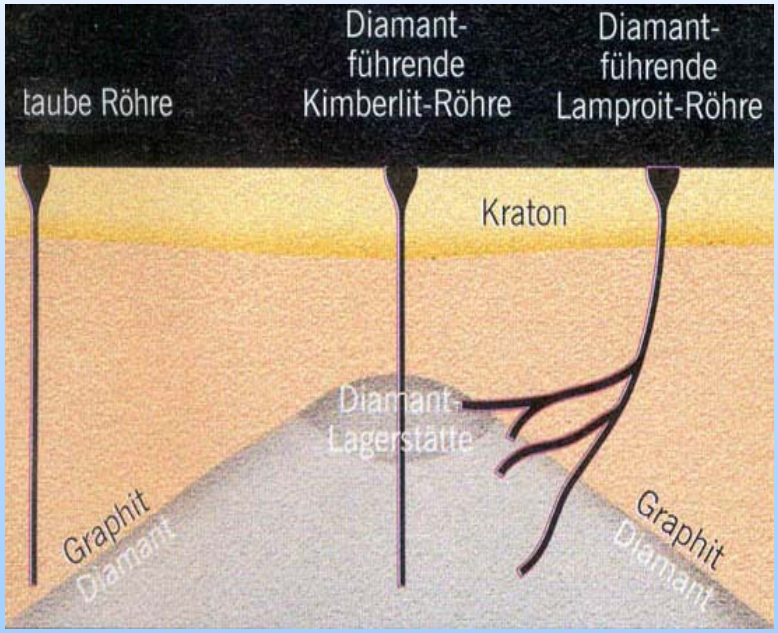
Kohlenstoff-Phasendiagramm



Die Herkunft von Diamant

(Spektrum der Wissenschaft Jan. 1999)





CVD-Diamond deposition

Gas inlet

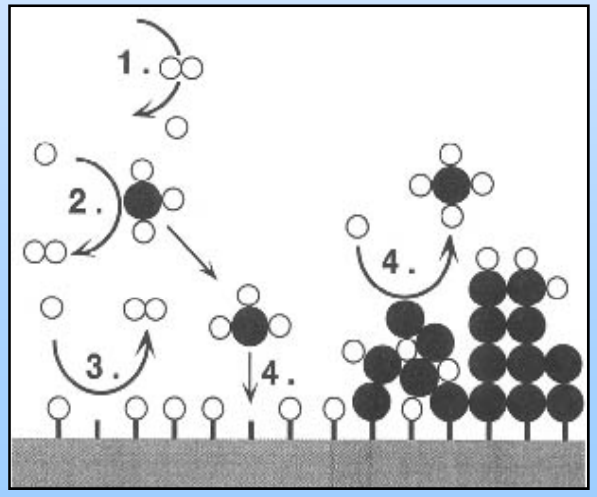
$H_2 + CH_4$

(M. Frenklach et al., 1991)

Thermal or electrical activation (HF, Flame, MWP, DC, ...)

(1) $H_2 = 2H$

Hydrogen diss.



(2) $CH_4 + H = CH_3 + H_2$

Gas phase reaction
Kinetic, Transport
Surface reaction and
C-deposition

(3) $CH\ (s) + H = C\ (s) + H_2$
(4) $C\ (s) + CH_3 = C_2H_3\ (s)$

Substrate

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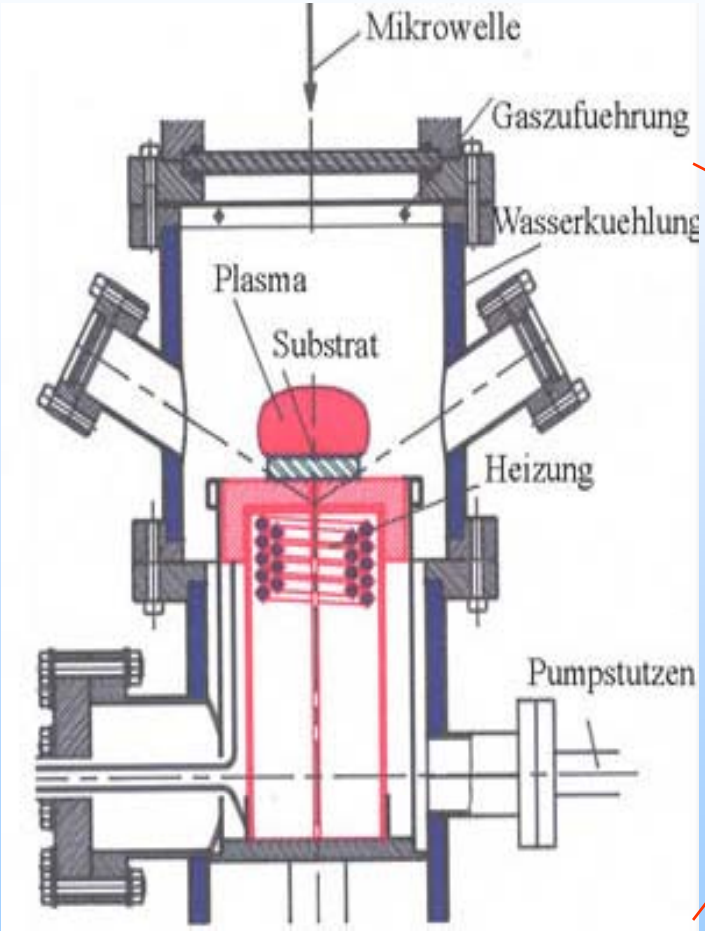
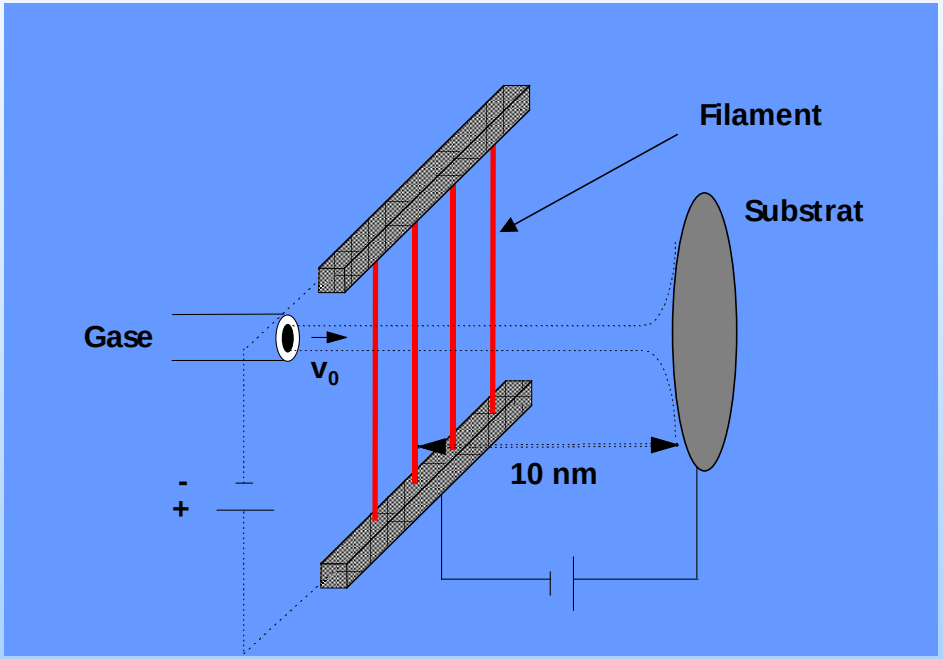
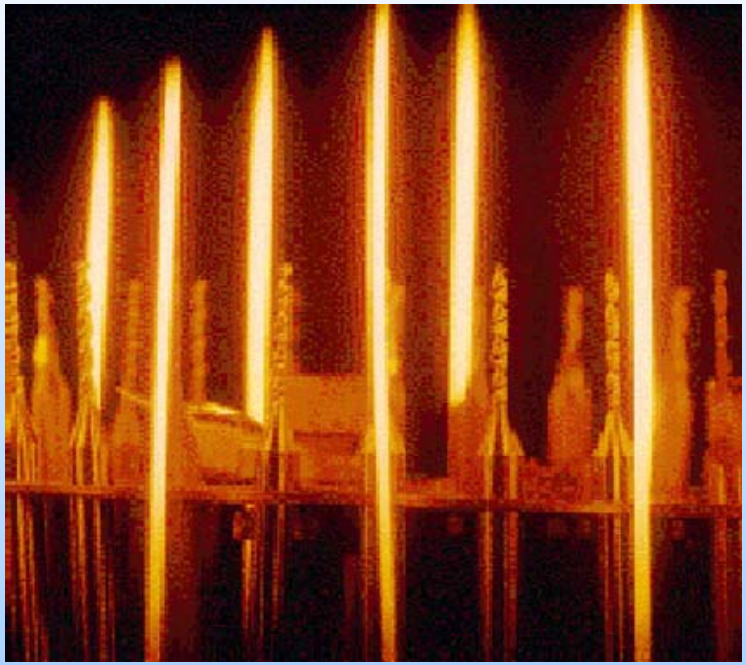
Microwave-Plasma-CVD



T_S = 500 - 700 C, CH_4/H_2 = 1:98-99.5, p = 10 - 40 mbar, P = 500 - 1000 W

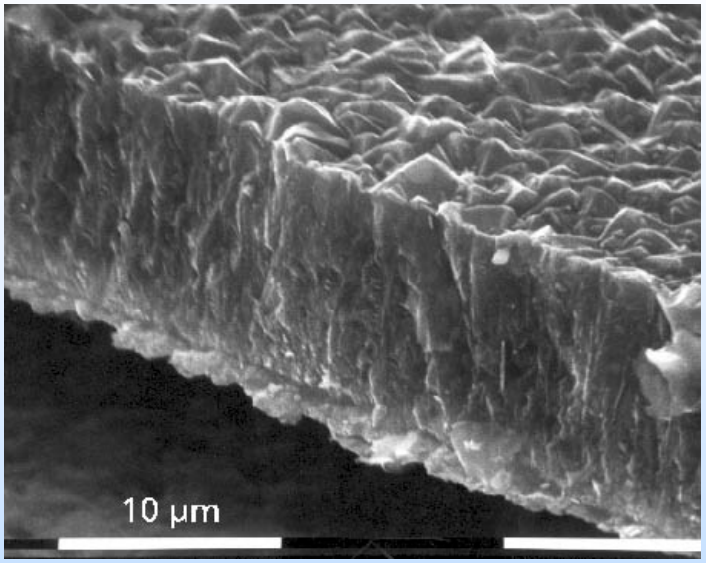
Hot-Filament-CVD

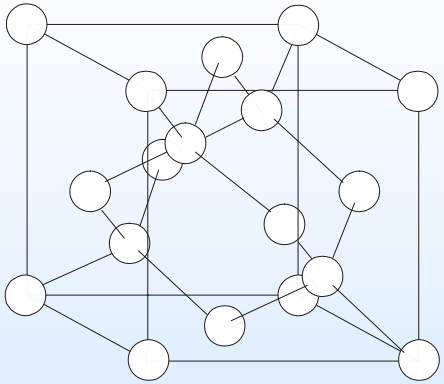




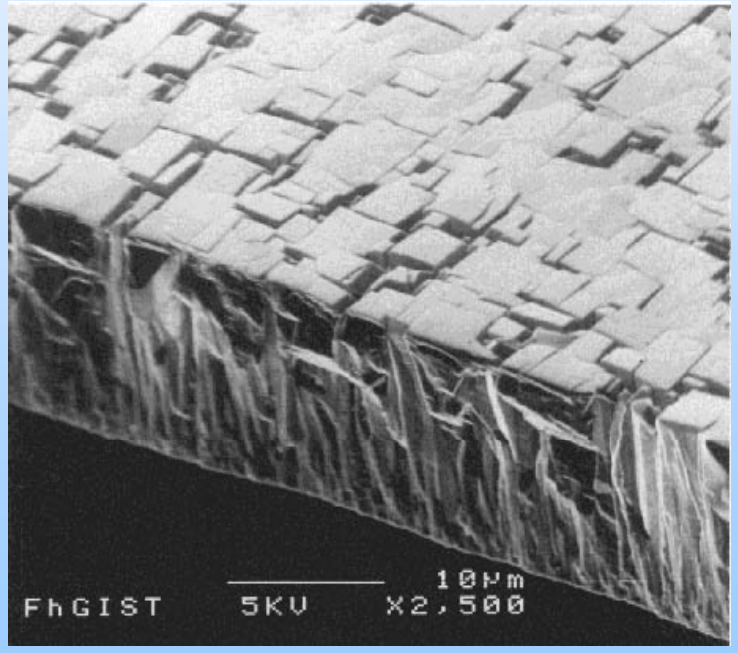
T_F = 2200 °C, T_S = 500 – 900 °C, CH_4/H_2 = 0,5 - 2%, Druck = 10 - 40 mbar

Structure of diamond films





Material	Lattice constant	Surface Energiy
Diamond	3,5667 Å	ca. 6,0 J/m^2
c-BN	3,612 Å	4,8 J/m^2
Si	5,4388 Å	1,5 J/m^2



Appl. Phys. Lett. 62, 3438 (1993)

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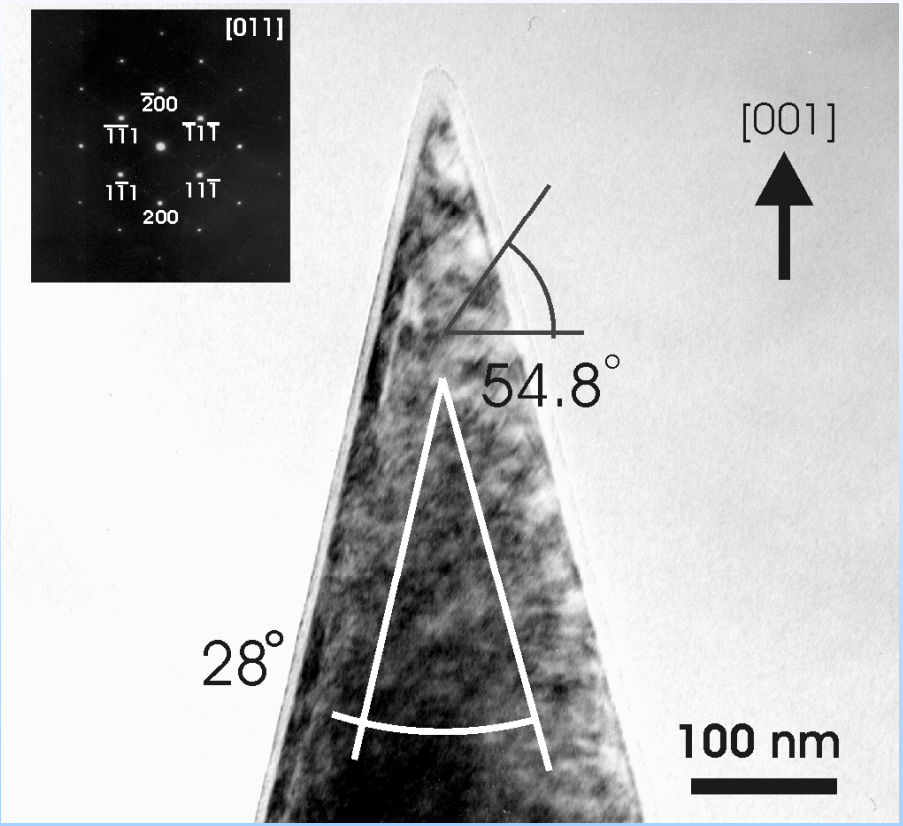
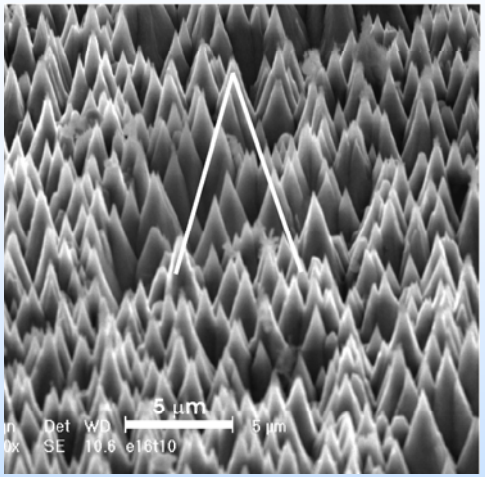
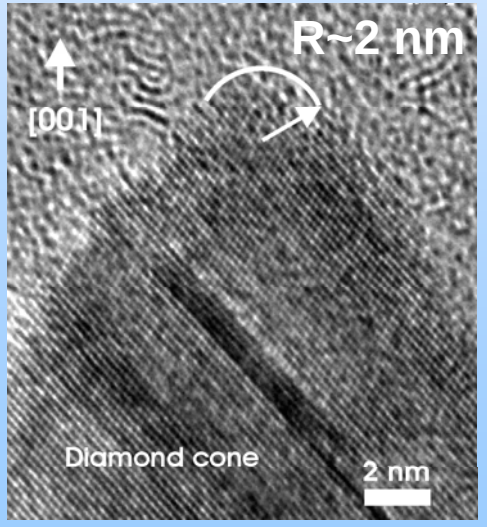
AFM (Atomic Force Microscopy)-Tips







Single crystalline; Tip angle ~28°;
[001]-oriented

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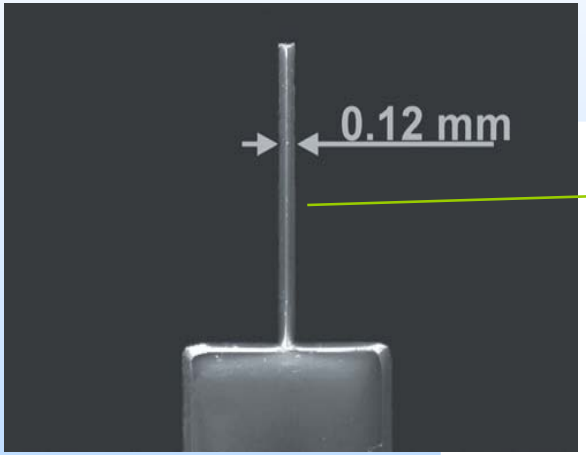
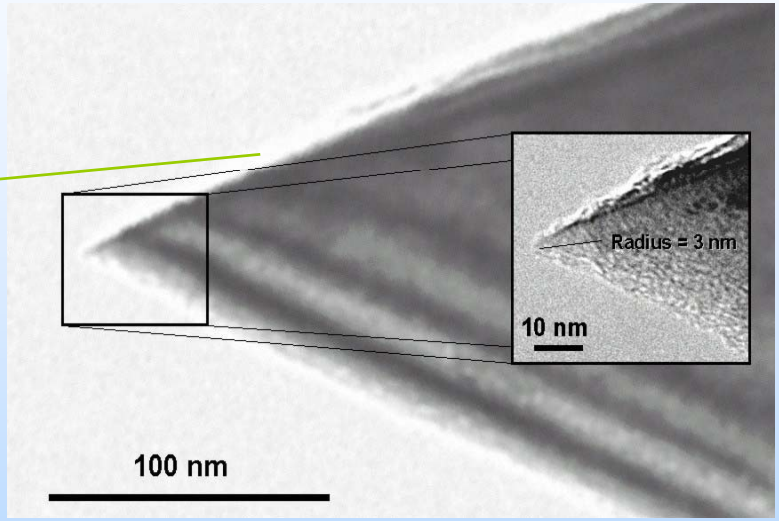
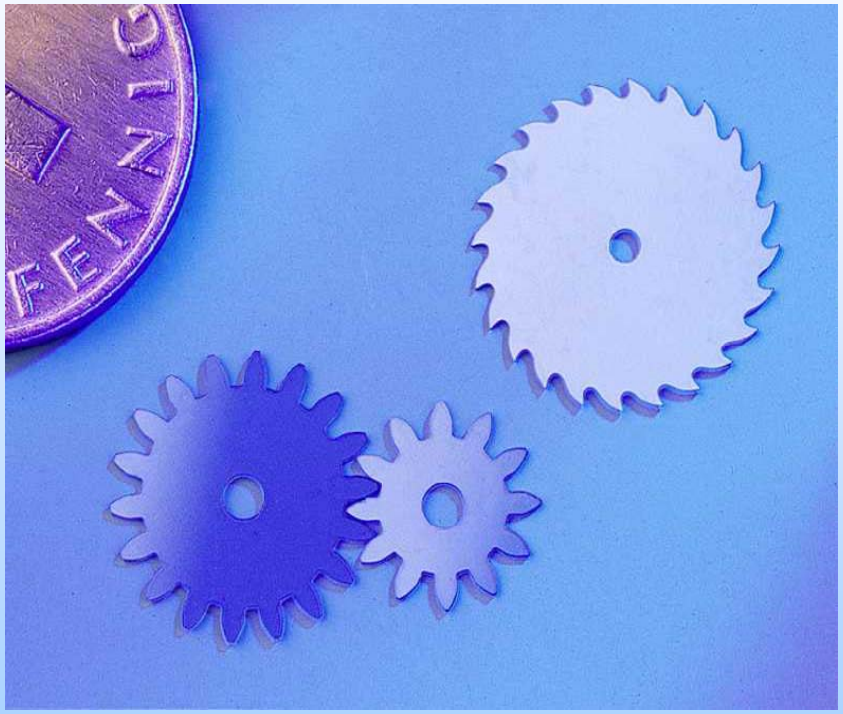
Diamond scalpels with atomic tip cutting edges





Fraunhofer Institut Angewandte Festkörperphysik

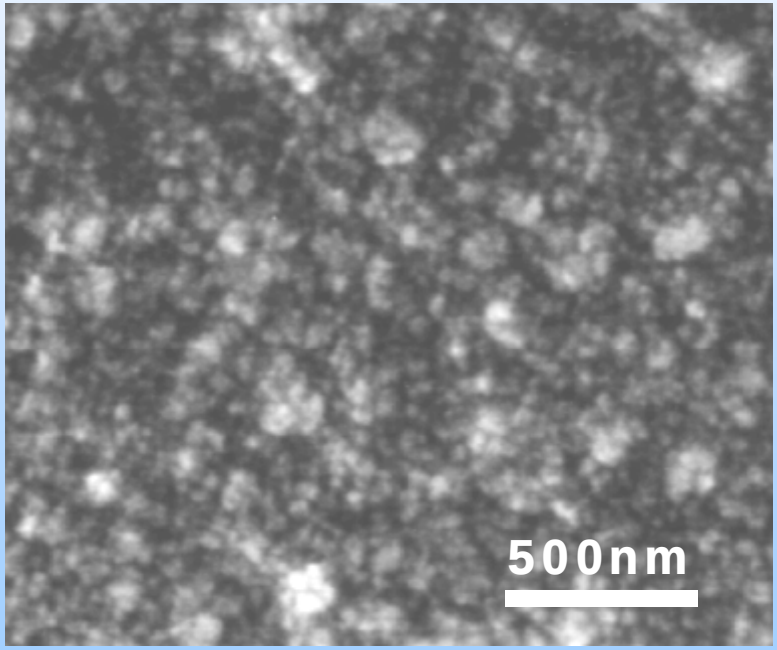
Machine parts for micromechanics



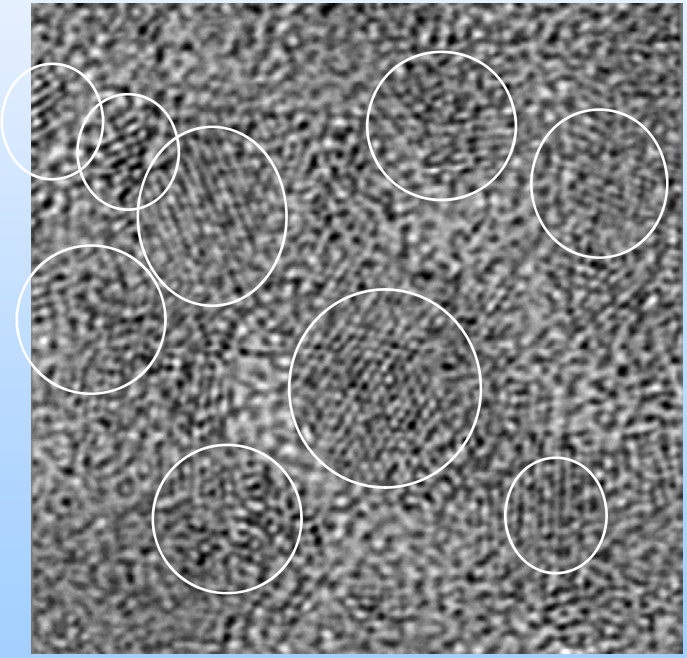
Computer controlled laser cutting (Nd:YAG)

Synthesis of nanodiamond

– **Ion bombardment induced nucleation**

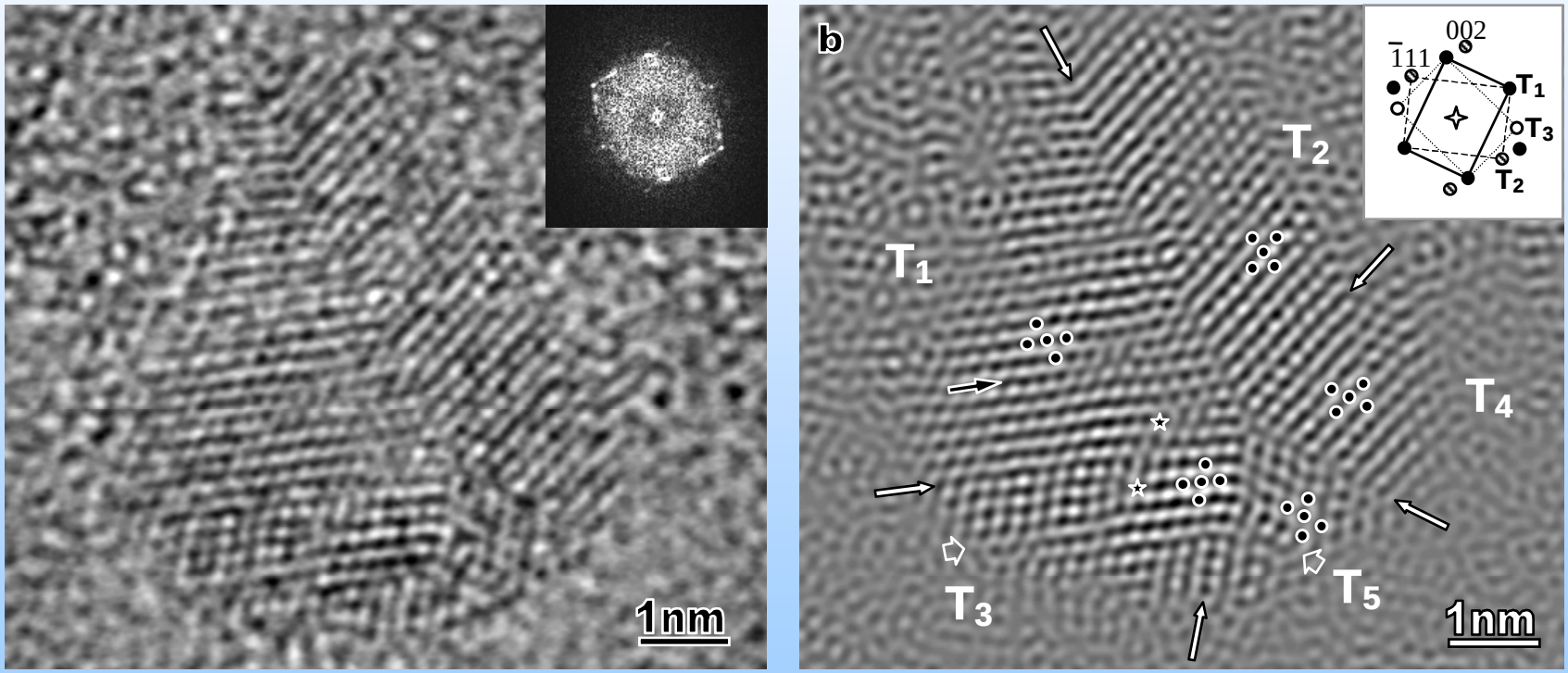


Surface roughness = 2 nm

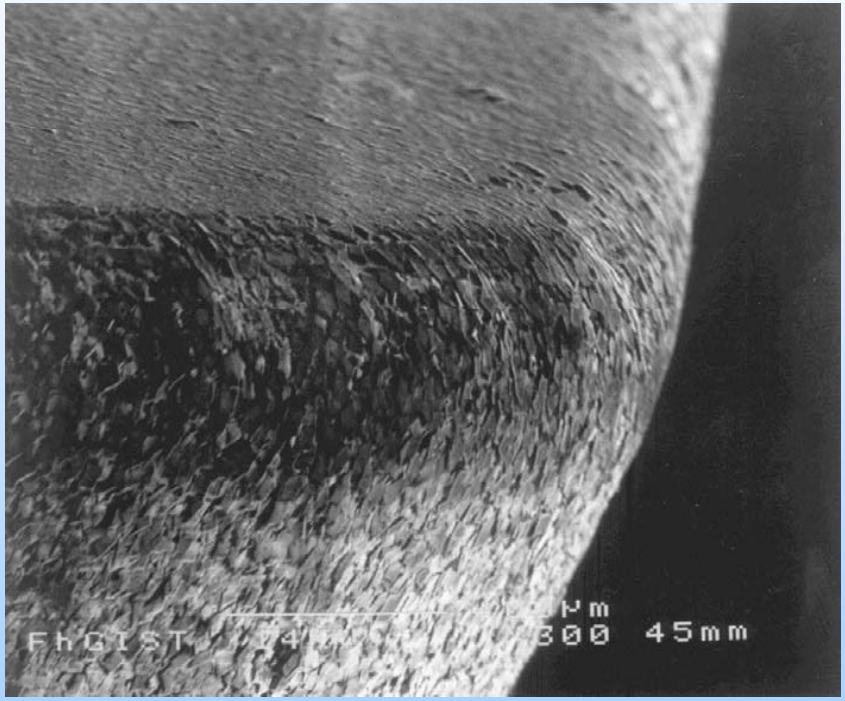


Grain size = 10 nm

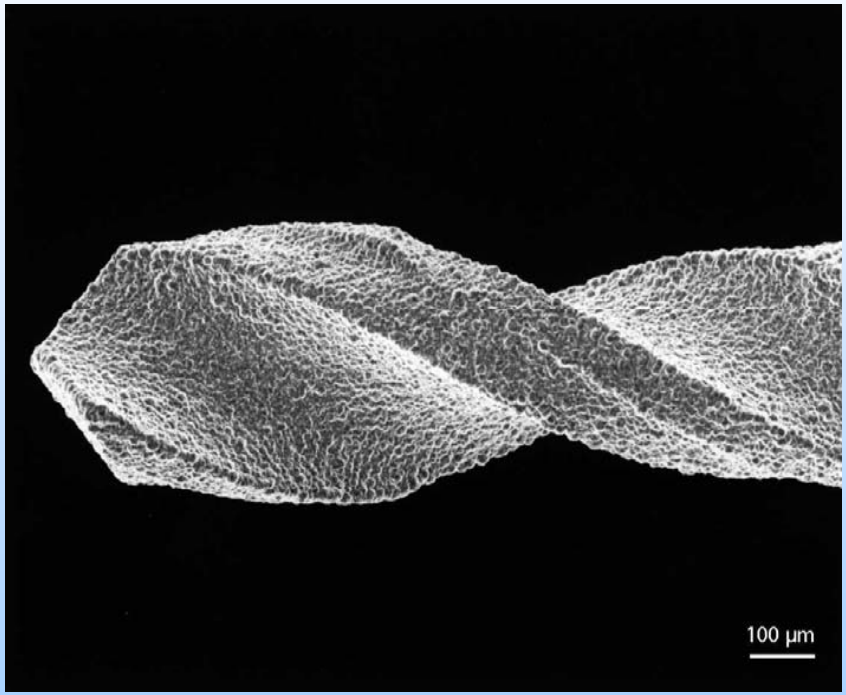
HRTEM-images of nanodiamond



Coating of cutting tools

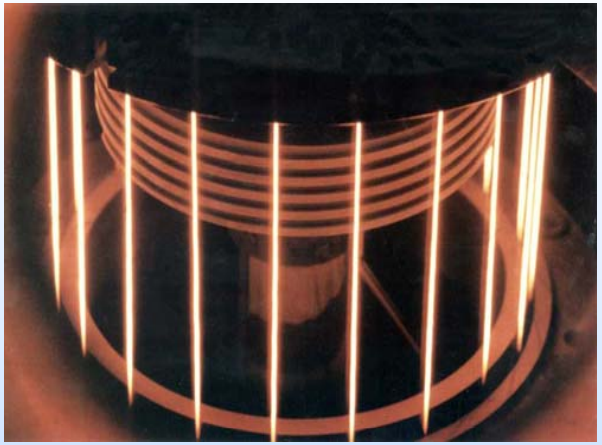


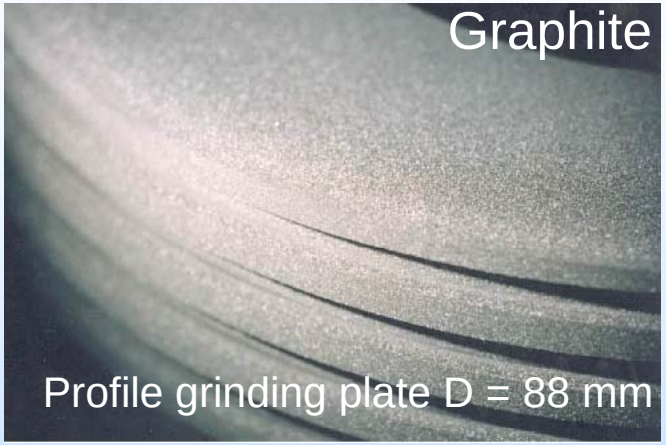
Edge of a cutting plate
with (100)-diamond film

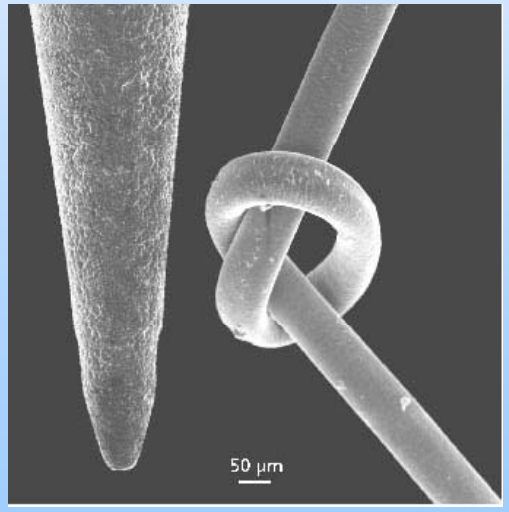


Micro-drills D = 0,15 mm

Coating of abrasive grinding tools

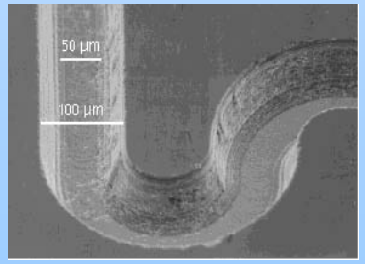


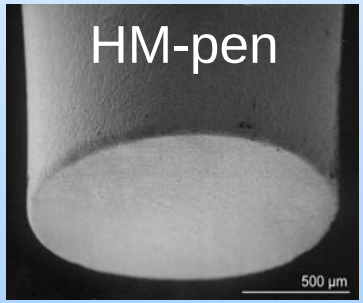




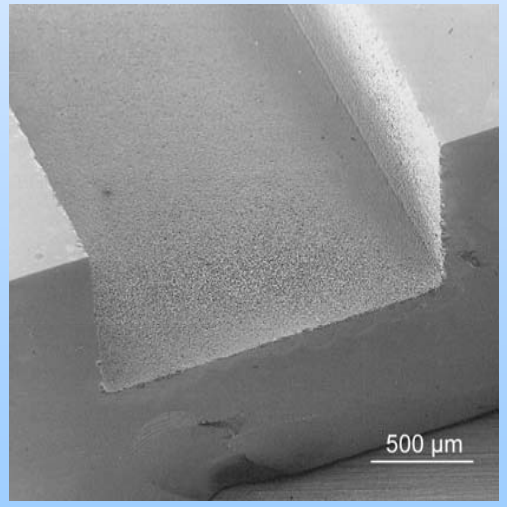
Small grinding pen, D = 50 µm

Grinded channel in silicon





Glass



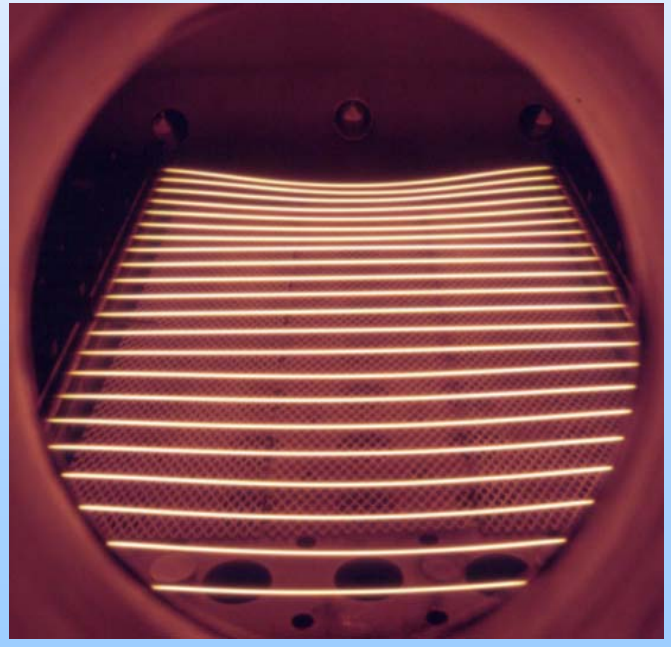
Main problems for the applications

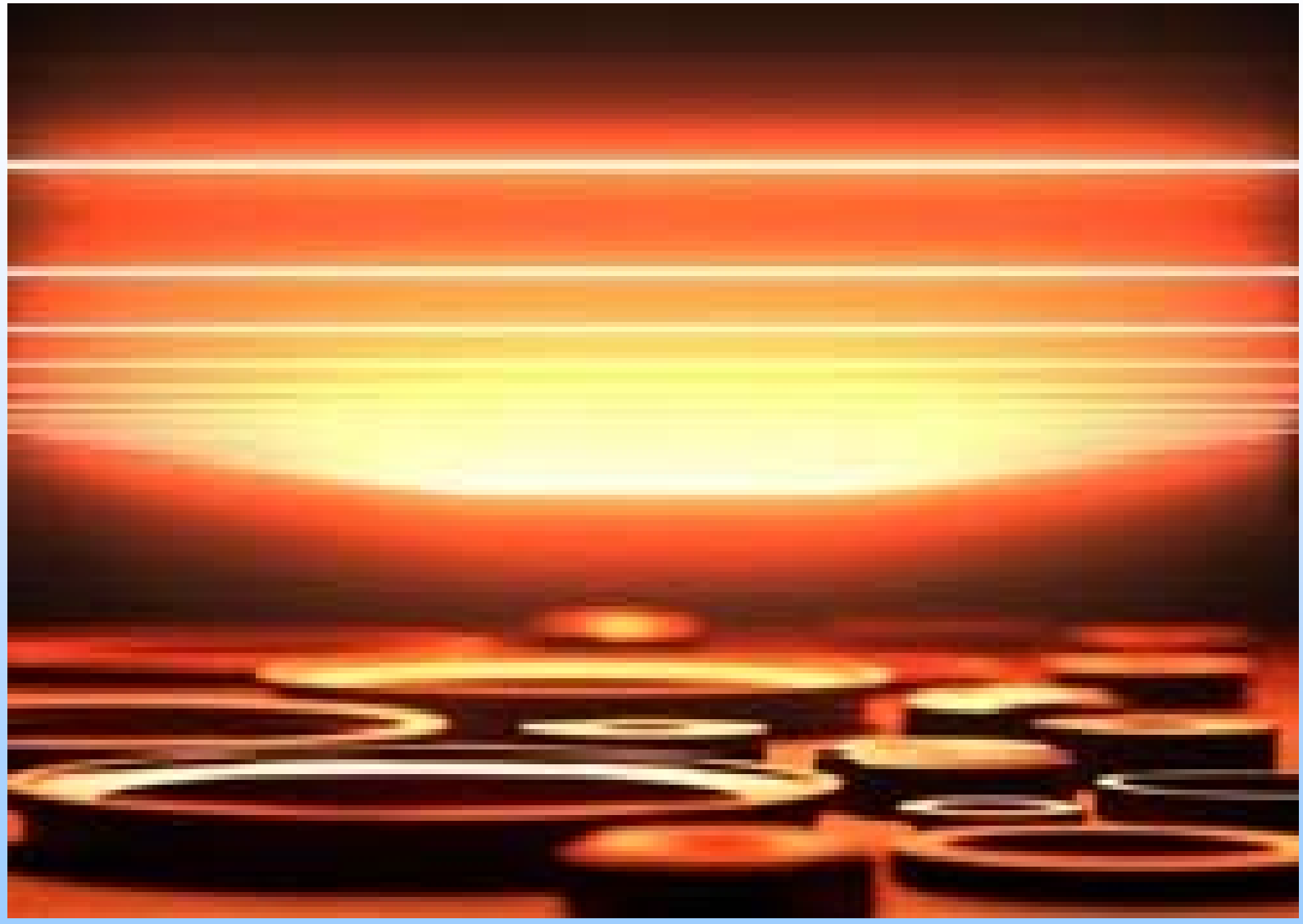
- High cost
- High defect density
- Poor film adhesion

Fraunhofer Institut Schicht- und Oberflächentechnik

Large area HFCVD diamond deposition

Planar substrates with
Filament array up to
500 mm x 1000 mm





Die Diamantschicht auf den Gleitringdichtungen wächst im Vakuumbehälter unter weiß glühenden Drähten. © Rainer Meier BFF

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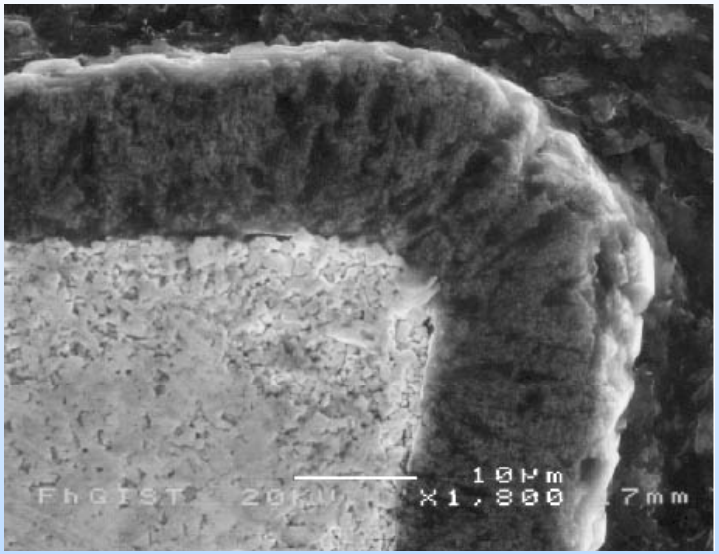
Adhesion problem prevent the application

Reason: film stress

$$\sigma_f(T) = (\alpha_s - \alpha_f)\Delta T \frac{E_f}{(1-\nu_f)}$$



α_s, α_f : thermal expansion coefficients of substrate and film

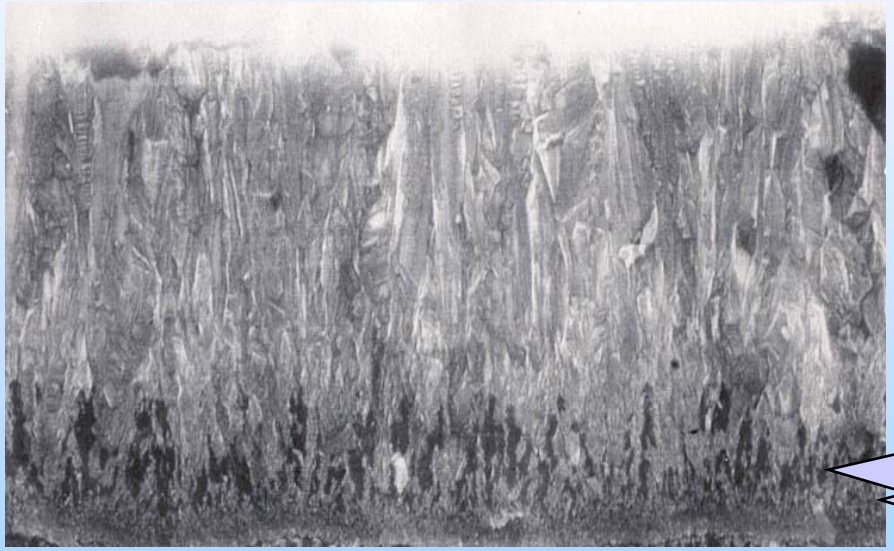
E_f, ν_f : Young's modulus and Poisson's ratio

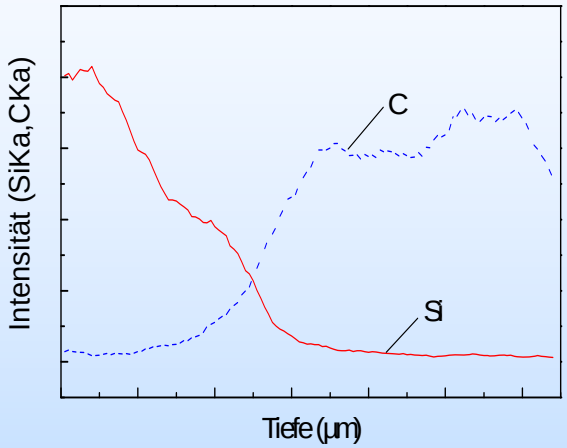
Material	Diamond	Al_2O_3	Silicon	ß-SiC	TiC	Steel
α (10^{-6}°C^{-1})	1,2	3,3	4,0	6,6	8,3	12,0
σ_f (GPa)	0,0	2,1	2,7	5,4	7,4	10,7

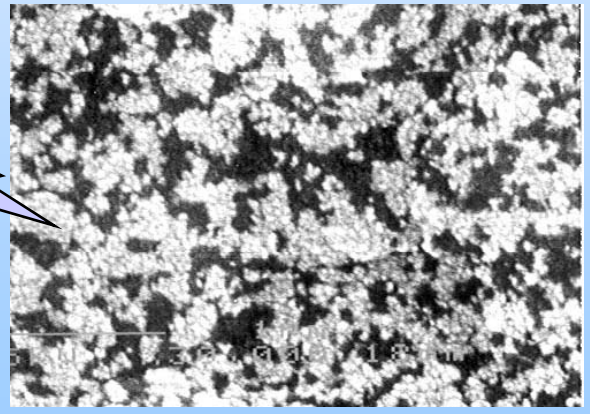
T_s = 800 °C

Carbide / diamond nano-composite films

Achieved syntheses
ß-SiC,TiC,WC/diamond composite films







Grain size: about 10 nm

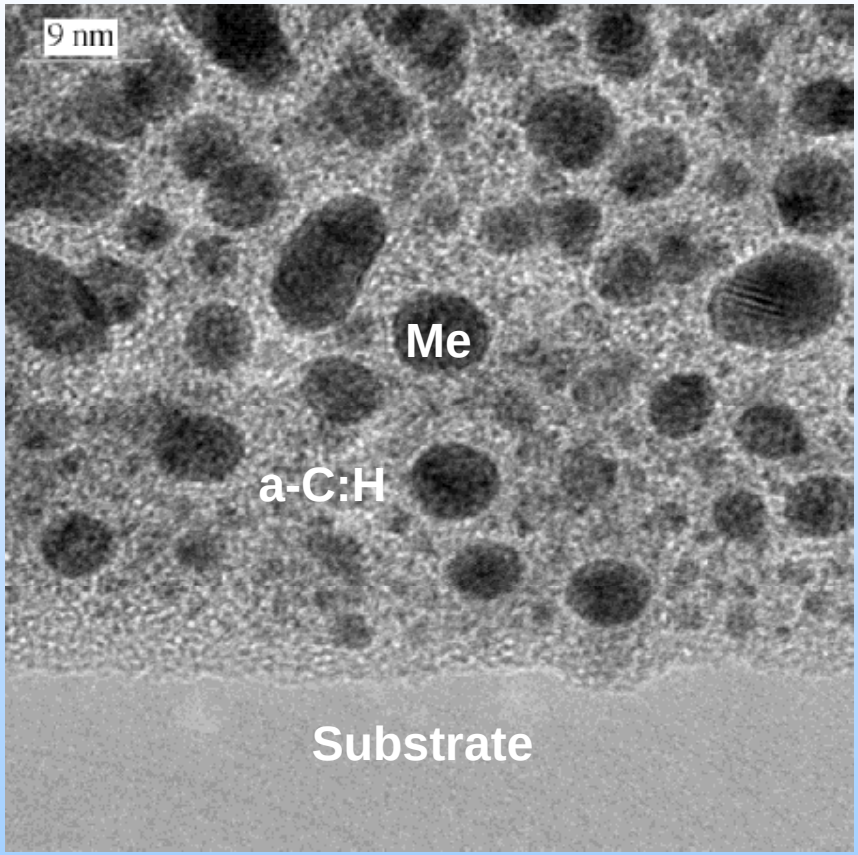
Reactive gas mixture:

$H_2/CH_4/TMS = 99{,}3\%/0{,}7\%/0{,}007\%$

$H_2/CH_4/Ti[OCH(CH_3)_2]_4$

$H_2/CH_4/WCl_6$

Metal / a-C:H-nanocomposite films



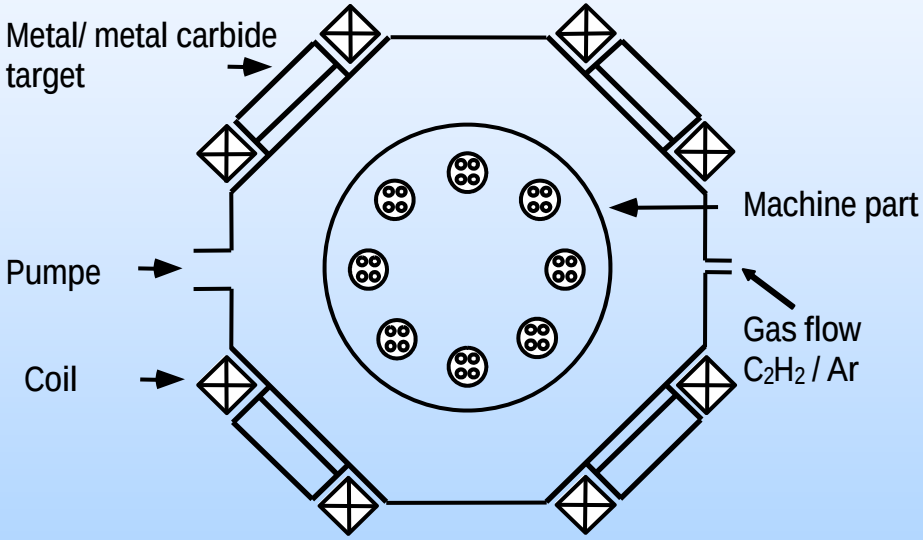
K. Schiffmann, Univ. Diss., Hamburg (1997), p22

Properties:

- high adhesion strength
- High hardness (20 GPa)
- Low friction coefficient against steel ($\mu < 0{,}2$)
- 100 time lower wear than steel
- Biocompatible

TEM image

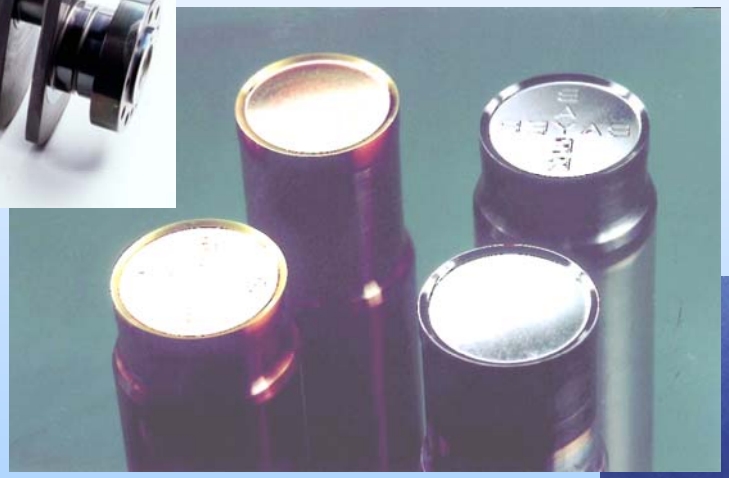
HTC 1000 magnetron sputtering set up



By variation of C_2H_2 concentration a graded film preparation is possible

Application of carbon films

Antriebselemente - Kurbelwelle für Verbrennungsmotoren:
-Reibungs- und Verschleißreduzierung
→ höhere Beschleunigung



Tablettierwerkzeug – Stempel zum Pressen von Tabletten:
-Vermeidung des Anhaftens am Werkzeug

In der Medizintechnik - Hüftgelenkprothese
Schutz des unbeschichteten Gegenkörpers-
kein Abrieb an der PE-Pfanne-