Nucleation and Plasma Enhanced Chemical Vapor Deposition of Ultrananocrystalline Diamond Films on Different Substrates

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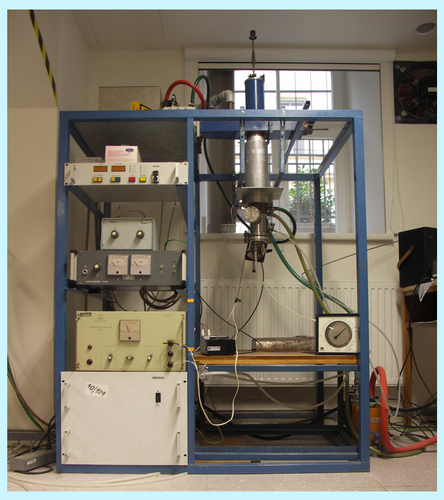
Introduction

- recent progress in nanotechnology has motivated research into small grain-sized diamond films knows as nanocrystalline diamond (NCD) and ultrananocrystalline diamond (UNCD)
- NCD and UNCD films keep advantageous properties of polycrystalline diamond films without high surface roughness [1]

Experimental

Deposition:

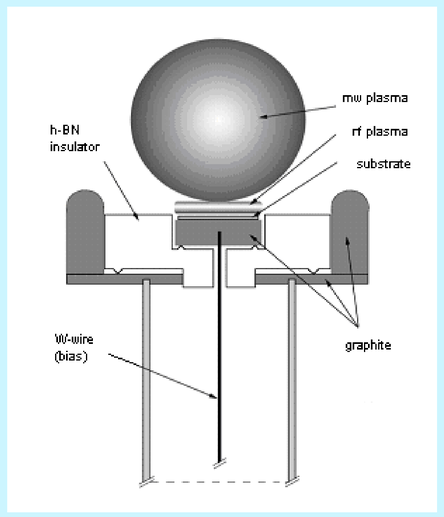
- bell jar microwave plasma reactor of ASTeX type



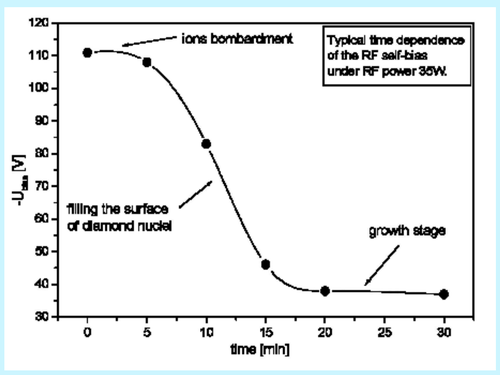
- microwave power → 800 - 950 W, pressure → 7.5 kPa, substrate temperature → 1000 - 1100 K, depositon mixture → 2 % and 9.4 % of methane in methane/hydrogen gas feed
- substrates → mirror polished (111) n-doped silicon substrates and cemented carbides

Nucleation:

- modified substrate holder for using bias enhanced nucleation (BEN) methode as a pretreatement method



- the monitoring the self-bias voltage provides important information about the diamond growth

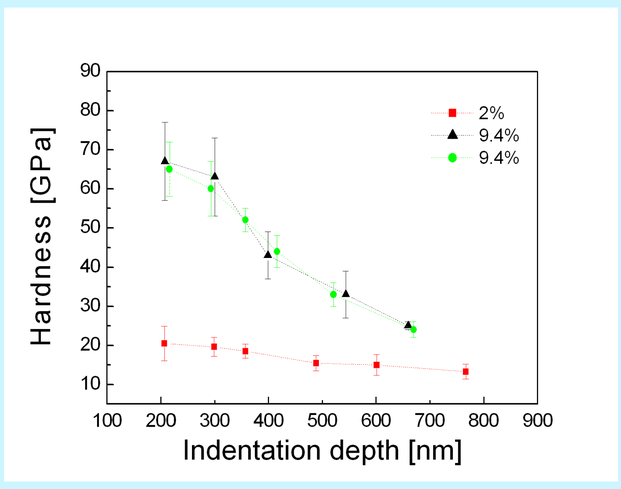


- the BEN method was used during the whole growth of the diamond film because of continuous diamond crystals nucleation leading to the deposition of UNCD films

Results

UNCD films deposited on silicon substrates

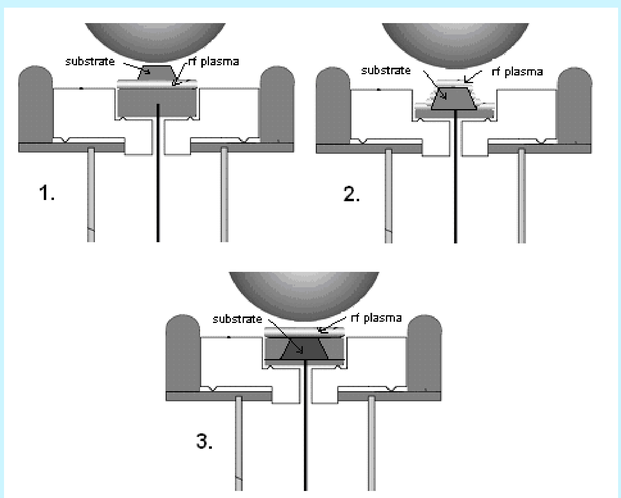
- mechanical properties were studied by depth sensing indentation technique using FISHERSCOPE H100 XYp
  - ▷ the effect of CH_4 concentration (2 % and 9.4 %) was studied



  - ▷ for 2 % the film was created from crarcity of nano-sized crystallites embedded in amorphous carbon matrix
  - ▷ for 9.4 % the films were nanocomposite with same properties, film hardness and elastic modulus were 75 GPa and 375 GPa
- surface morphology was studied by SEM and AFM and evaluated by the Gwyddion program [2]
  - ▷ the rms of heights and autocorrelation length were 13 - 18 nm and 60 - 78 nm, respectively
- optical properties were studied by spectroscopic ellipsometry and spectroscopic reflectometry [3]
  - ▷ rms and autocorrelation lengths were in the ranges 13 - 16 nm and 46 - 59 nm, respectively

UNCD films deposited on cemented carbides

- possibility of use on cutting tools → enhancement of mechanical properties and adhesion
- three type of substrate holder was construct



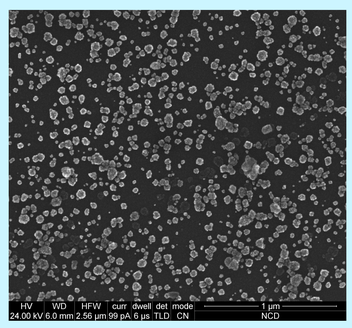
1. rf discharge wasnt on the top of the substrate → no film
2. rf discharge was around whole substrate but after end of the deposition, substrate was covered by soot
3. rf discharge was on the top of the substrate → same configuration as deposition on silicon substrate → the top of the substrate was covered by the film

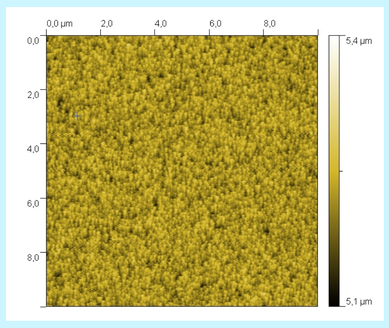
- substrates deposited with 3.substrate holder are analyzed by common analytical methodes
- UNCD films will be deposited on the cemented carbide substrates covered by TiN film on the top

Study of nucleation phase

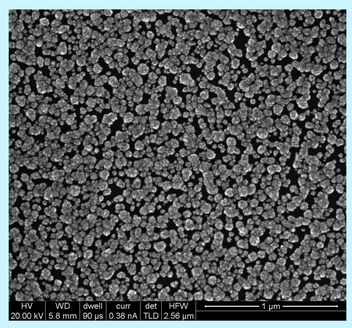
- four samples were deposited at the same deposition conditions, deposition mixture was 9,4 %, but the total preparation time varied
- the deposition was time 1 min, 2 min, 4 min and 14 min for sample S1, S2, S3 and S4, respectively
- nucleation mechanism was studied with the help of SEM and AFM

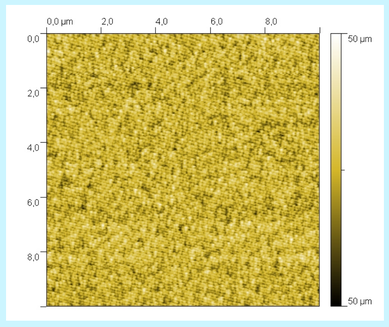
Sample S1: nucleation of individual crystallites on the substrate surface



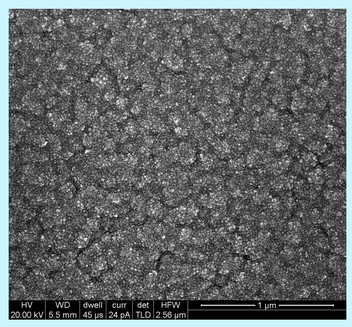


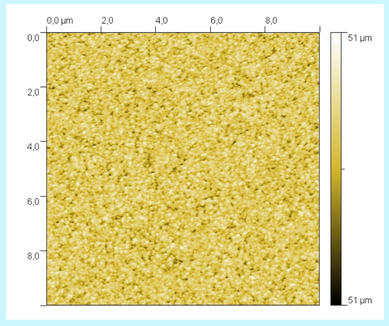
Sample S2: termination of surface nucleation and subsequent three-dimensional growth of individual crystallites



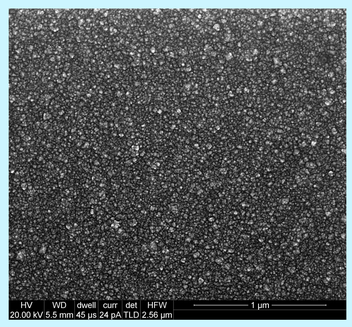


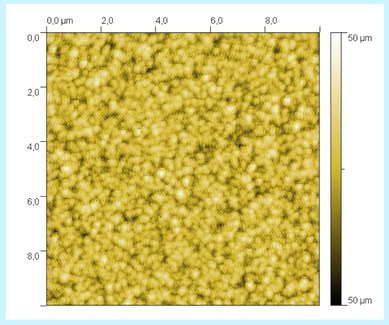
Sample S3: faceting and merging with neighboring crystallites





Sample S4: growth of the contignuous film





- it coresponded to conclusions described in the literature [1, 4]

Acknowledgement

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