NANOCRYSTALLINE DIAMOND FILMS PREPARED BY UNIQUE PLASMA ENHANCED LINEAR ANTENNAS MICROWAVE CVD SYSTEM

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Abstract
We introduce the concept of novel linear antennas (LA) sources using high-frequency pulsed microwave (MW) discharge with a high plasma density. This type of pulse discharges leads to the chemical vapour deposition (CVD) of nanocrystalline diamond (NCD) thin films, compared to ultra-nanocrystalline diamond (UNCD) thin films prepared in Ref [1]. We discuss the Raman spectral analysis and basic properties of the NCD films grown in different H_2+CH_4+CO_2 plasma chemistry conditions.

Keywords: nanocrystalline diamond films,
chemical vapour deposition (CVD),
microwave plasma,
linear antennas.

Diamond films – applications and preparation
Ultra-nanocrystalline diamond (UNCD) and nanocrystalline (NCD) diamond films have attracted more and more interest [错误！未找到引用源。] due to their unique electrical, optical and mechanical properties, which make them widely suitable for different applications, such as: MEMS devices, lateral field emission diodes, biosensors, thermoelectrics, etc. Additionally nanodiamond offer properties such as biocompatibility and non-toxicity. Typical conditions for microwave plasma assisted growth of diamond films are a mixture of CH_4 and H_2 with a very low proportion of CH_4 and a substrate temperature of about 600-1000 ºC [0]. From the point of view of the material structure and properties, it is important to develop a wide range of technologies allowing growth of thin films from UNCD (i.e continuously renucleating) to NCD (columnar) type of diamond growth. High substrate temperatures restrict the range of suitable substrates and therefore possible applications of these films. Another restriction of microwave plasma assisted growth is the growth area; typically it is restricted to a maximum diameter

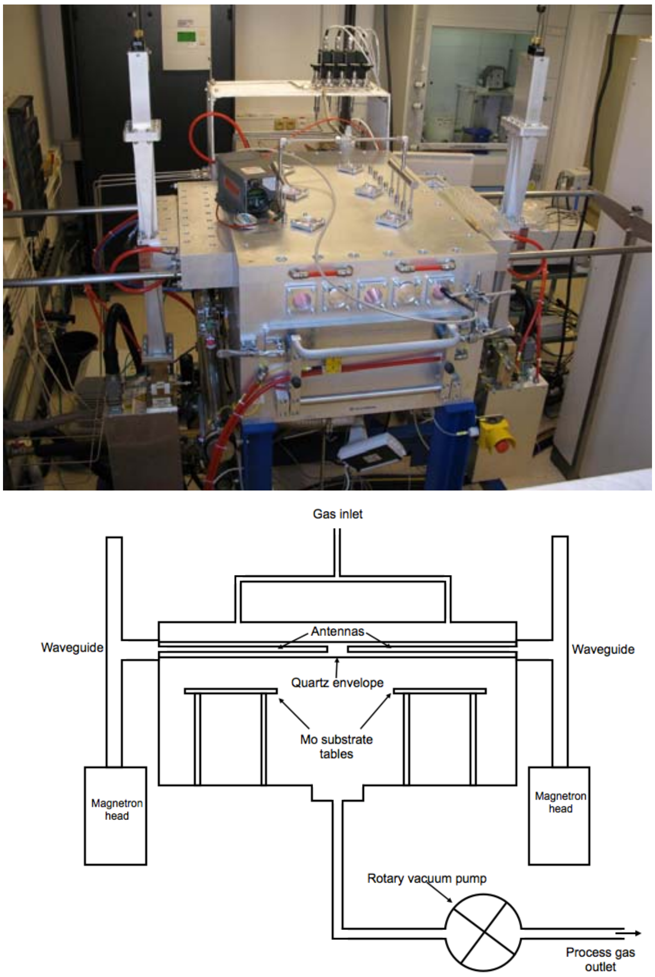

Fig. 1 Photo and scheme of the non-commercial PELAMWCVD apparatus.

of 15 cm. Again this not only restricts the range of applications but also their scale. The presented apparatus enables to produce diamond films at low temperatures (< 400 ºC) and on large areas (> 15 cm diam.) and extends it with the addition of tunable pulsed modes of MW deposition plasma generation.

Plasma Enhanced Linear Antennas MicroWave Chemical Vapour Deposition apparatus (PELAMWCVD)

The PELAMWCVD apparatus (see **Fig. 1**) consists of a rotary pump (producing a base pressure of 0.005 mbar - a turbomolecular pump allowing a vacuum of 10^{-7} mbar is planned), a growth chamber, a pressure control system, a process gas delivery control system, a microwave power controller and delivery system, a water cooling system and an air cooling system. The substrate temperature is measured by a Williamson Pro 92-38 infrared thermometer. The PELAMWCVD apparatus is capable of producing both continuous wave (at a maximum of 2 x 3 kW) and tunable pulsed microwaves (at a maximum of 2 x 10 kW). The growth chamber potentially allows the deposition on substrates up to the size of 500mm x 300mm. Microwave power is controlled by the use of a pulse-generator, magnetron heads, rectangular tunable wave guides and coaxial power distributors. Significantly higher powers (2 x 20 kW CW) are possible by this construction due to extreme low losses. Microwaves are delivered into the growth chamber in a linear form by four pairs of antennas enclosed in quartz envelopes. The linear microwave plasma sources are arranged parallel to one another above the substrate holder.

Properties of the prepared NCD films

Deposited diamond films have nanocrystalline structure (see **Fig. 2**). Their Raman spectra shows improvement of sp^3 content (peak at 1332 cm^{-1}) and reduction of sp^2 content (broad peak at about 1530 cm^{-1}) with the addition of CO_2 (see **Fig. 3**).

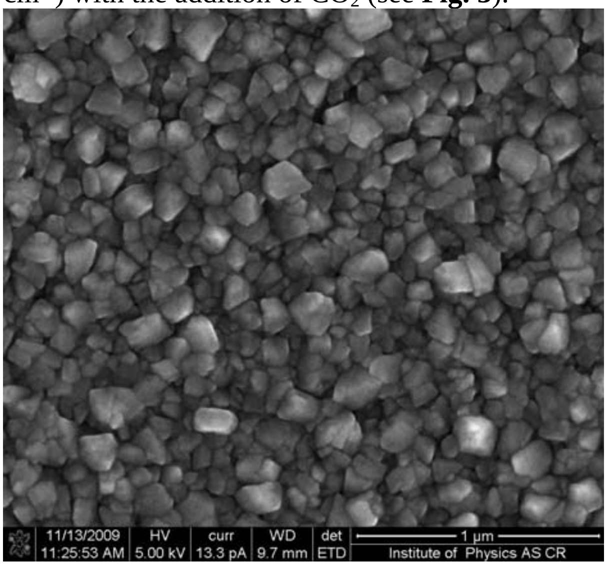

Fig. 2 SEM micrograph of prepared NCD film.

Conclusions

A unique PELAMWCVD apparatus working with pulsed plasmas at high frequency (10 kHz), 2 x 10 kW

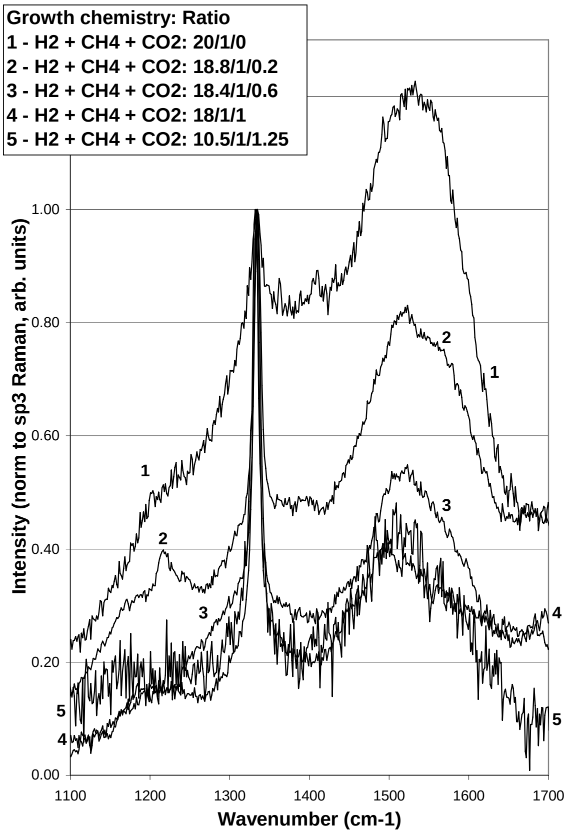

Fig. 3 Raman spectra of NCD films depending on H_2+CH_4+CO_2 gas mixture.

maximum power input and a growth area of 30 x 50 cm was built allowing exploration of non-linear MW absorption plasma chemistry. Suitable low pressure plasma-chemical processes in H_2+CH_4+CO_2 gas mixture for enhanced diamond growth rates (20 nm/h) were established for low plasma power densities (4W/cm^2 compared to > 100W/cm^2 for classical MW plasma). Columnar i.e. NCD films with low sp^2 (~ 4% for 100nm), low Rms (7-15nm) and index of refraction of ~ 2.4 were prepared. All details are described in Ref [3].

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