Synthesis of large-area CVD Diamond Wafer by Single- cathode DC PACVD for Thermal Management

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Introduction

- *Conventional DC PACVD*
  - *Advantages*
    - *High growth rate*
    - *Low capital cost*
  - *Problems*
    - *Small deposition area*
    - *Instability of plasma*
- *Scope of this paper*
  - *Stabilization of Single-Cathode DC PACVD*
  - *Improvements in 4-inch Free-standing thick diamond wafer fabrication*
    - *Thickness uniformity & bow control*
    - *Quality control*
  - *Characterization*

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Experimental

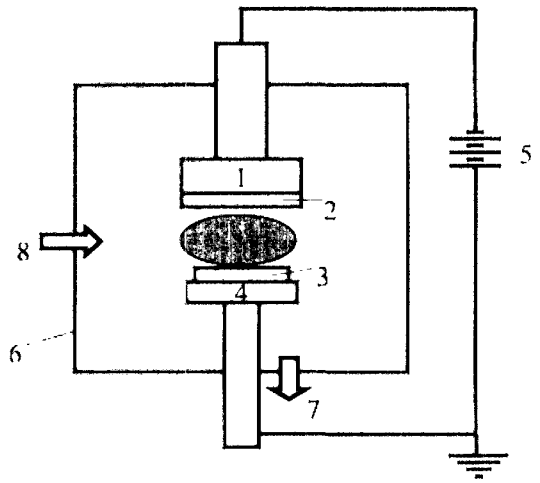

Fig. 1 Deposition system
1. Cathode holder, 2. Cathode, 3. Substrate
4. Anode, 5. DC Power Supply, 6. Chamber
7. Vac. Pump, 8. Gas Inlet

- *Diamond Deposition*
  - *Power: 35-45 kW, Pulsed DC*
  - *Gas Flow rate: 200 sccm*
  - *Pressure: 120-150 Torr*
  - *Substrate Temp.:1120~1300°C*
  - *Gas : H2+CH_4*
- *Characterization*
  - *Thickness distribution*
  - *Bow*
  - *Thermal conductivity*
  - *Raman Spectroscopy*

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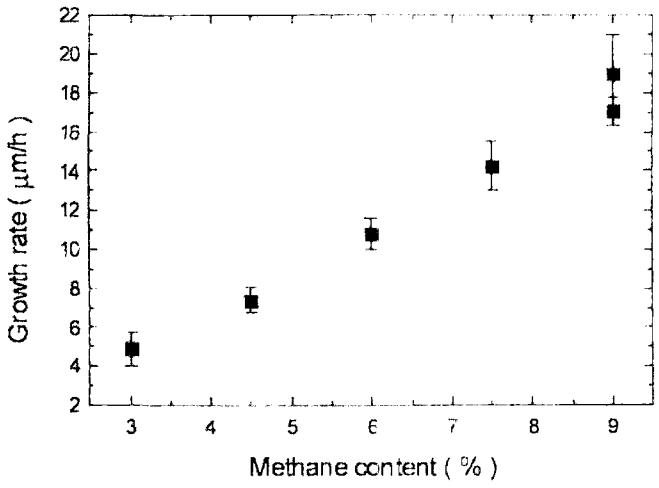
Effect of CH_4 % on the growth rate of 4-inch diamond wafer



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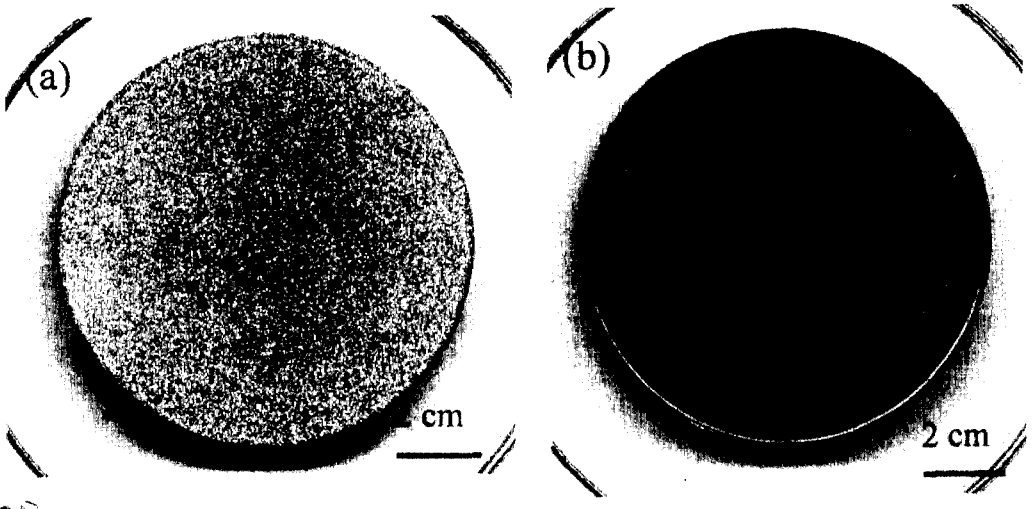
Morphology of 4-inch diamond wafer grown by single-cathode DC PACVD



Growth surface *Back surface*

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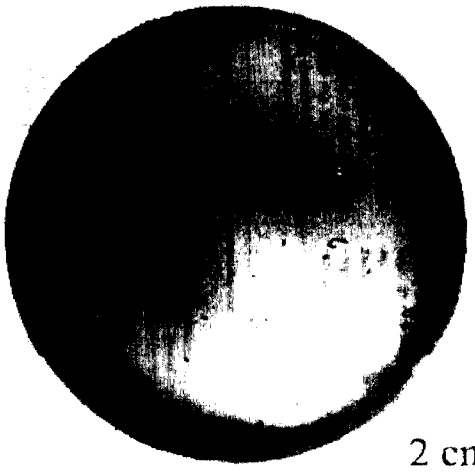
Transparency of 4-inch diamond wafer grown at 3% CH_4



- *Thickness ~ 700μm*
- *Growth rate ~ 5μm/h*
- *Grown at 3% CH_4*
- *Illuminated from the back side*

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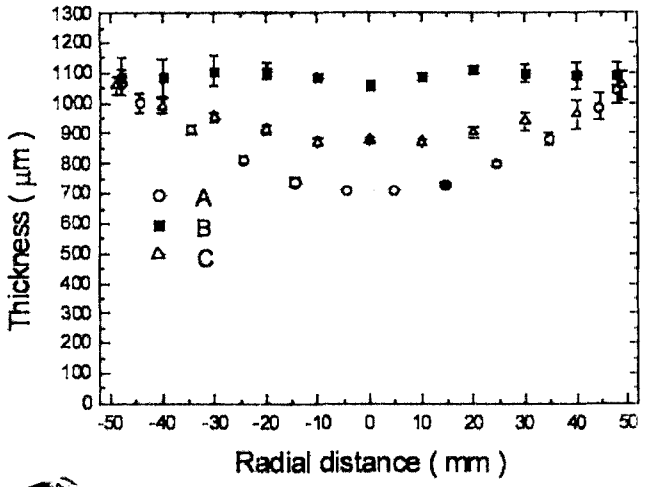
Controlling Thickness uniformity



- *Thickness distribution could be greatly modified by controlling the process parameter*
- *A :Controlled in 'negative' direction*
- *B :Controlled in 'positive' direction*
- *C : Not controlled*

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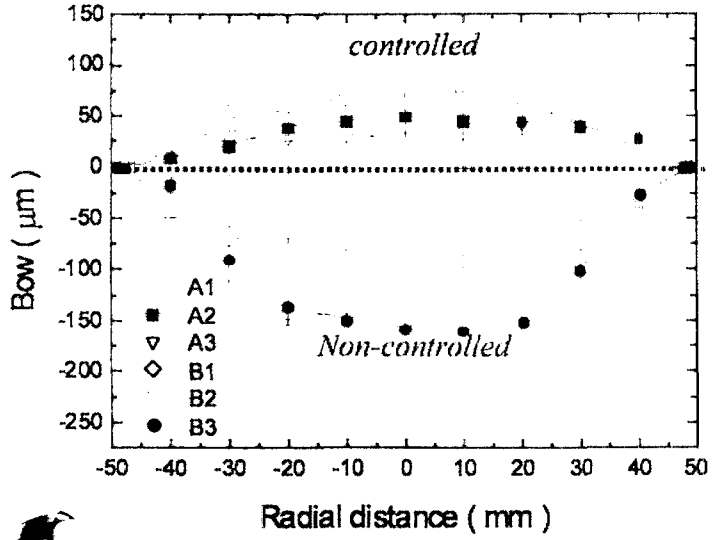
Controlling the bow of 4-inch diamond wafers



- *Bow of wafer could be controlled by controlling the process*
- *When the process was not controlled (B1~B3), bow was as large as over 150 μm*
- *When microstructure was controlled (A1~A3),*
  - *bow was reduced down to 50 μm*
  - *the sign of the bow was reversed*

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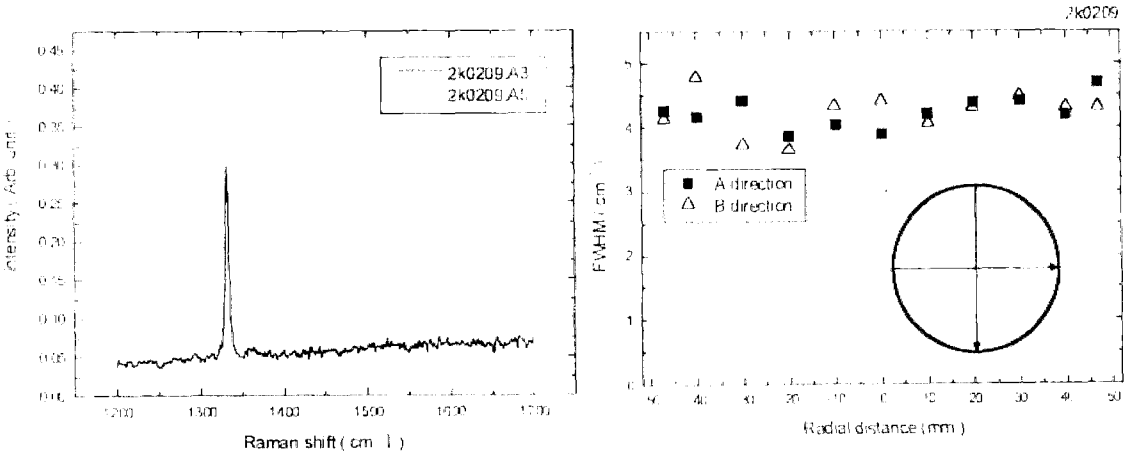
Characterization by macro-Raman Spectroscopy over 4-inch Wafer



9 % CH_4, 17μm/h, 41.2 kW, Thickness ~1mm

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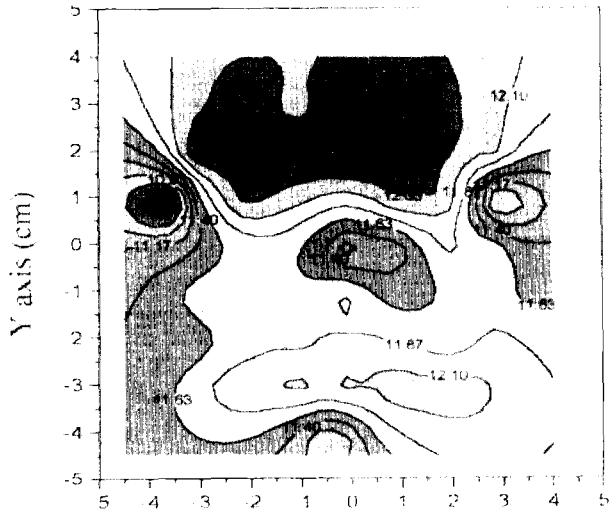
Thermal Conductivity Mapping Over 4-inch Diamond Wafer by Converging Thermal Wave Technique



- *Growth rate 14 μm/h*
- *Thickness 1074 μm*
- *Power 41.4kW*
- *Gas flow rate 200sccm*

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Conclusions

- *Long-term stabilization of dc plasma was achieved*
- *The uniformity and the flatness of 4-inch diamond wafer could be greatly improved by process control*
- *The high growth rate of 17 μm/h was obtained by increasing methane concentration and power*
- *The thermal conductivity of 4 inch wafer grown at a rate of 14 μm/h was as high as 10~13 W/cmK*
- *Further scale-up can be easily achieved by simple increase of electrode diameter and power, which will enable the synthesis of larger diamond wafers with higher growth rate and higher quality than those presented in this paper*

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