

# Surface and quality modification of diamond-like carbon films by CO<sub>2</sub> laser heating assisted hot filament chemical vapor deposition



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An infrared CO<sub>2</sub> laser was used for regional heating to study the heating effect on HF-CVD of DLC formation on Si(100) face substrates. The micro-Raman spectrometer and scanning electron microscope were used for characterization of the chemical bonding types and surface morphology. The silicon substrate was loaded into the load-lock system and manually transferred into the ultra high vacuum chamber at a pressure of 10<sup>-8</sup> mbar, evacuated by means of combined titanium sublimation pump (TSP) and turbomolecular pump (Fig.1) for keeping the silicon surface clean before the deposition process was started. The tungsten filament temperature was about 1850-1950 °C, detected by optical pyrometer. The substrate surface temperature was about 450-500 °C, detected by chromel-alumel thermocouple (TC). A CO<sub>2</sub> laser beam, 2 mm in diameter, continuous wave, was used to heat the substrate for a further 20 minutes. Ultrapure H<sub>2</sub> was flowed into the chamber with a flow rate about 200-215 sccm, followed by flowing CH<sub>4</sub> gas with flow rate about 0.40-0.50 sccm. The power of the laser was varied by biasing the CO<sub>2</sub> laser tube at three different input currents, 6, 7 and 8 mA which raised the temperature on the substrate locally by 25, 45 and 55 °C respectively. These raising temperatures were calculated by the heat conduction equation.

$$\frac{\partial T}{\partial t} = k \nabla^2 T$$

Where  $k$  is the thermal conductivity and  $T$  denotes the temporal and spatial distribution of temperature. The deposition conditions were 5 hours and 21-25 mbar of pressure.

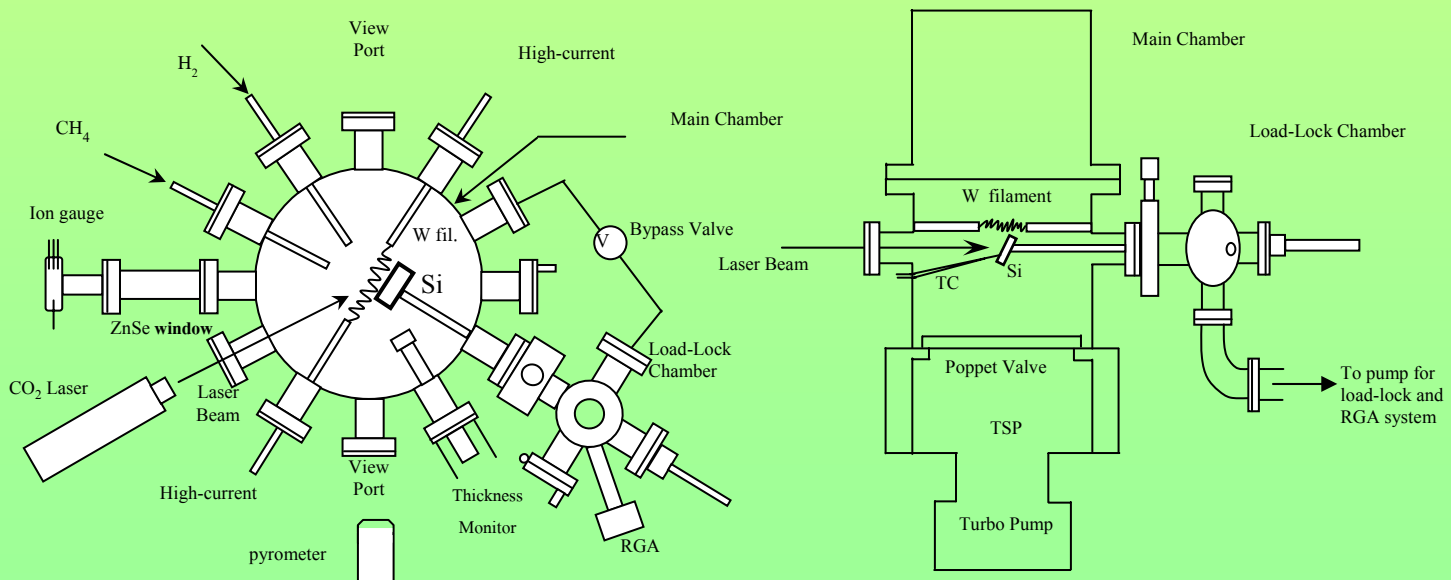


Fig. 1. Plane and sideview diagram of CO<sub>2</sub> laser heating assisted HF-CVD system.

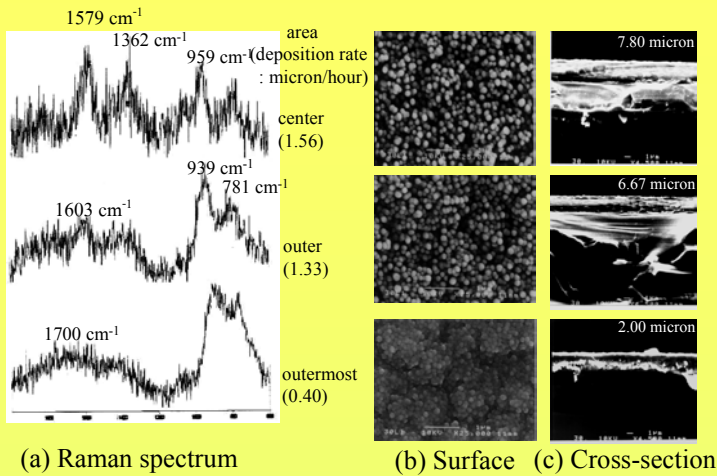


Fig. 2 (a) Raman spectrum (b) surface morphology and (c) cross-section of the low-power laser film has particle size 0.12 micron

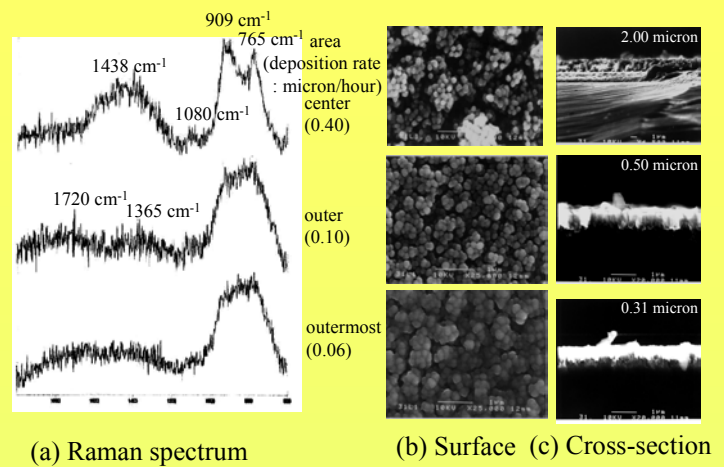


Fig. 3 (a) Raman spectrum (b) surface morphology and (c) cross-section of the medium-power laser film has particle size 0.20 micron

## Results

The Raman spectrographs, SEM pictures of surface and cross section in these deposition conditions are shown in Fig. 2, 3 and 4. For medium laser power, at the central laser beam region a broad Raman peak centered at  $1438\text{ cm}^{-1}$  was detected which had more intensity than D peak ( $1365\text{ cm}^{-1}$ ) and G peak ( $1720\text{ cm}^{-1}$ ) at the outer region. It can be concluded that this region had a good quality of DLC. This moderate high frequency peak corresponds to the four fold rotation symmetry atom in amorphous carbon network from the tight binding molecular dynamic simulation of C.Z. Wang and K.M. Ho[1]. The SiC Raman sharp peak at  $765\text{ cm}^{-1}$  observed should be due to a phase at the interface between DLC film and Si substrate. We observed this interface region in the cross sectional SEM image. In this Raman spectrograph a small peak about  $1080\text{ cm}^{-1}$  was observed. This may be nanocrystalline or amorphous diamond phase [2,3] in cluster which corresponds to some nano DLC particles observed by SEM.

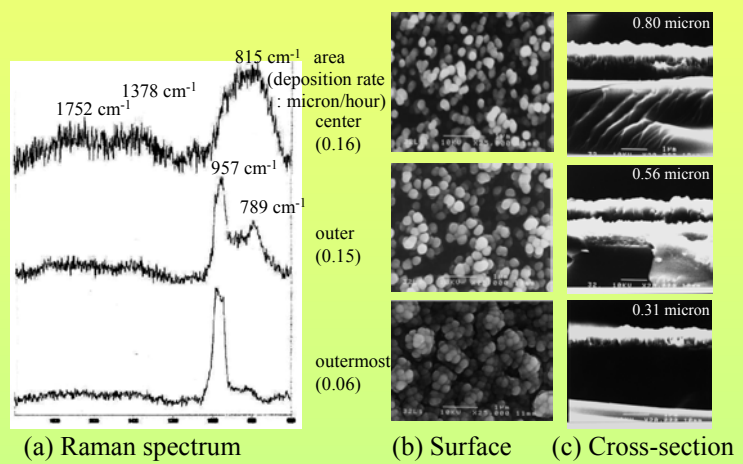


Fig. 4 (a) Raman spectrum (b) surface morphology and (c) cross-section of the high-power laser film has particle size 0.25 micron

## Conclusion

In DLC deposition by laser assisted HFCVD, the temperature had more effect on pure DLC phase and homogenous surface. We observed the most homogenous DLC deposition condition for coating on Si substrate which can be applied for development of solar cell efficiency improvement.

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## Reference

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