Comparison of Carbon Coatings Deposited by Different Techniques

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Funded by SwRI: Project No. 18-R8130

Discussion Topics

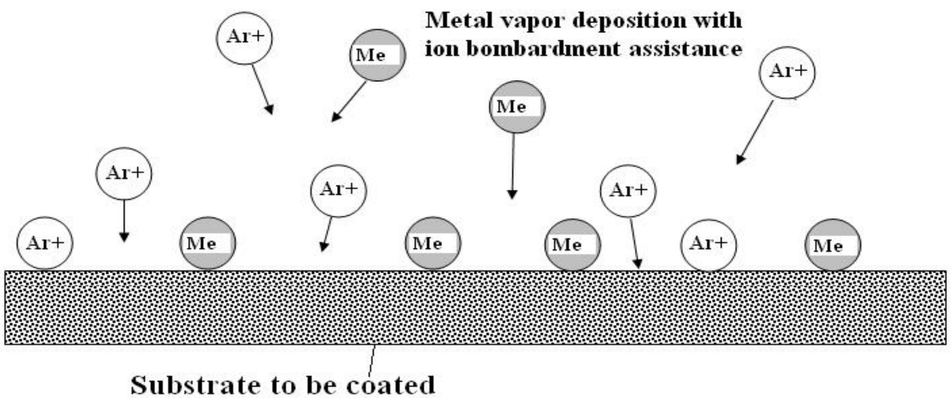
- **Motivation for Research: Understanding the role of processing techniques on structural and physical properties of carbon coatings deposited under conditions of ion bombardment**

- **Characterization of carbon coatings vs. bulk carbon materials**

- **Correlations of characteristic parameters of RAMAN spectra with coating properties**

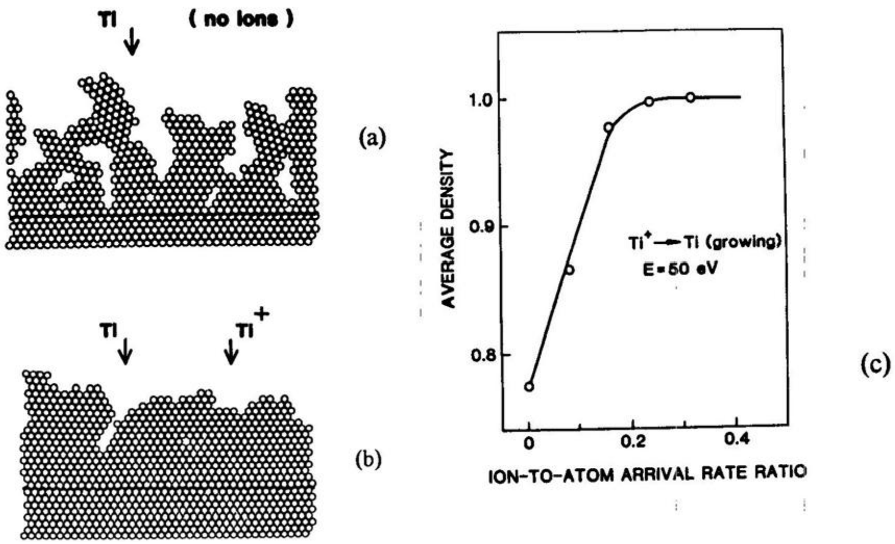
- **Influence of ion bombardment energies on coating structure and properties**

Background on Condensation with Ion Bombardment (CIB)



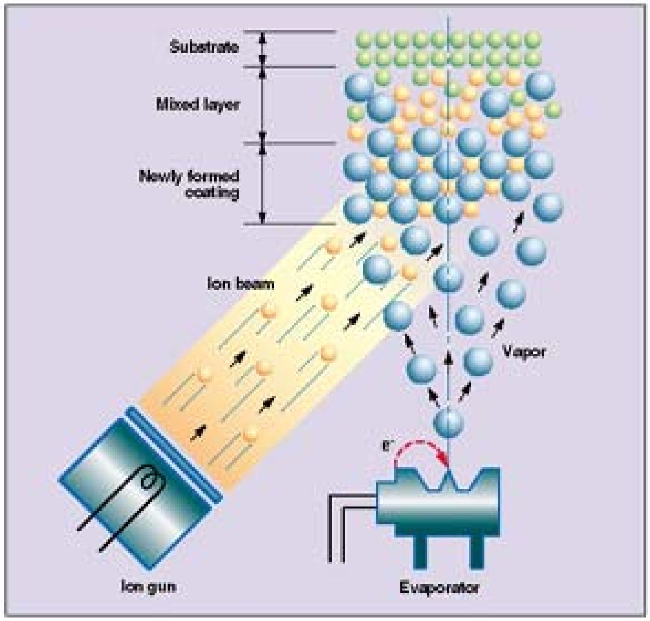
Why Metal Ion Bombardment?

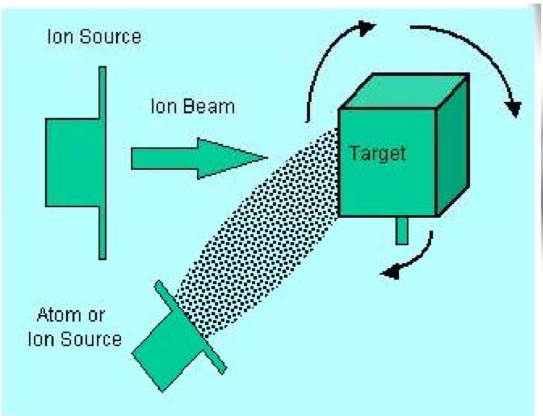
Metal ion bombardment is always concurrent with condensation, while gaseous ions impinge the surface at different locations and at different times then that of the metal atoms condensation sites



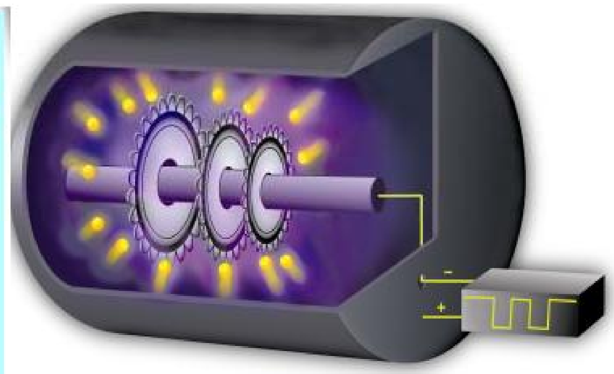
Columnar Growth of (a) Ti film resulting from the deposition of 0.2 eV Ti; (b) densification resulting from ion-vapor-arrival ratio γ_i=0.2 @ ion energy 50eV; (c) average density of Ti film vs. γ_i

Ion Beam Assisted Deposition (IBAD) vs. Plasma Immersion Ion Deposition (PIID)





Ion Beam Assisted Deposition (IBAD)



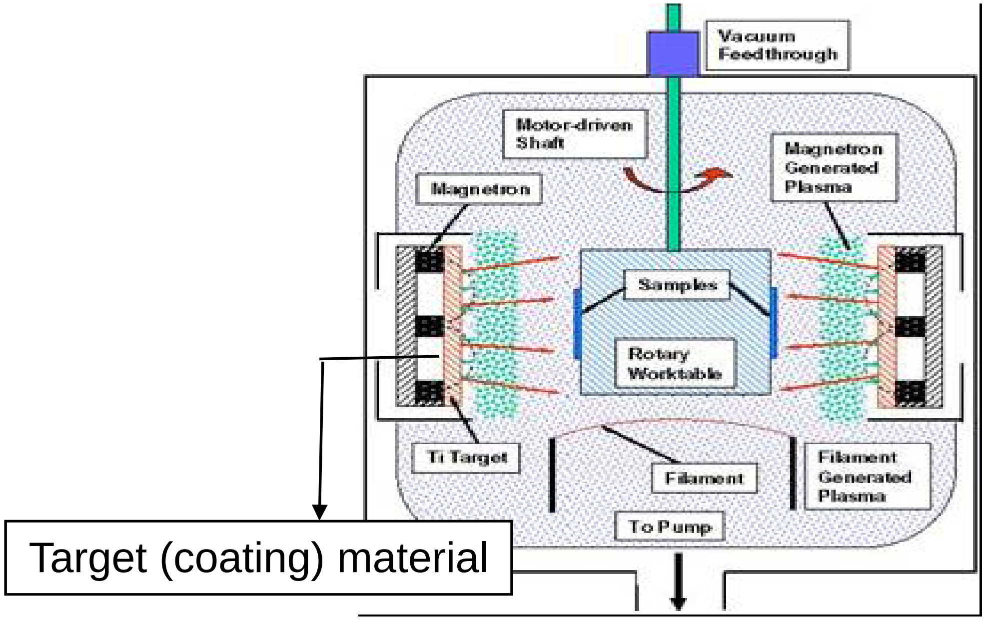
Plasma Immersion Ion Deposition (PIID)

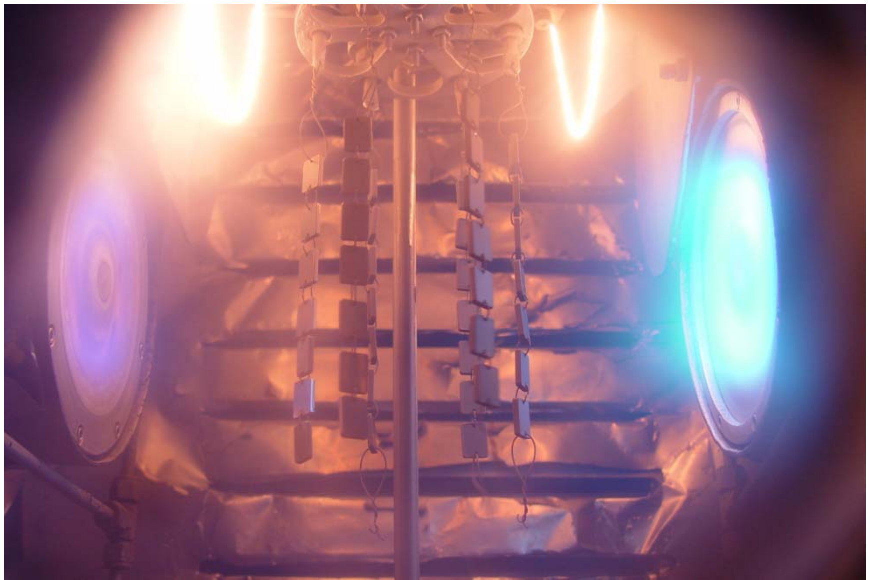
IBAD is line-in-sight process. The deposition rate, ion energy and ion-to-atom arriving ratio are critical parameters determining the coating properties.

PIID overcomes line-in-sight limitation of IBAD process by deposition of doped DLC coatings on complex shape components immersed into the dense reactive plasma environment.

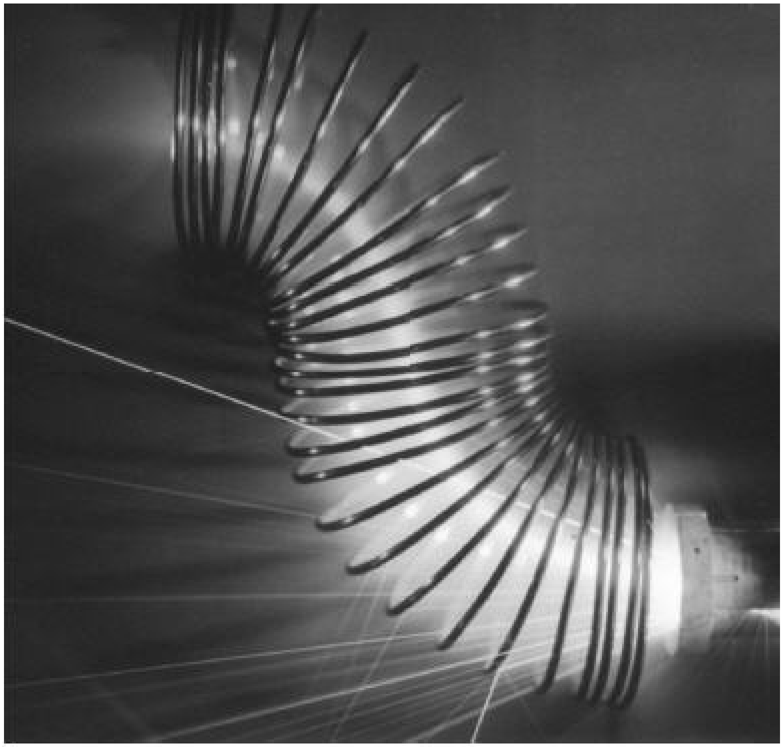
Plasma Enhanced Magnetron Sputtering Process

Metal or Graphite Targets





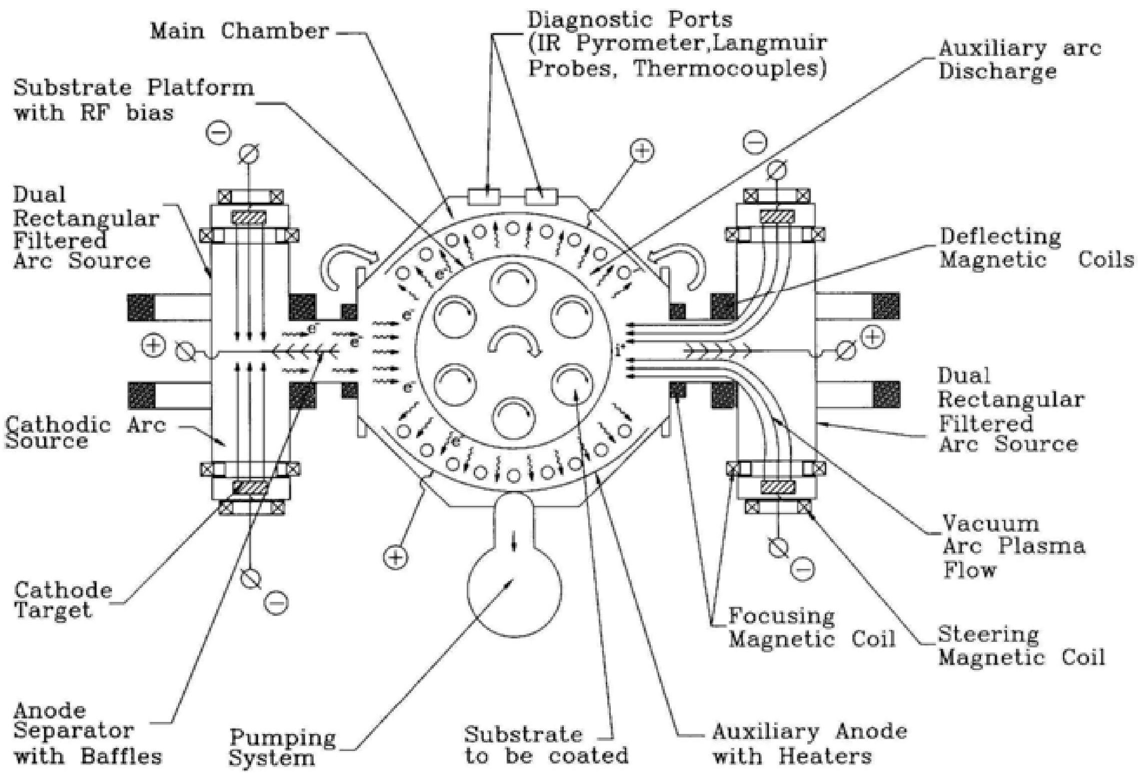
Filtered arc deposition (FAD) plasma sources with arc plasma confined in a curvilinear magnetic field



S-shape tubular solenoid- plasma duct
Courtesy of A.Anders et al.

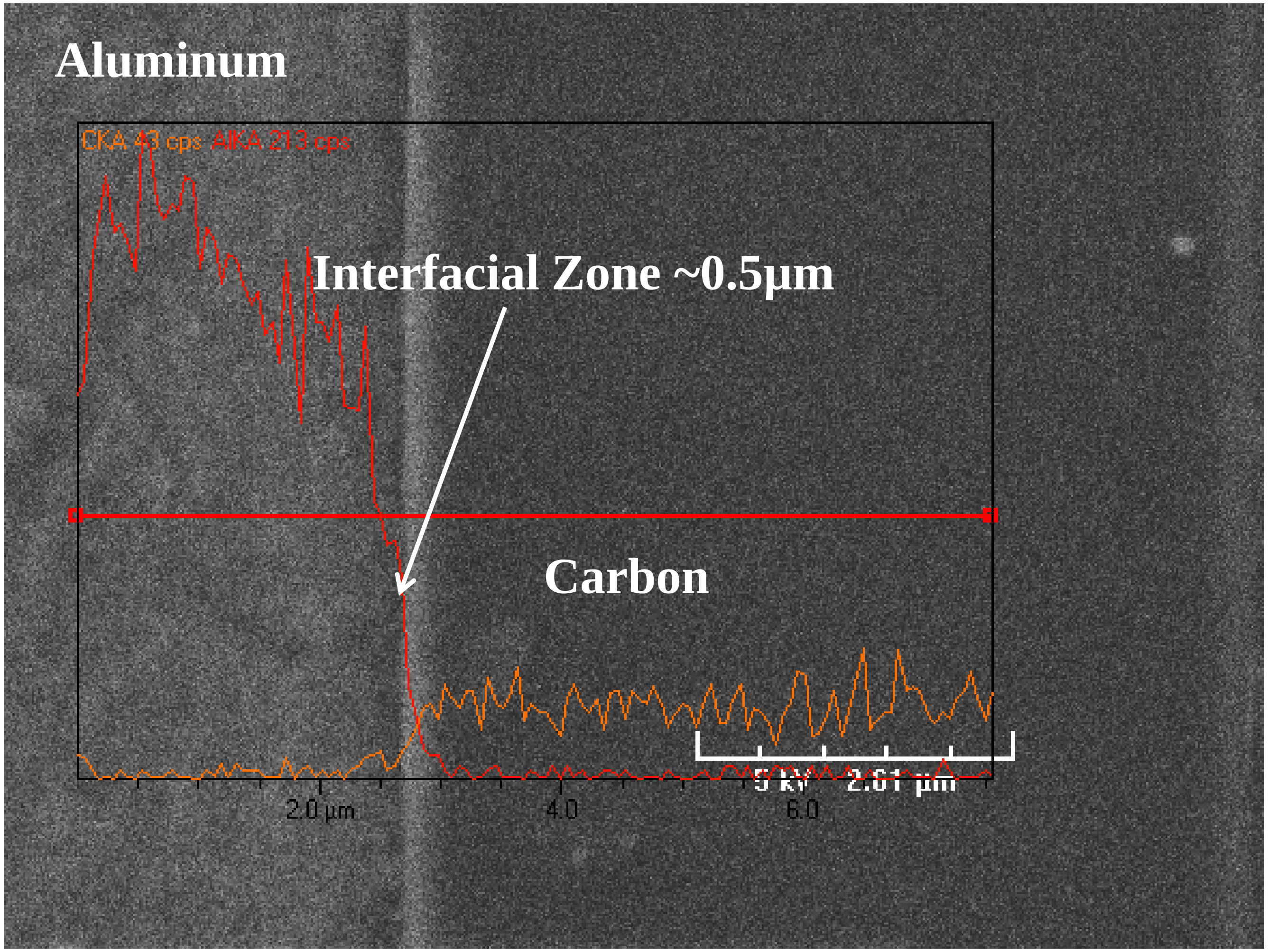
Quarter-torus tubular solenoid- plasma duct

Large Area Filtered Arc Deposition (LAFAD) Process



Courtesy of Arcomac Surface Engineering, LLC

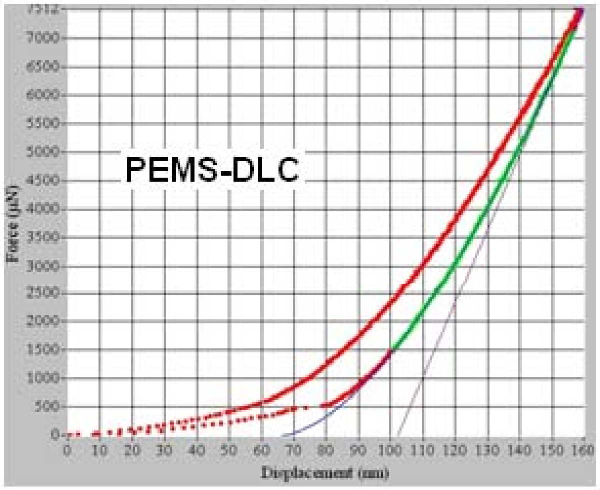
Elemental distribution in filtered arc DLC deposited on water-cooled aluminum substrate by ~100eV carbon ions

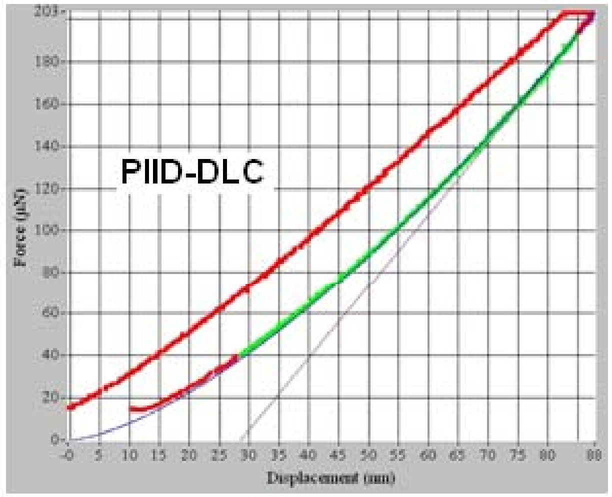


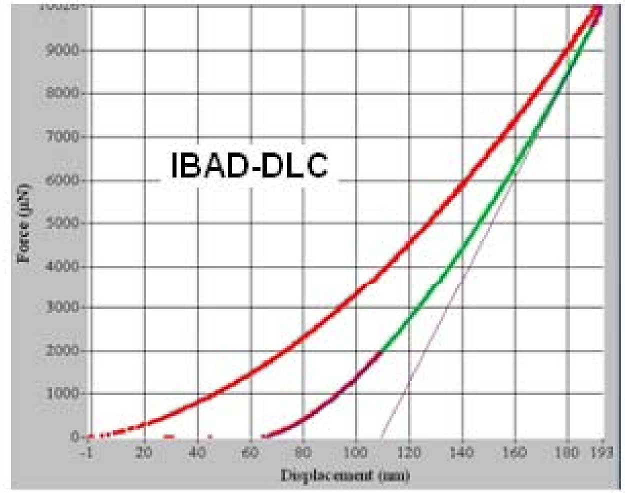
Mechanical Properties

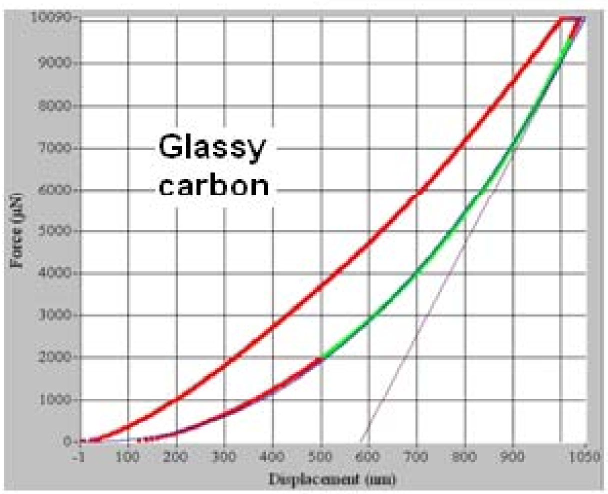
Item #	Sample ID	Thickness, µm	Hardness, GPa	Elastic Modulus, GPa	Substrate
1	Graphite	bulk	0.3	5	Microcrystalline graphite
2	T-25	bulk	0.6	4.6	Glass carbon
3	IBAD-L	1	1.6	8.6	Silicon
4	PIID-1 (SB4)	5	16.4	135.9	304 Steel
5	PIID-2 (SB1)	5	15.9	135.9	1018 Steel
6	CRNC-16 (PEMS)	1	14. 8	163.4	Steel with CrN coating
7	FAD- double rotation (DR)	~ 0.5	20.7	220	Mean value for DLCs deposited on titanium and copper substrates
8	FAD- single rotation (SR)	6	71.2	423	Water cooled aluminum

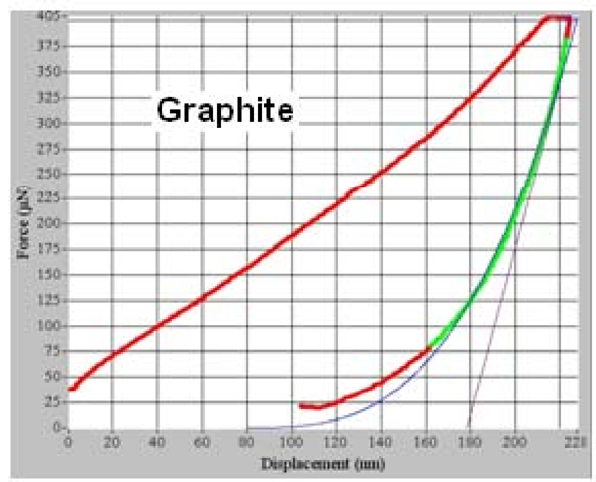
Load Displacement Curve for Carbon Coatings Deposited by Different Techniques and Bulk Carbon Materials



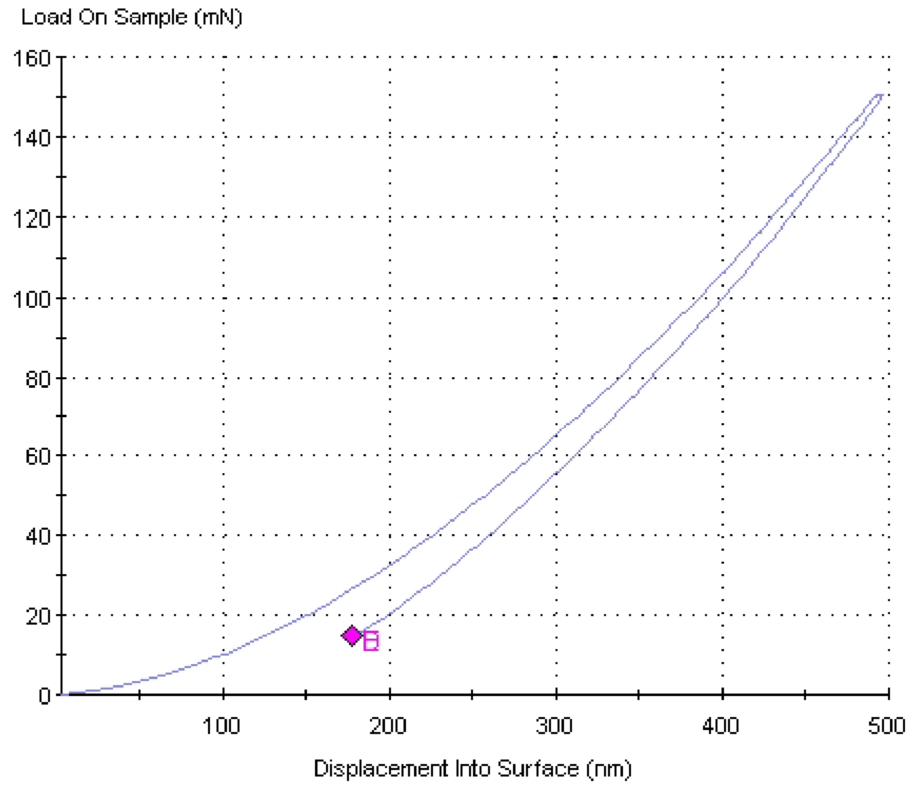






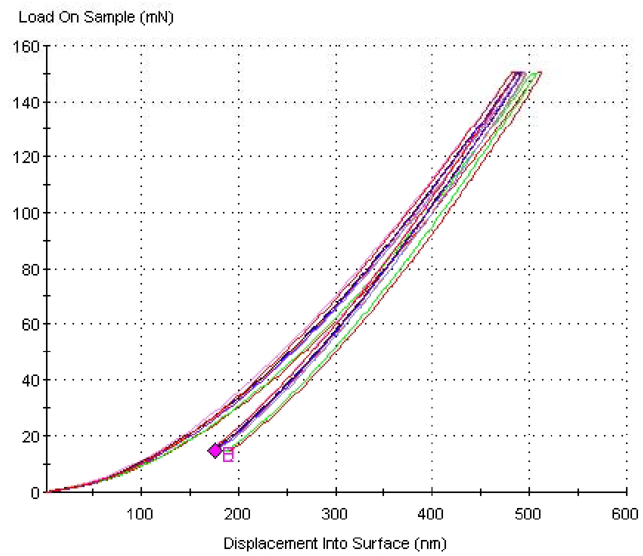


Load Displacement Curve for DLC (6um) Deposited on Water Cooled Aluminum Substrate

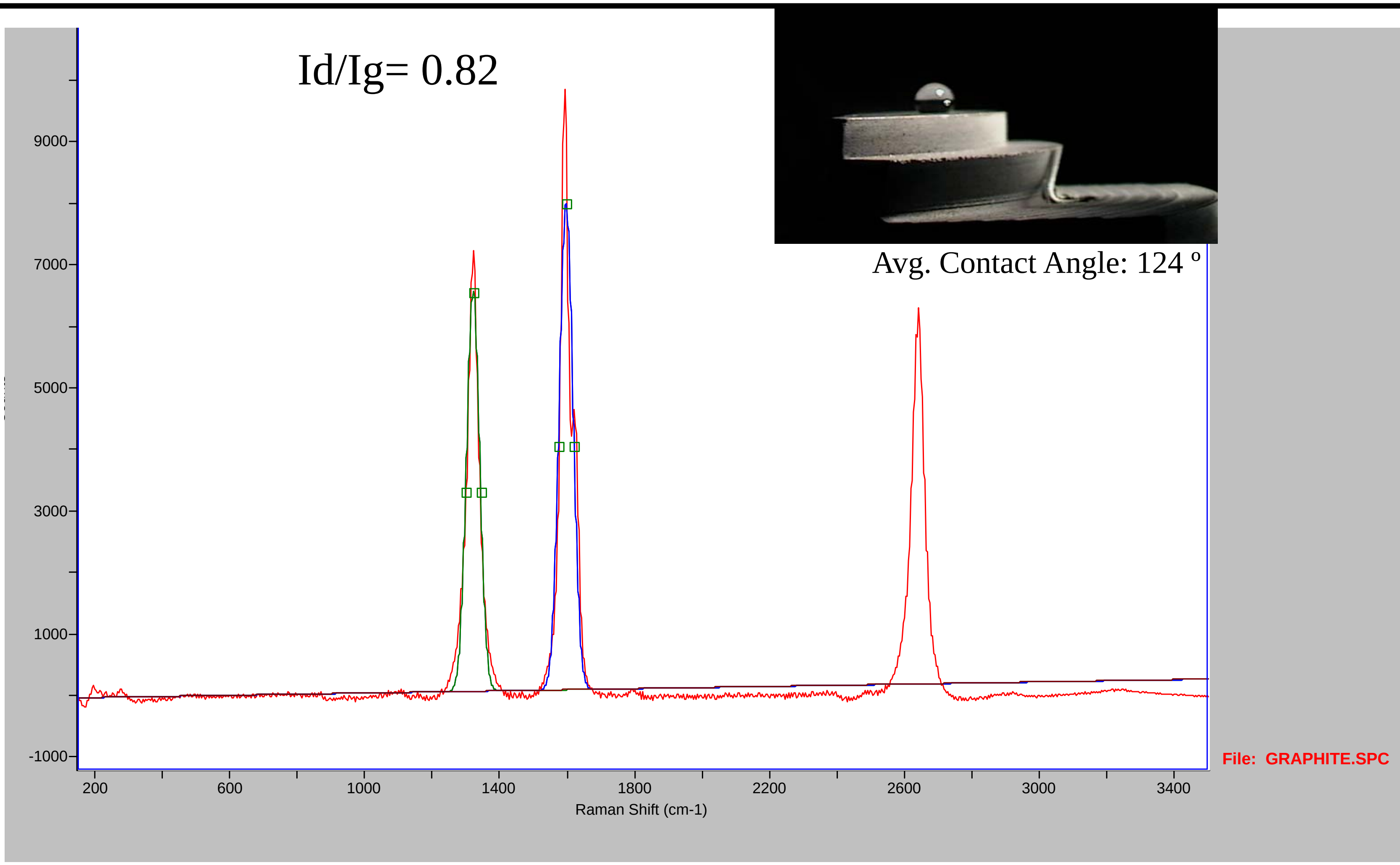


H = 71.2GPa +/-4.4

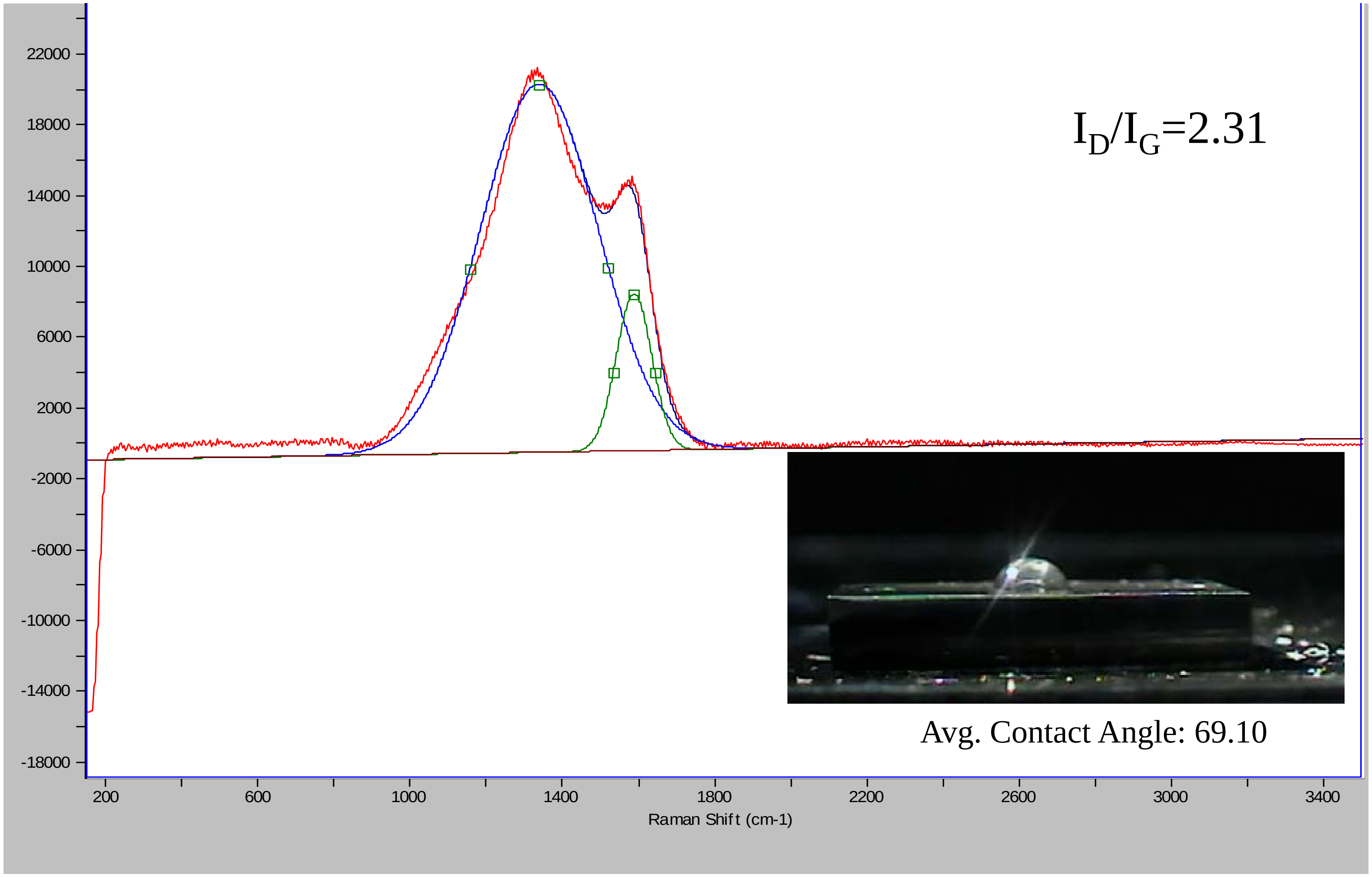
E = 423GPa* +/-17



Microcrystalline Graphite

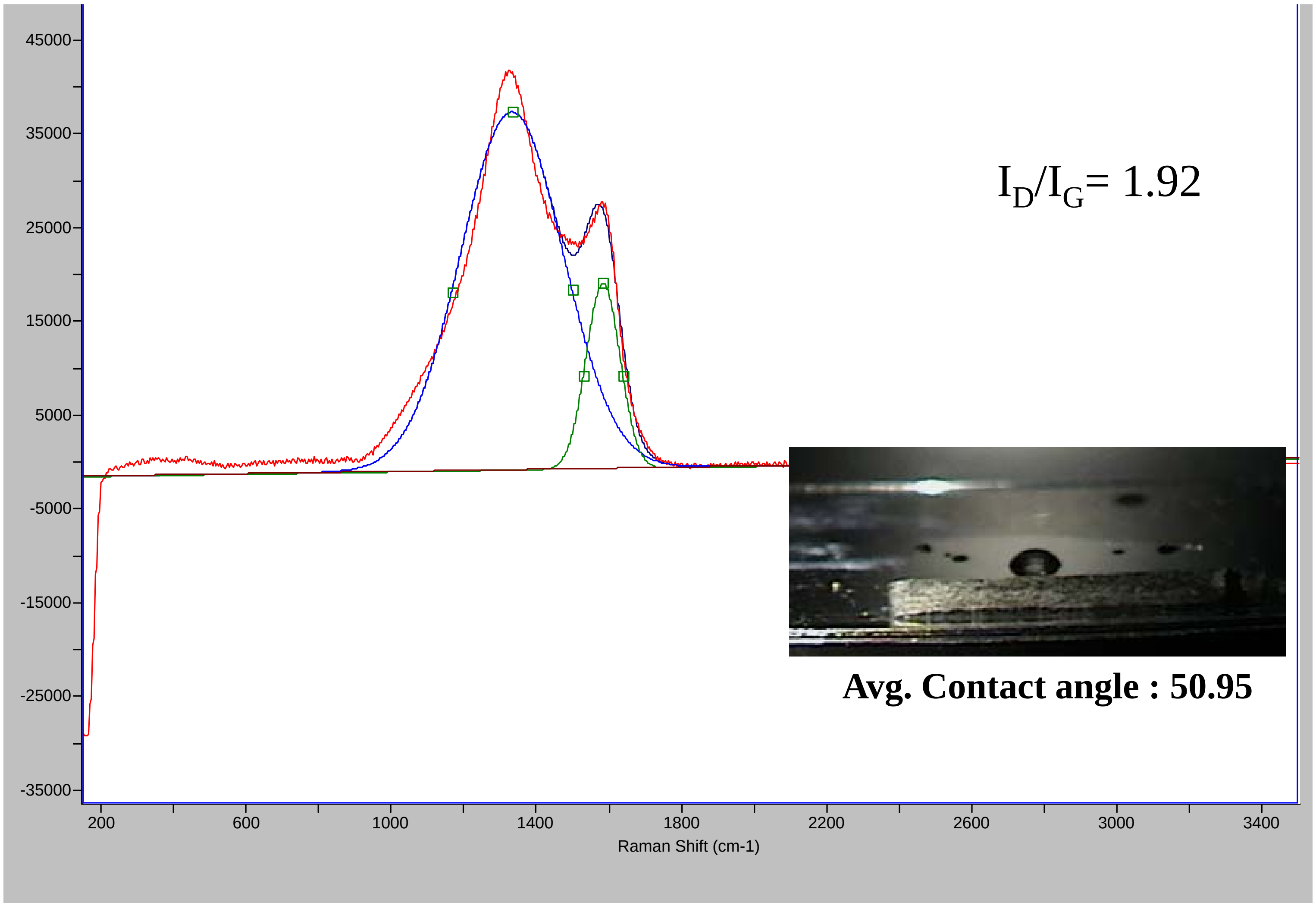


IBAD-Carbon



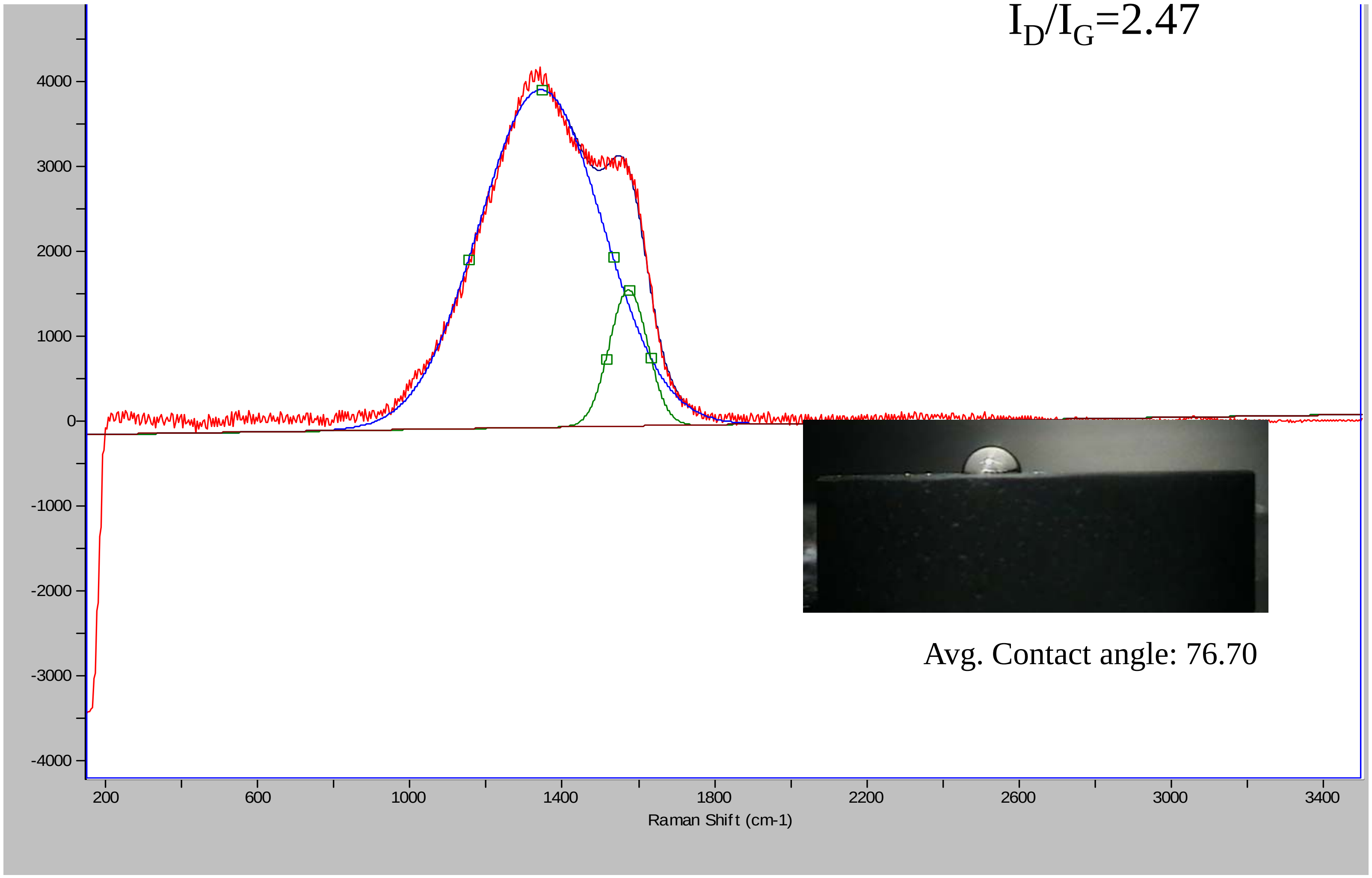
22000
18000
14000
10000
6000
2000
-2000
-6000
-10000
-14000
-18000
200
600
1000
1400
1800
2200
2600
3000
3400
Raman Shift (cm-1)
I_D/I_G=2.31
Avg. Contact Angle: 69.10

PIID-DLC

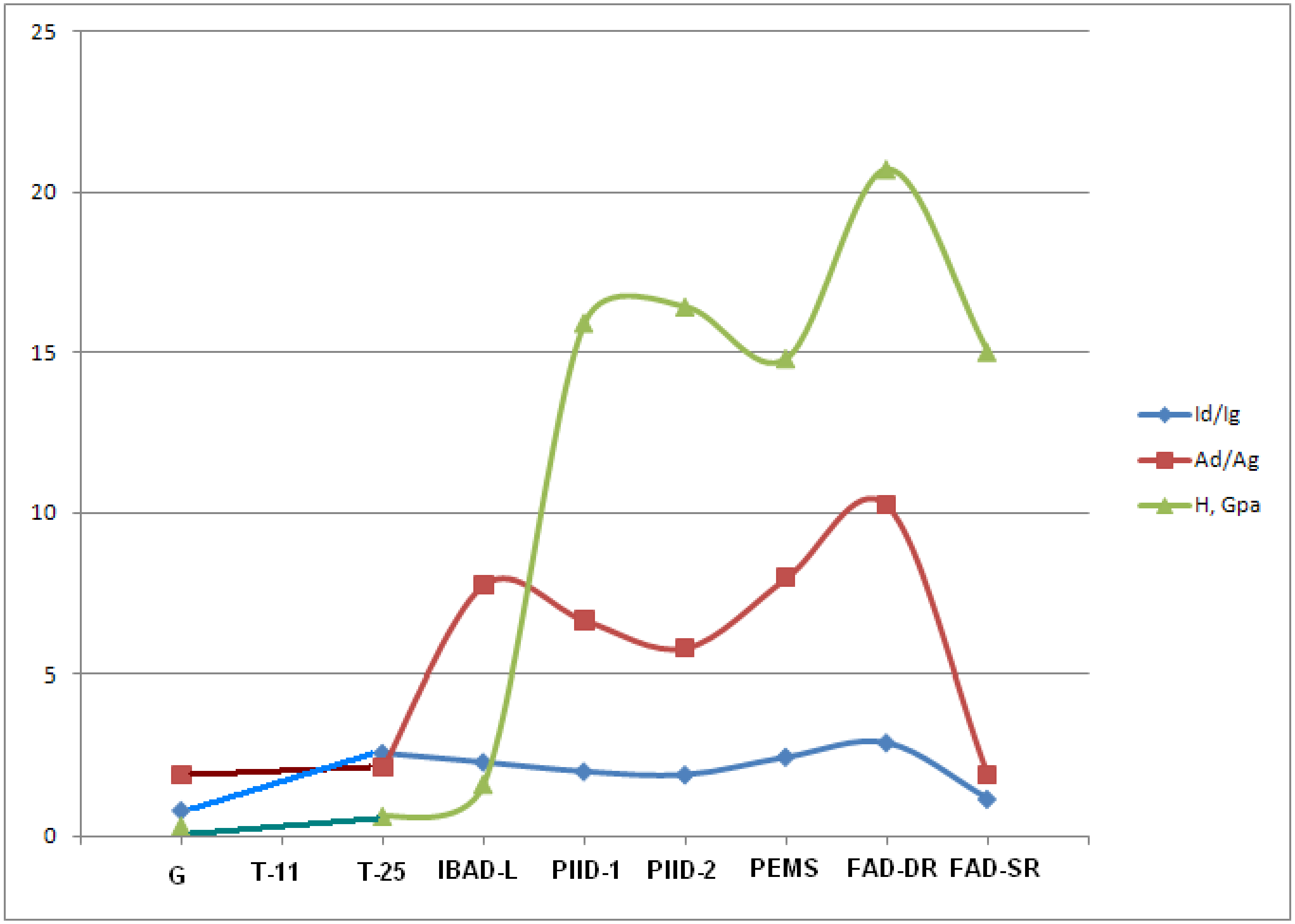


Avg. Contact angle : 50.95

PEMS-DLC


I_D/I_G=2.47
4000
3000
2000
1000
0
-1000
-2000
-3000
-4000
200
600
1000
1400
1800
2200
2600
3000
3400
Raman Shift (cm-1)
Avg. Contact angle: 76.70

Correlations between RAMAN Spectra and Hardness



Id/Ig- ratio between D- and G-bands;
Ad/Ag- ratio between D-band area and G-band area;
H- hardness;

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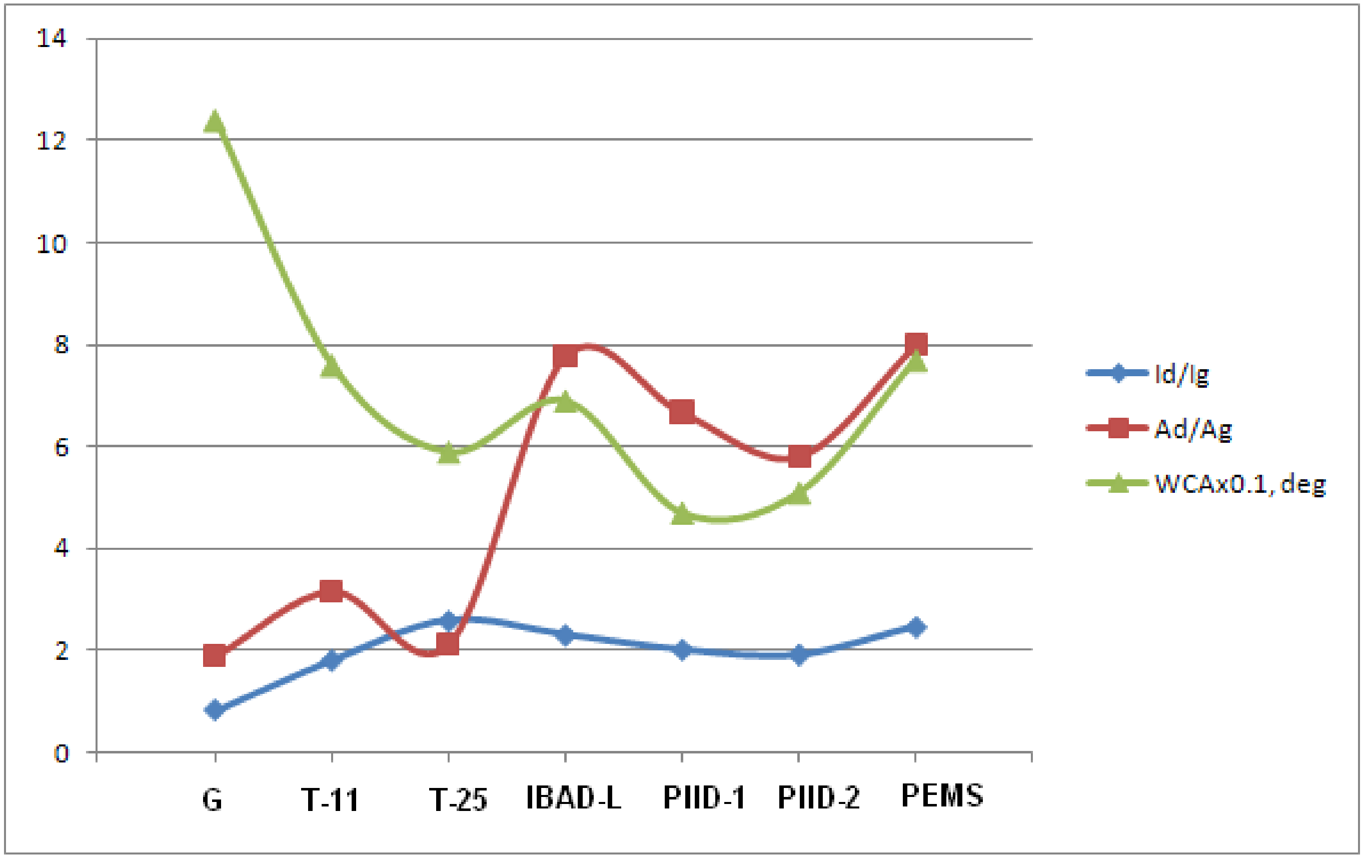
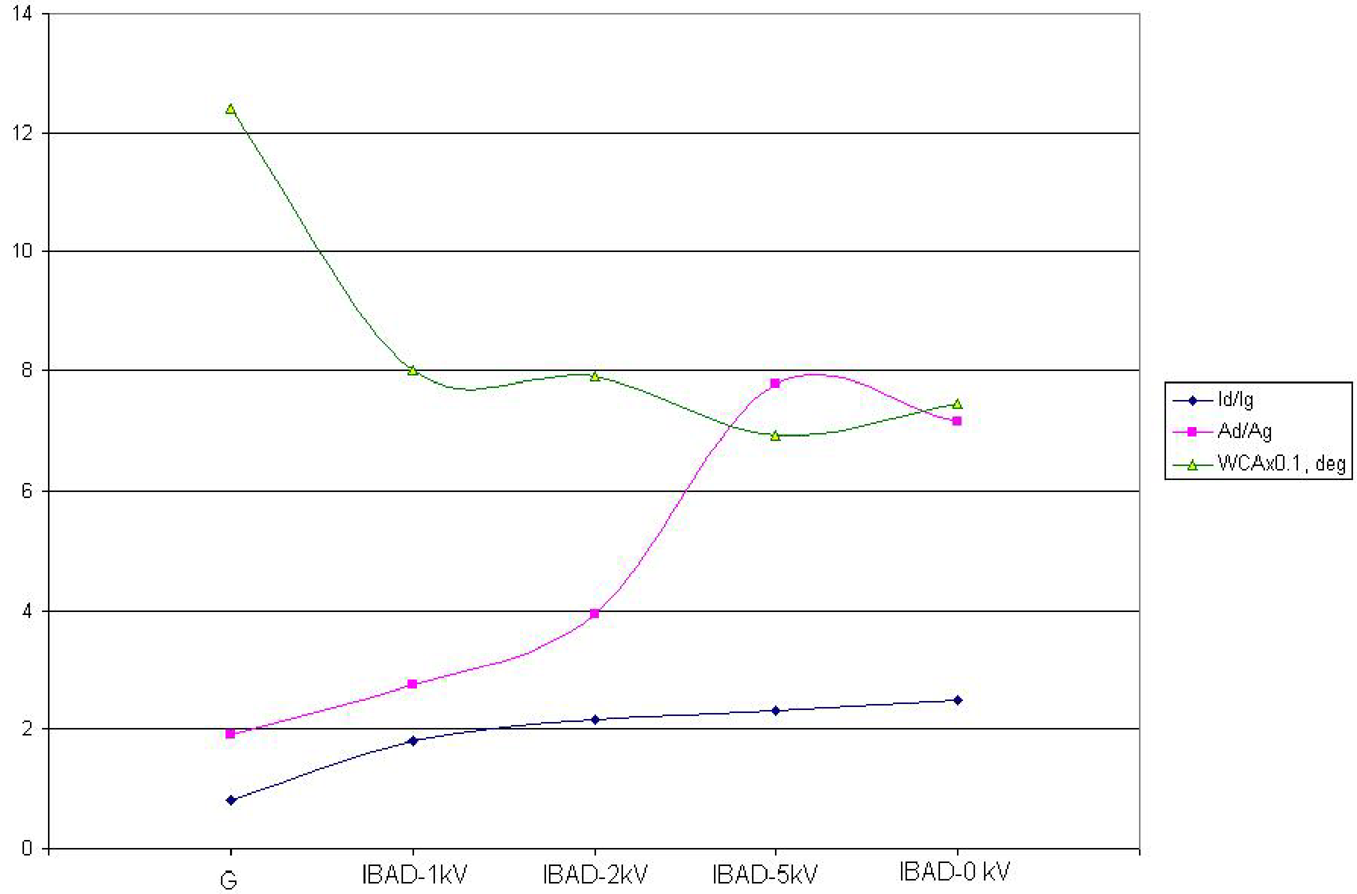
Correlations between RAMAN Spectra and Water Wetting Contact Angle



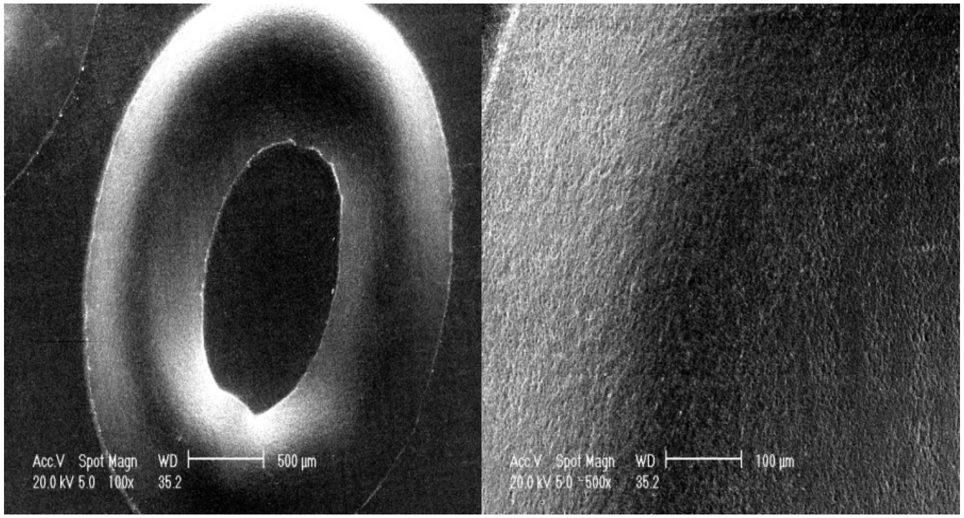
Id/Ig- ratio between D- and G-bands;
Ad/Ag- ratio between D-band area and G-band area;
WCA- water wetting contact angle

Correlations between RAMAN Spectra and Water Wetting Contact Angle for IBAD Carbon Coatings Deposited with Different Energy of Bombarding Ions

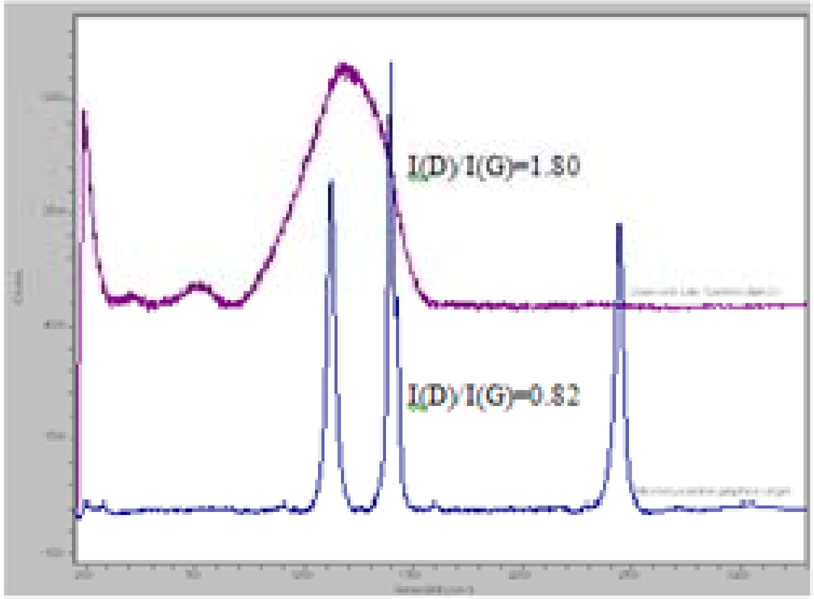


Id/Ig- ratio between D- and G-bands;
Ad/Ag- ratio between D-band area and G-band area;
WCA- water wetting contact angle;

IBAD Carbon Coatings Response to Large Mechanical Deformation and its Characteristic RAMAN Spectra



SEM images of stamping pattern 0.5 mm high, on thin sheet SS sample, 0.25 mm thick, with iC coating having a thickness of 120 nm deposited by IBAD: (left)- low magnification; (right)- high magnification.



Raman spectral comparison of microcrystalline graphite target used in the IBAD process and the diamond like carbon films (DLC) created. The graphite target is made up of purely sp^2 sites. The drastic change in the amorphous carbon films spectra corresponds to disorder and loss of aromaticity in the graphite layers and perhaps a small increase in sp^3 content.

Conclusions

- Deposition of carbon coatings with ion bombardment assistance results in increase of hardness and decrease in water wetting contact angle associated with improved diamond-like properties
- The coating properties correlate with characteristic parameters of RAMAN spectra: the intensity ratio between I_D and I_G bands and the ratio between the areas of I_D and I_G bands, respectively
- Thin IBAD carbon coatings have demonstrated their hydrophobic properties, improved mechanical properties, and exhibit excellent resistance to large mechanical deformation, making the coating a good candidate for bi-polar plates of PEM Fuel Cells

THANK YOU FOR YOUR ATTENTION!