REFERENCES

[1] May, P. W. Diamond thin films: a 21-st century material. *Phicosophical Transactions of the Royal Society A* **358** (2000): 473-495.

[2] Esteve, J., Polo, M.C., and Sanchez, G. Diamond and diamond-like carbon films. *Vacuum* 52 (1999) 133-139.

[3] Settineri, L., Bucciotti, F., Cesano, F., and Faga M.G. Surface Properties of Diamond Coatings for Cutting Tools. *Annals of the CIRP* **56** (2007): 573-576.

[4] Roger J. Narayan. Nanostructured diamond-like carbon thin films for medical applications. *Materials Science and Engineering* C **25** (2005) 405 – 416.

[5] Olszyna, A., and Smolik, J. Nanocrystalline diamond-like carbon coatings produced on the Si_3N_4–TiC composites intended for the edges of cutting tools. *Thin Solid Films* **459** (2004) 224–227.

[6] Silva, S., Mammana, V.P., Salvadori, M.C., Monteiro, O.R., and Brown, I.G. WC-Co cutting tool inserts with diamond coatings. *Diamond and Related Materials* **8** (1999) 1913–1918.

[7] Carter, C. B., and Norton, M. G. *Ceramic Materials Science and Engineering.* USA: Springer Science and Business Media, LLC., 2007.

[8] Hari Singh Nalwa. *Handbook of Thin Film materials.* Vol. 2: Characterization and Spectroscopy of Thin Films. USA: Academic Press, 2002.

[9] Dandy, D.S., and Coltrin, M.E. *Diamond Thin Films Handbook.* New York: Marcel Dekker, 2002.

[10] Huang, W. S., Tran, D. T., Asmussen, J., Grotjohn, T. A., and Reinhard, D. Synthesis of thick, uniform, smooth ultrananocrystalline diamond films by microwave plasma-assisted chemical vapor deposition. *Diamond and Related Materials* **15** (2006) 341-344.

[11] Hiramatsu, M., Lau, C. H., Bennett, A., and Foord, J. S. Formation of diamond and nanocrystalline diamond films by microwave plasma CVD. *Thin Solid Films* **407** (2002) 18-25.

[12] Nagatsu, M., Miyake, M., and Maeda, J. Plasma CVD reactor with two-microwave oscillator for diamond films synthesis. *Thin Solid Films* **506-507** (2006) 617-621.

[13] Ternyak, O, Akhvlediani, R., and Hoffman, A. Evolution and properties of adherent diamond films with ultra high nucleation density deposited onto alumina. *Diamond and Related Materials* **14** (2005) 144-154.

[14] Liang, X., Wang, L., Zhu, H., and Yang, D. Effect of pressure on nanocrystalline diamond films deposition by hot filament CVD technique from CH_4/H_2 gas mixture. *Surface and Coating Technology* **202** (2007) 261-267.

[15] Yu, S. J., Ding, Z. F., Xu., J., Zhang, J. L., and Ma, T. C. CVD of hard DLC films in a radio frequency inductively coupled plasma source. *Thin Solid Films* **390** (2001) 98-103.

[16] Gomes, J. R., Camargo Jr., S. S., Simao, R. A., Carrapichano, J. M. Achete, C. A., Silva, R. F. Trobological properties of silicon nitride ceramics coated with DLC and DLC-Si against 316L stainless steel. *Vacuum* **81** (2007) 1448-1452.

[17] Meng, X. M., Tang, W. Z., Hei, L. F., Askari, S. J., Chen, G. C., and Lu, F. X. Application of CVD nanocrystalline diamond films to cemented carbide drill. *International Journal of Refractory Metals and Hard Materials* **26** (2008) 485-490.

[18] Li, D., Zuo, D., Lu, W., Chen, R., Xiang, B., and Wang, M. Effects of methane concentration on diamond spherial shell films prepared by DC-plasma jet CVD. *Solid State Ionics* **179** (2008) 1263-1267.

[19] Quan-yan, Q., Wan-qi, Q., De-chang, Z., Zhong-wu, L, Ming-jiang, D., and Ke-song, Z. Effects of deposition parameters on microstructure and thermal conductivity of diamond films deposited by DC arc plasma jet chemical vapor deposition. Trans. *Nonferrous Met. Soc. China* **19** (2009) 131-137.

[20] Wang, L., Lu, J., Su, Q., Wu, N., Liu, J., Shi, W., and Xia, Y. [100]-textured growth of polycrystalline diamond films on alumina substrates by microwave plasma chemical vapor deposition. *Materials Letters* **60** (2006) 2390–2394.

[21] Mo, Y., Xia Y., and Wu, W. A nucleation mechanism for diamond film deposited on alumina substrates by microwave plasma CVD. *Journal of Crystal Growth* **191** (1998) 459-465.

[22] Wikipedia. The free encyclopedia of aluminum oxide [online]. 2009. Available from: http://en.wikipedia.org/wiki/Alumina [2010, March 19]

[23] Terpstra, R.A. Ceramic Processing. New Delhi: Chapman & Hall, 1995.

[24] Othmer, K. *Encyclopedia of Chemical Technology*. 3rd ed. Vol. 5. USA: John Wiley and Sons, 1978.

[25] Accuratus. Aluminium Oxide [online]. 2002. Available from: http://www.accuratus.com/alumox.html [2010, March 19]

[26] Xia, Y., Mo., Y., Wang, Y., Huang, X., Chen, D., and Wang, H. Nucleation mechanism of polycrystalline diamond film deposited on ceramic alumina by microwave plasma chemical vapor deposition. *Chinese Physics Letters* **13** (1996) 557-560.

[27] Othmer, K. *Encyclopedia of Chemical Technology*. 3rd ed. Vol. 4. USA: John Wiley and Sons, 1978.

[28] The A to Z nanotechnology [online]. 2010. Available from: http://www.azonano.com/details.asp [2010, March 9]

[29] Spear, K. E., and Dismukes, J. P. *Synthetic diamond: Emerging CVD science and technology*. USA: John Wiley and Sons, 1994.

[30] Lewis, I. R., and Edwards, G. M. *Handbook of Raman Spectroscopy from the Research Laboratory to the Process Line (Practical Spectroscopy Series)*. Volume 28. USA: Marcel Dekker Inc, 2001.

[31] Diameter Advanced Material Applications. Diamond-like Carbon [online]. 2007. Available from: http://www.diameterltd.co.uk/images/dlc-structure.gif [2010, March 9]

[32] Goldston, R. J., and Rutherford, P. H. *Introduction to Plasma Physics*. UK: IOP Publishing Ltd., 1995.

[33] Sugawara, M. *Plasma Etching Fundamentals and Applications*. USA: Oxford Science Publications by Oxford University Press Inc, 1998.

[34] Plasma Technology. Korea Plasma Civil Engineering Co. Ltd. [online]. 2007. Available from: http://koreaplasma.net/english/koreap2_1.htm [2010, March 9]

[35] Satas, D., and Tracton, A. A. *Coating Technology Handbook.* 2nd ed. USA: Marcel Dekker Inc, 2001.

[36] Field, J.E. *The Properties of Natural and Synthetic Diamond.* USA: Academic Press, 1992.

[37] Ohring, M. *Materials Science of Thin Films Deposition and Structure.* 2nd ed. USA: Academic Press, 2002.

[38] Pohang University of Science and Technology All Rights Reserved, Chemical Vapor Deposition (CVD) [online]. 2007. Available from: http://www.postech.ac.kr/ce/lamp/research/cvd/cvd-1.jpg [2010, March 9]

[39] Roth, J. R. *Industrial Plasma Engineering.* Vol. 2 (Application to Nonthermal Plasma Processing). UK: Institute of Physics Publishing Bristol and Philadelphia, 2001.

[40] Smirnov, B. M. *Physics of Ionized Gaseous.* USA: John Wiley and Sons, 2001.

[41] Eliezer, S. and Eliezer, Y. *The Fourth State of Matter an Introduction to Plasma Science.* 2nd ed. UK: IOP Publishing Ltd., 2001.

[42] Kulisch, W., Popov, C., Boycheva, S., Jelinek, M., Gibson, P.N., and Vorlicek, V. Influence of the substrate temperature on the properties of nanocrystalline diamond/amorphous carbon composite films. *Surface and Coating Technology* **200** (2006) 4731-4736.

[43] Askari, S.J., Chen, G.C., and Lu, F.X. Growth of polycrystalline and nanocrystalline diamond films on pure titanium by microwave plasma assisted CVD process. *Materials Research Bulletin* **43** (2008) 1086–1092.

[44] Buhlmann, S., Blank, E., Haubner, R., and Lux, B. Characterization of ballas diamond depositions. *Diamond and Related Materials* **8** (1999): 194-201.

[45] Wang, W.L., Liao, K.J., Fang, L., Esteve, J., and Polo, M.C. Analysis of diamond nucleation on molybdenum by biased hot filament chemical vapor deposition. *Diamond and Related Materials* **10** (2001) 383-387.

[46] Askari, S.J., Akhtar, F., Islam, S.H., Qi, H., Tang, W.Z., and Lu, F.X. Two-step growth of high-quality nano-diamond films using CH_4/H_2 gas mixture. *Vacuum* **81** (2007) 713-717.

[47] Yagyul, H., Deguchi, M., Won, J. H., Mori, Y., Hatta, A., Kitabatake, M., Ito, T., Hirao, T., and Hiraki, A. Ion implantation in CVD diamond and plasma treatment effect. *Diamond and Related Materials* **4** (1995) 575-579.

[48] Baba, K., and Hatada, R. Deposition of diamond-like carbon films on polymers by plasma source ion implantation. *Thin Solid Films* **506– 507** (2006) 55 – 58.

[49] Chattopadhyay, A., Sarangi, S.K., and Chattopadhyay, A.K. Effect of negative dc substrate bias on morphology and adhesion of diamond coating synthesised on carbide turning tools by modified HFCVD method. *Applied Surface Science* **255** (2008) 1661–1671.

[50] Ristic, G.C., Bogdanov, Z.D., Zec, S., Romcevic, N., Mitrovic, Z.D., and Miljanic, S.S. Effect of the substrate material on diamond CVD coating properties. *Materials Chemistry and Physics* **80** (2003) 529-536.

[51] Tyagi, P.K., Misra, A., Narayanan Unni, K.N., Rai, P., Singh, M.K., Palnitkar, U., Misra, D.S., Normand, F.L., Roy, M., and Kulshreshtha, S.K. Step growth in single crystal diamond grown by microwave plasma chemical vapor deposition. *Diamond and Related Materials* **15** (2006) 304 – 308.

[52] Flegler, S. L., Heckman, J. W., and Klomparens, K. L. *Scanning and Transmission Electron Microscopy an Introduction.* USA: Oxford University Press Inc, 1993.

[53] Rujisamphan, N. *Design and construction of microwave-PECVD and preliminary characterizations of synthesized polycrystalline diamond film.* Thesis of master degree, Department of Physics Faculty of Science, Chulalongkorn University, 2006.

[54] Smith, E., and Dent, G. Modern Raman Spectroscopy (A Practical Approach). UK: John Wiley and Sons, 2005.

[55] Fischer-Cripps, A. C. *Nanoindentation.* 2nd ed. USA: Springer-Verlag New York LLC, 2004.

[56] Nanoindentation [online]. 2003. Available from: http://www.nanoindentation.cornell.edu/Machine/commercial_macine.htm [2010, March 19]

[57] Martinez, E., Polo, M. C., Pascual, E., and Esteve, J. Substrate temperature effects on the microhardness and adhesion of diamond-like thin films. *Diamond and Related Materials* **8** (1999) 563-566.

[58] Kulich, W., Popov, C., Boycheva, S., Buforn, L., Favaro, G., and Conte, N. Mechanical properties of nanocrystlline diamond/amorphous carbon composite films prepared by microwave plasma chemical vapor deposition. *Diamond and Related Materials* **13** (2004) 1997-2002.

[59] Cho, C. W., Hong, B., and Lee, Y. Z. Wear life evaluation of diamond-like carbon films deposited by microwave plasma-enhanced CVD and RF plasma-enhanced CVD method. *Wear* **259** (2005) 789-794.

[60] Mallika, K., and Komanduri, R. Low pressure microwave plasma assisted chemical vapor deposition (MPCVD) of diamond coating on silicon nitride cutting tools. *Thin Solid Films* **396** (2001) 145-165.

[61] Analytical Techniques lectures at University of Bristol [online]. 2009. Available from: http://www.chm.bris.ac.uk/pt/diamond/rolythesis/chapter2.htm [2010, March 14].

[62] Kulisch, W., Popov, C., Vorlicek, V., Gibson, P.N., and Favaro, G. Nanocrystalline diamond growth on different substrates. *Thin Solid Films* **515** (2006) 1005-1010.

[63] Popov, C., Novotny, M., Jelinek, M., Boycheva, S., Vorlicek, V., Trchova, M., and Kulisch, W. Chemical bonding study of nanocrystalline diamond films prepared by plasma techniques. *Thin Solid Films* **506-507** (2006) 297-302.

[64] Sahoo, S., Pradhan, S.S., Bhavanasi, V., and Pradhan, S.K. Structural and mechanical characterization of diamond like carbon films grown by microwave plasma CVD. *Surface and Coating Technology* **204** (2010) 2817-2821.

[65] Johnson, C., Crossley, A., Jones, A.M., Chalker, P.R., Cullen, F.L., and Buckley-Golden, I.M. High temperature stress measurement in CVD diamond films. *Journal De Physique II* **1** (1991) 931-937.

[66] Chowdhury, S., Barra, E.D., and Laugier, M.T. Study of mechanical properties of CVD diamond on SiC substrates. *Diamond and Related Materials* **13** (2004) 1625-1631.

[67] Ravi, N., Bukhovets, V.L., Vashavskaya, I.G., and Sundararajan, G. Deposition of diamond-like carbon films on alumina substrates by RF-PECVD technique: Influence of process parameters. *Diamond and Related Materials* 16 (2007) 90-97.

[68] Ye, H., Sun, C.Q., Hing, P., Xie, H., Zhang, S., and Wei, J. Nucleation and growth dynamics of diamond films by microwave plasma-enhanced chemical vapor deposition (MPECVD). *Surface and Coatings Technology* **123** (2000) 129.

APPENDICES

APPENDIX A
Raman spectra of the DLC films

A-1 Raman spectra of the DLC films grown under various CH_4 concentrations, deposition pressure of 30 torr, and deposition time of 30 hr.

A-1.1 Raman spectra of the films deposited at 0.5% CH_4 concentration.

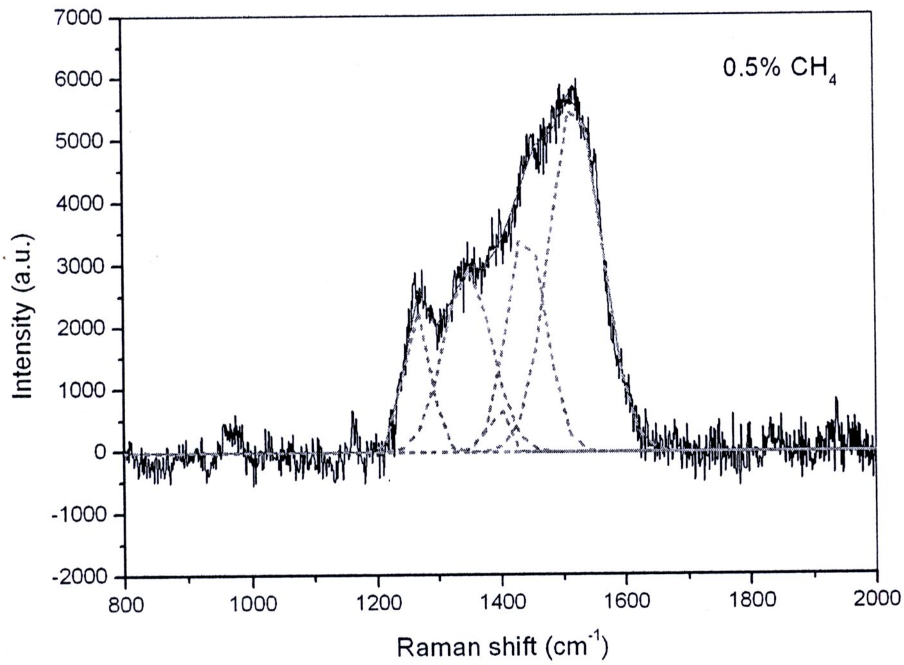

Figure A-1 Raman spectra of DLC film deposited at 0.5% CH_4 concentration with three Gaussians peak.

A-1.2 Raman spectra of the films deposited at 2% CH_4 concentration.

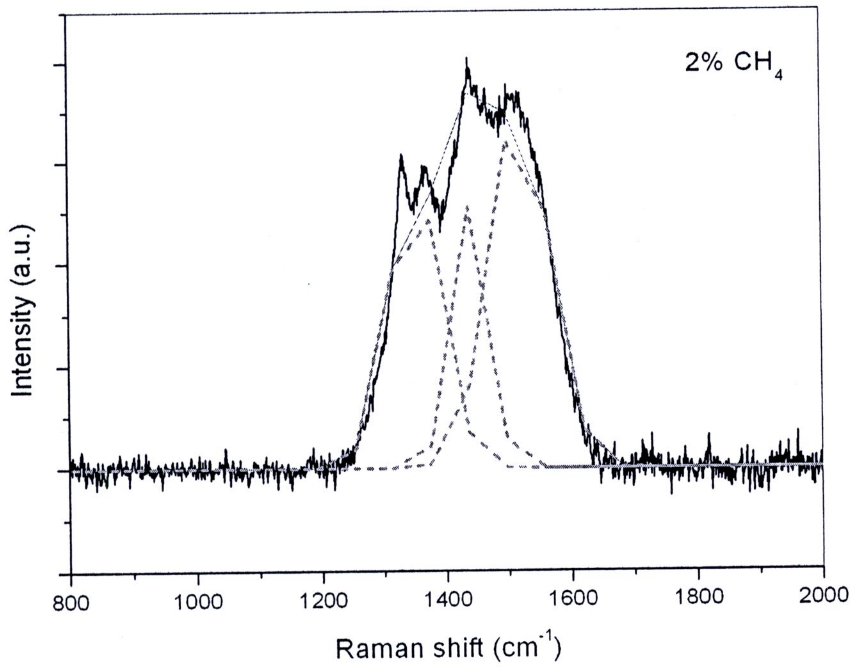

Figure A-2 Raman spectra of DLC film deposited at 2% CH_4 concentration with three Gaussians peak.

A-1.3 Raman spectra of the films deposited at 2% CH_4 concentration.

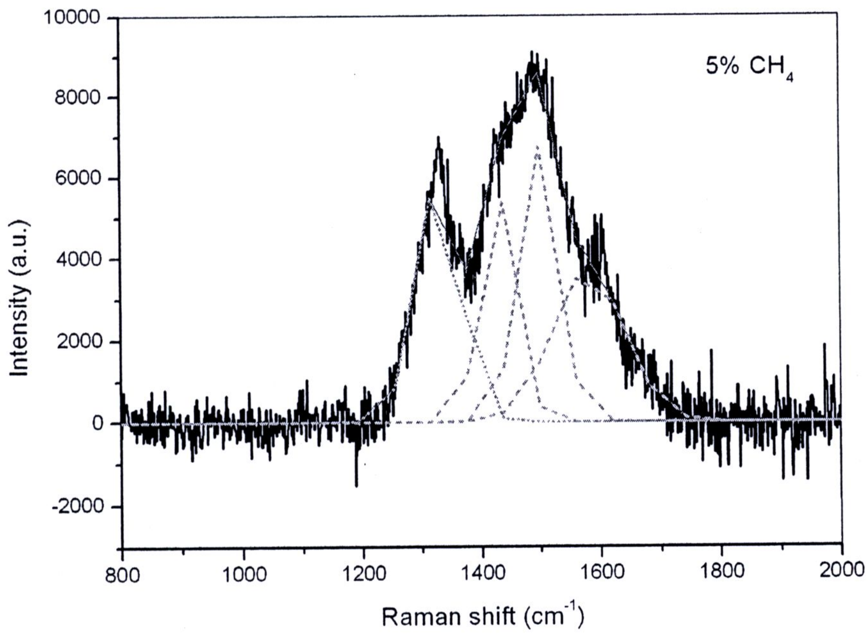

Figure A-3 Raman spectra of DLC film deposited at 5% CH_4 concentration with three Gaussians peak.

A-2 Raman spectra of the DLC films grown under different deposition pressure, CH_4 concentration of 1%, and deposition time of 30 hr.

A-2.1 Raman spectra of the films deposited at deposition pressure of 10 torr.

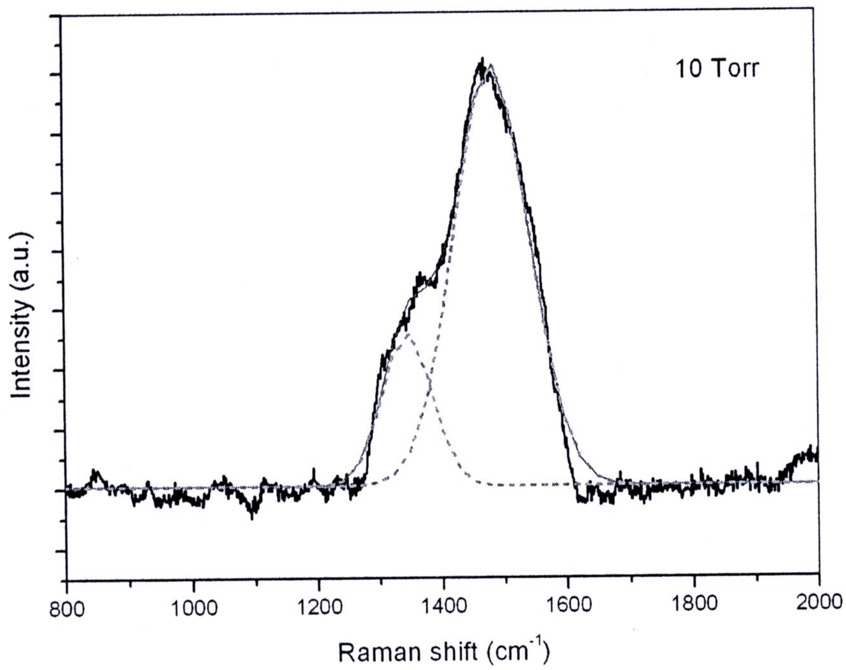

Figure A-4 Raman spectra of DLC film deposited at deposition pressure of 10 torr with two Gaussians peak.

A-2.2 Raman spectra of the films deposited at deposition pressure of 20 torr.

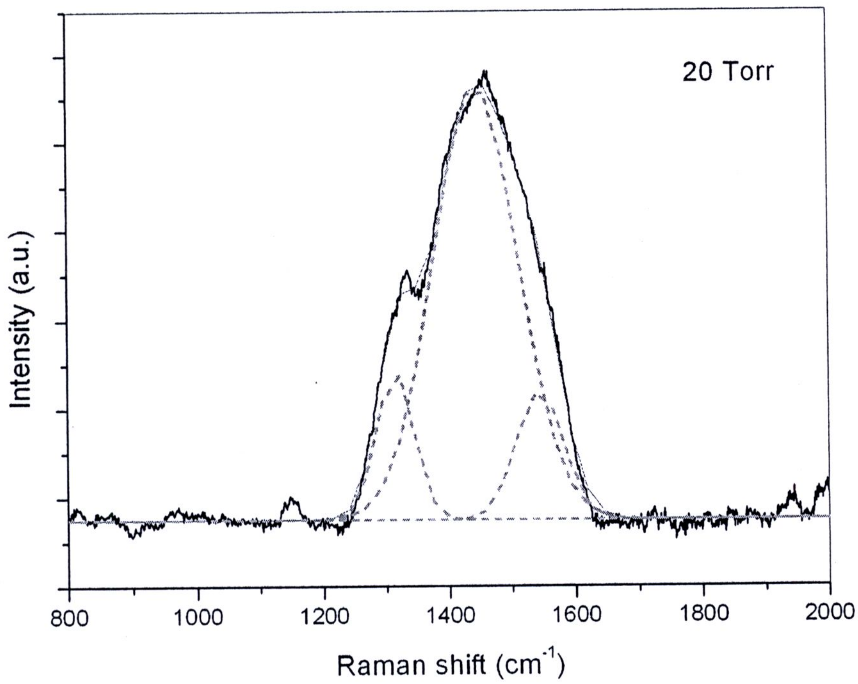

Figure A-5 Raman spectra of DLC film deposited at deposition pressure of 20 torr with two Gaussians peak.

A-2.3 Raman spectra of the films deposited at deposition pressure of 30 torr.

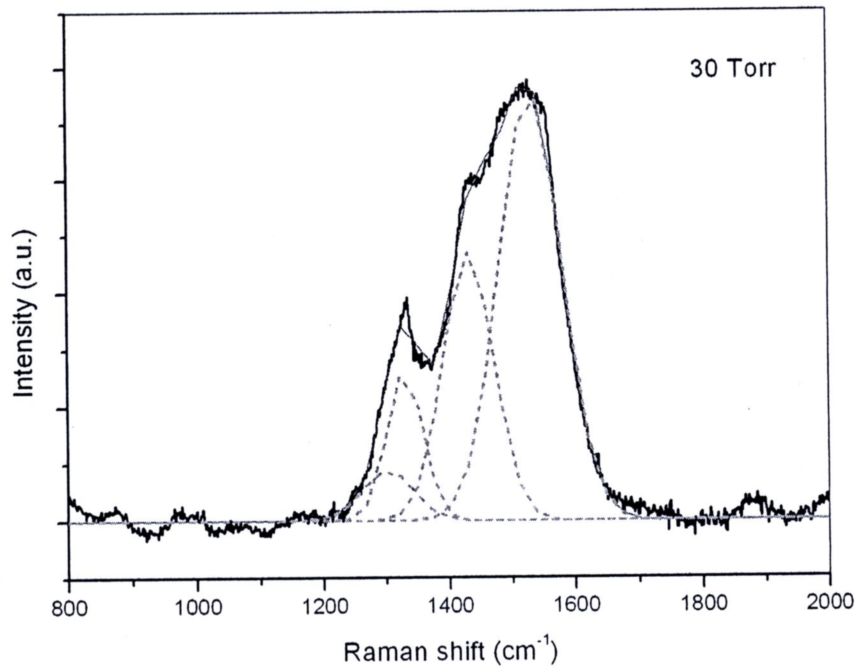

Figure A-6 Raman spectra of DLC film deposited at deposition pressure of 30 torr with three Gaussians peak.

A-2.4 Raman spectra of the films deposited at deposition pressure of 50 torr.

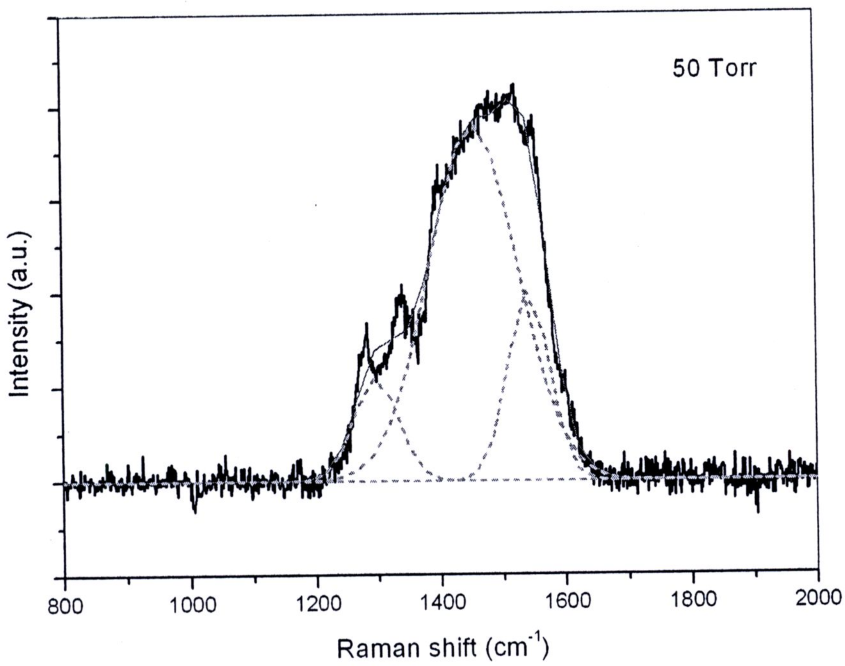

Figure A-7 Raman spectra of DLC film deposited at deposition pressure of 50 torr with three Gaussians peak.

APPENDIX B

(The Data of Nanoindentation test)

B-1 The experimental data and graph information.

Table B-1 The indentation parameters of Nanoindentation tester for all samples.

Indentation parameters
Standard
Standard
+ Instrument : TTX-NHT S/N: 00-00003
+ Hardware settings
Approach speed : 8000 nm/min
Dz sensor in fine range
Delta Slope contact : 20 %
+Measurement
Acquisition Rate : 10.0 [Hz]
Linear Loading
Max load : 5 mN
Loading rate : 10.00 mN/min
Unloading rate : 10 mN/min
Pause : 15.0 s

Indentors
Type : Berkovich
Serial number : BJ-07 (08_10_2009)
Material :Diamond

B-1.1 The Nanoindentation test data of the DLC films grown under various CH_4 concentrations, deposition pressure of 30 torr, and deposition time of 30 hr.

Table B-2 The hardness of the DLC films grown at 0.5% CH_4 concentration.

		DLC_CVD
Hit (O&P)	Data : 1	*27871.936*
[MPa]	Data : 2	*43647.578*
	Data : 5	*46539.113*
	Mean	39352.875
	Std Dev	10047.350
	Min	27871.936
	Max	46539.113
	N	3.000

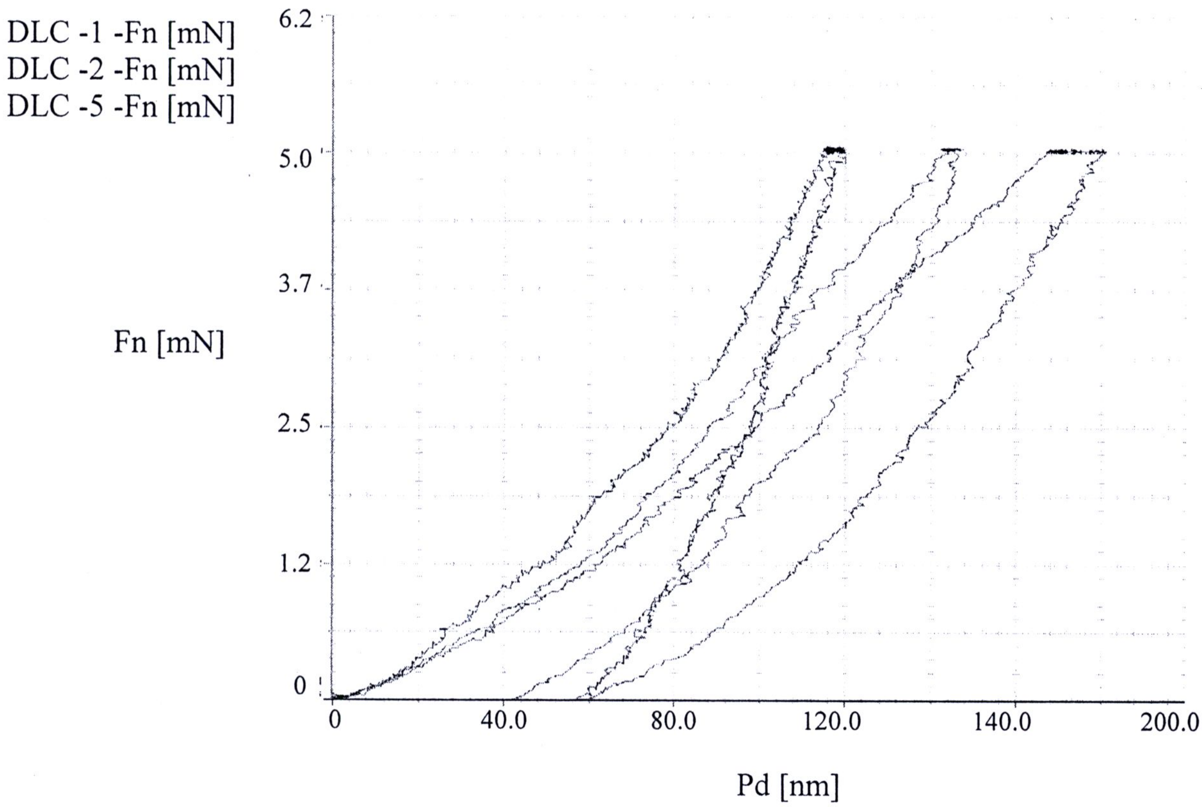

Figure B-1 Load-displacement curve of the DLC films deposited at 0.5% CH_4 concentration.

Table B-3 The hardness of the DLC films grown at 1% CH_4 concentration.

		DLC
Hit (O&P)	Data : 4	*49967.059*
[MPa]	Data : 7	*54165.820*
	Data : 8	*52553.164*
	Mean	52228.676
	Std Dev	2118.104
	Min	49967.059
	Max	54165.820
	N	3.000

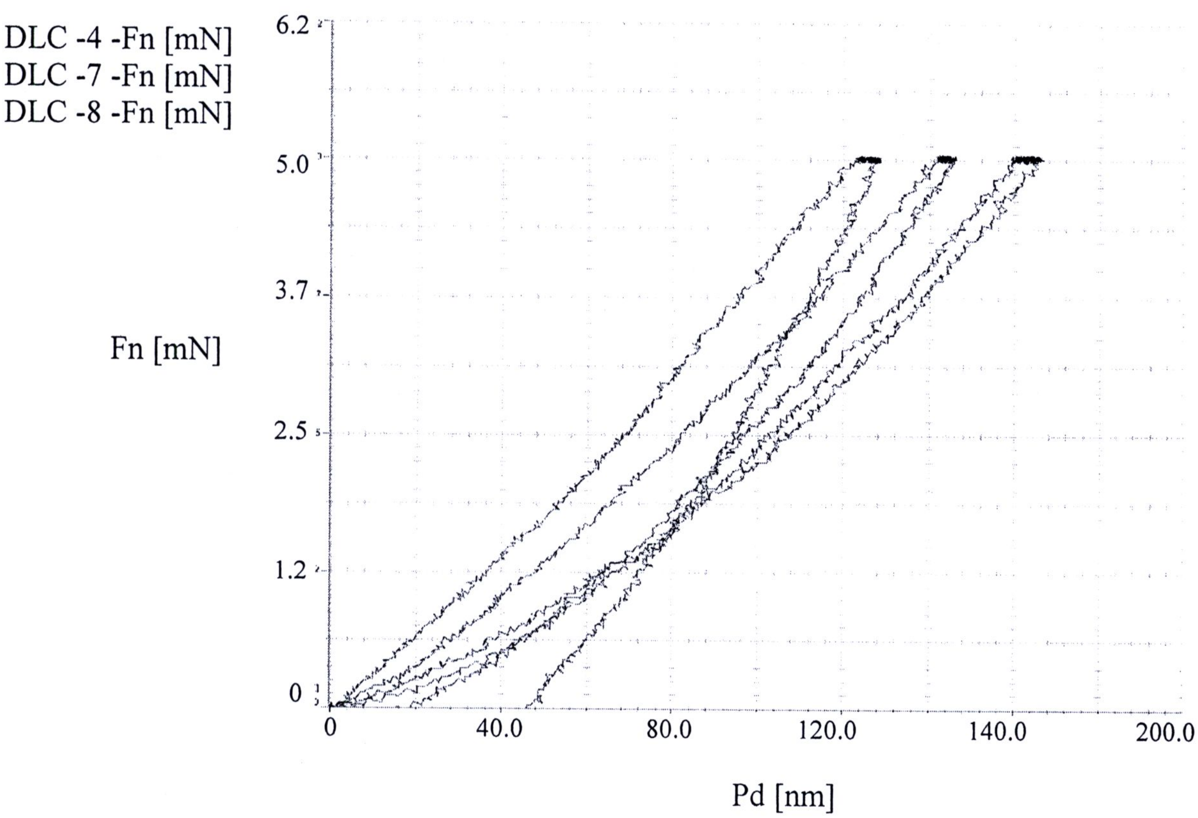

Figure B-2 Load-displacement curve of the DLC films deposited at 1% CH_4 concentration.

Table B-4 The hardness of the DLC films grown at 2% CH_4 concentration.

		DLC
Hit (O&P)	Data : 2	*34069.043*
[MPa]	Data : 3	*42916.535*
	Data : 5	*26838.486*
	Mean	34608.020
	Std Dev	8052.564
	Min	26838.486
	Max	42916.535
	N	3.000

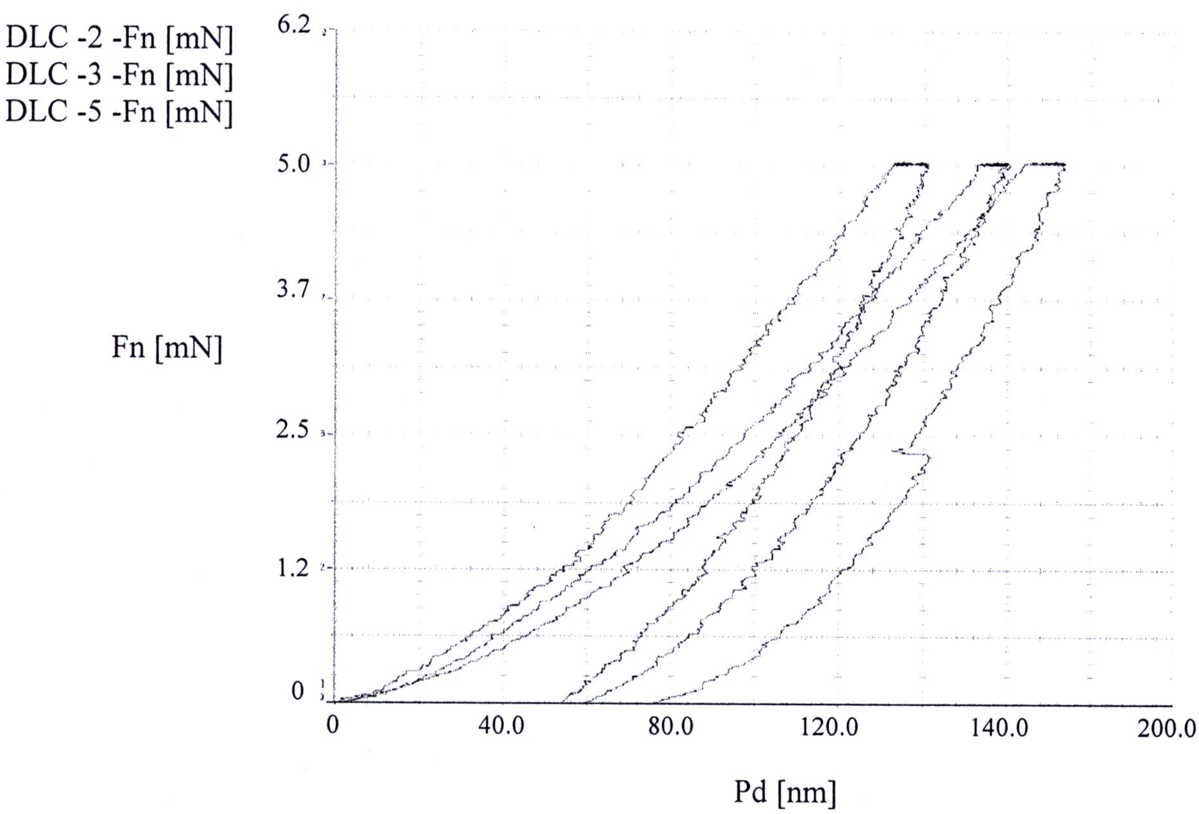

Figure B-3 Load-displacement curve of the DLC films deposited at 2% CH_4 concentration.

Table B-5 The hardness of the DLC films grown at 3% CH_4 concentration.

		DLC
Hit (O&P)	Data : 1	*37597.535*
[MPa]	Data : 2	*38739.555*
	Data : 3	*35724.324*
	Mean	37353.809
	Std Dev	1522.320
	Min	35724.324
	Max	38739.555
	N	3.000

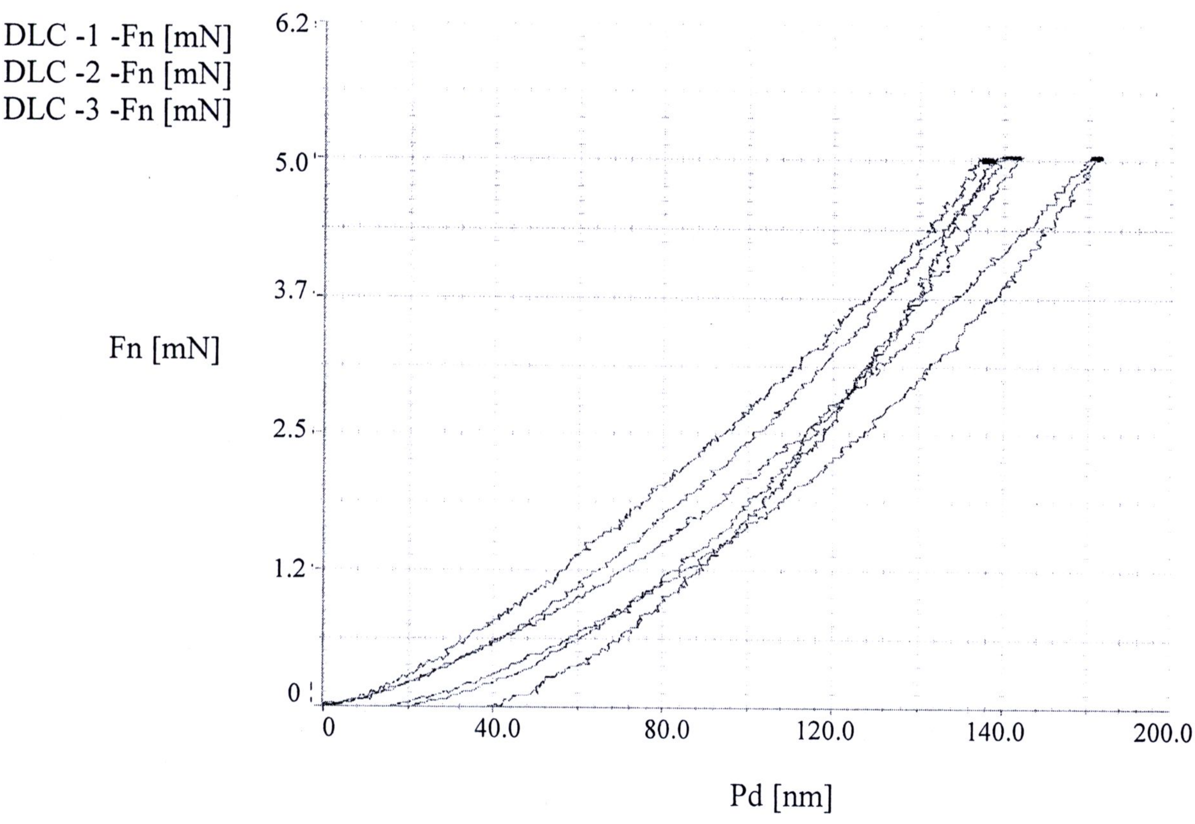

Figure B-4 Load-displacement curve of the DLC films deposited at 3% CH_4 concentration.

Table B-6 The hardness of the DLC films grown at 5% CH_4 concentration.

		DLC
Hit (O&P)	Data : 3	*43251.676*
[MPa]	Data : 4	*39622.559*
	Data : 5	*43180.512*
	Mean	42018.250
	Std Dev	2075.034
	Min	39622.559
	Max	43251.676
	N	3.000

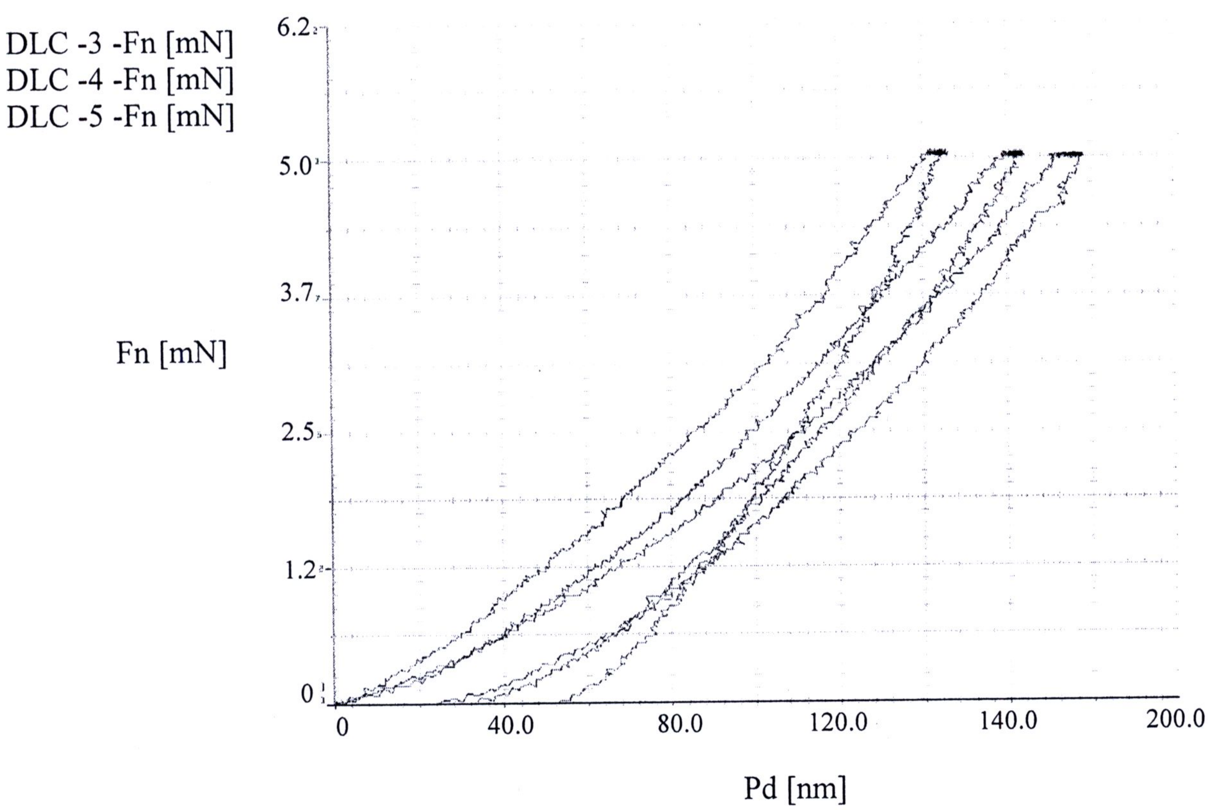

Figure B-5 Load-displacement curve of the DLC films deposited at 5% CH_4 concentration.

B-1.2 The Nanoindentation test data of the DLC films grown under different deposition pressure, CH_4 concentration of 1%, and deposition time of 30 hr.

Table B-7 The hardness of the DLC films grown at deposition pressure of 10 torr.

		DLC
Hit (O&P)	Data : 1	*12972.665*
[MPa]	Data : 2	*15365.926*
	Data : 3	*13201.118*
	Mean	13846.569
	Std Dev	1320.750
	Min	12972.665
	Max	15365.926
	N	3.000

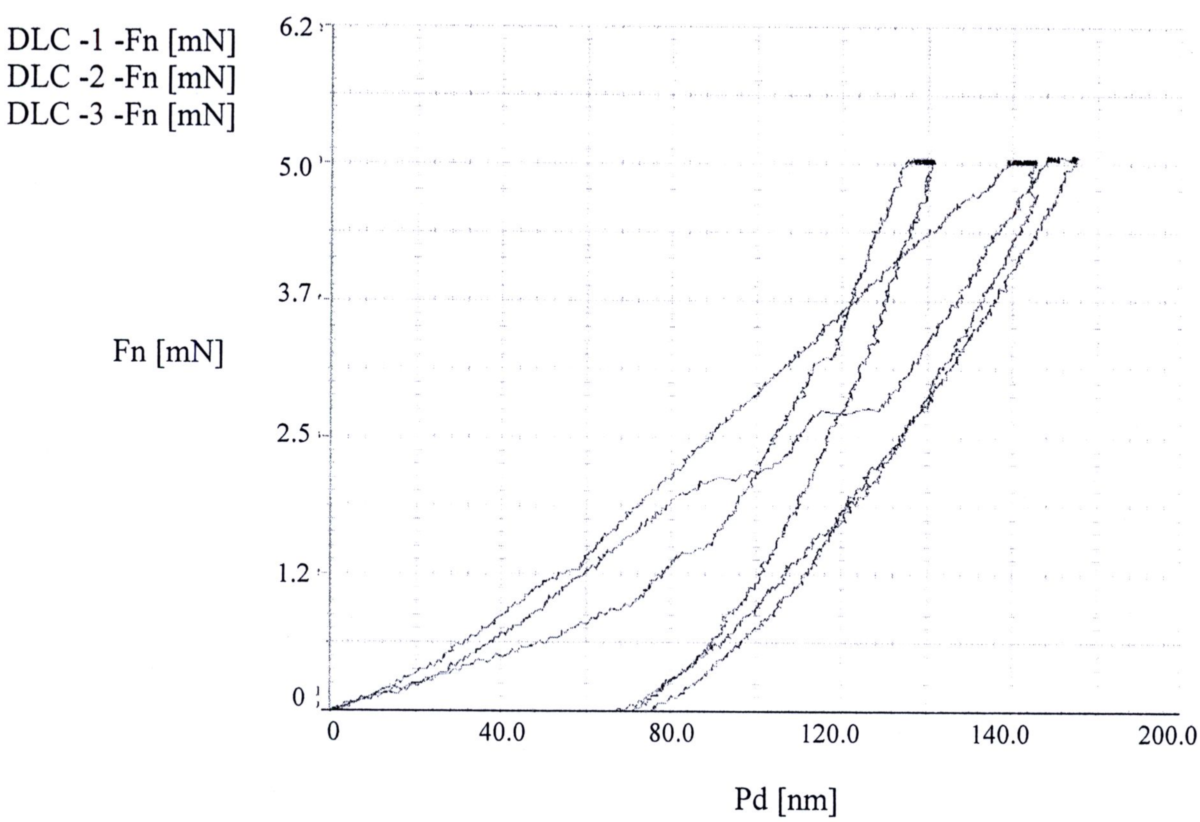

Figure B-6 Load-displacement curve of the DLC films deposited at deposition pressure of 10 torr.

Table B-8 The hardness of the DLC films grown at deposition pressure of 20 torr.

		DLC
Hit (O&P)	Data : 3	*27294.301*
[MPa]	Data : 5	*21069.807*
	Mean	24182.055
	Std Dev	4401.382
	Min	21069.807
	Max	27294.301
	N	2.000

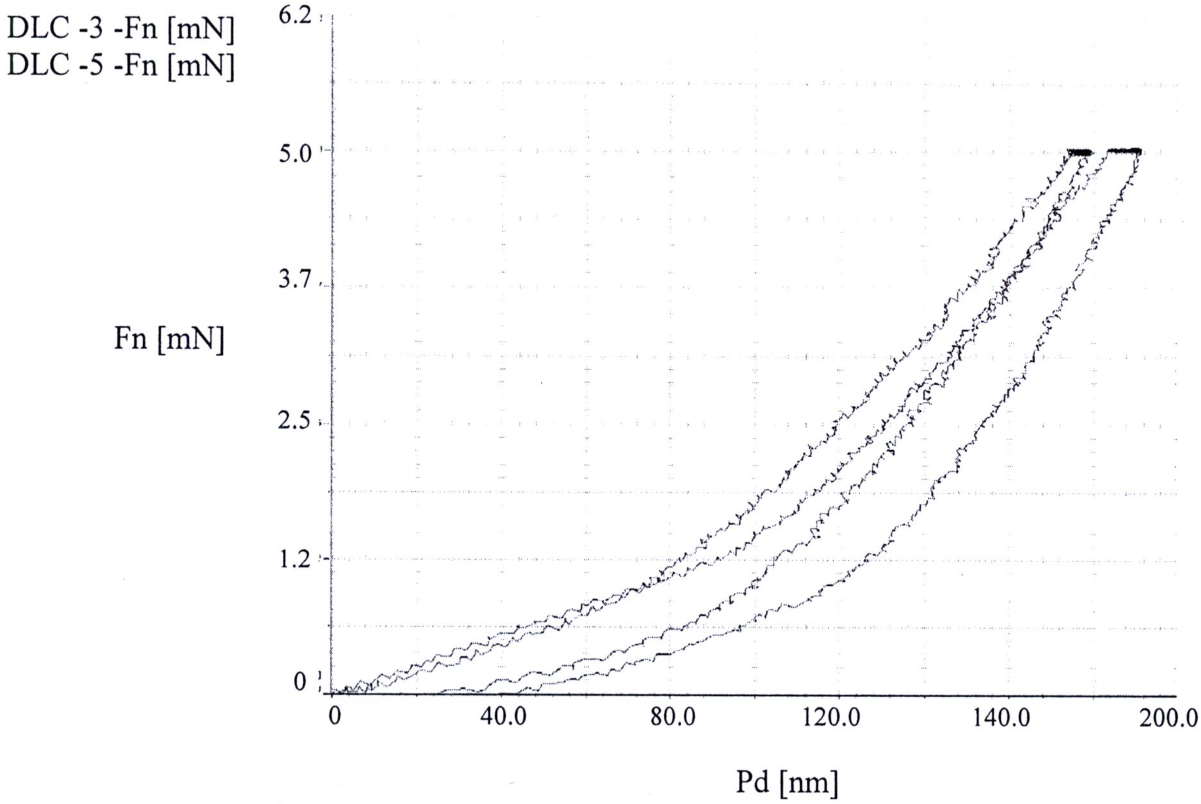

Figure B-7 Load-displacement curve of the DLC films deposited at deposition pressure of 20 torr.

Table B-9 The hardness of the DLC films grown at deposition pressure of 50 torr.

		DLC
Hit (O&P)	Data : 1	*34623.613*
[MPa]	Data : 4	*46998.160*
	Mean	40810.887
	Std Dev	8750.126
	Min	34623.613
	Max	46998.160
	N	2.000

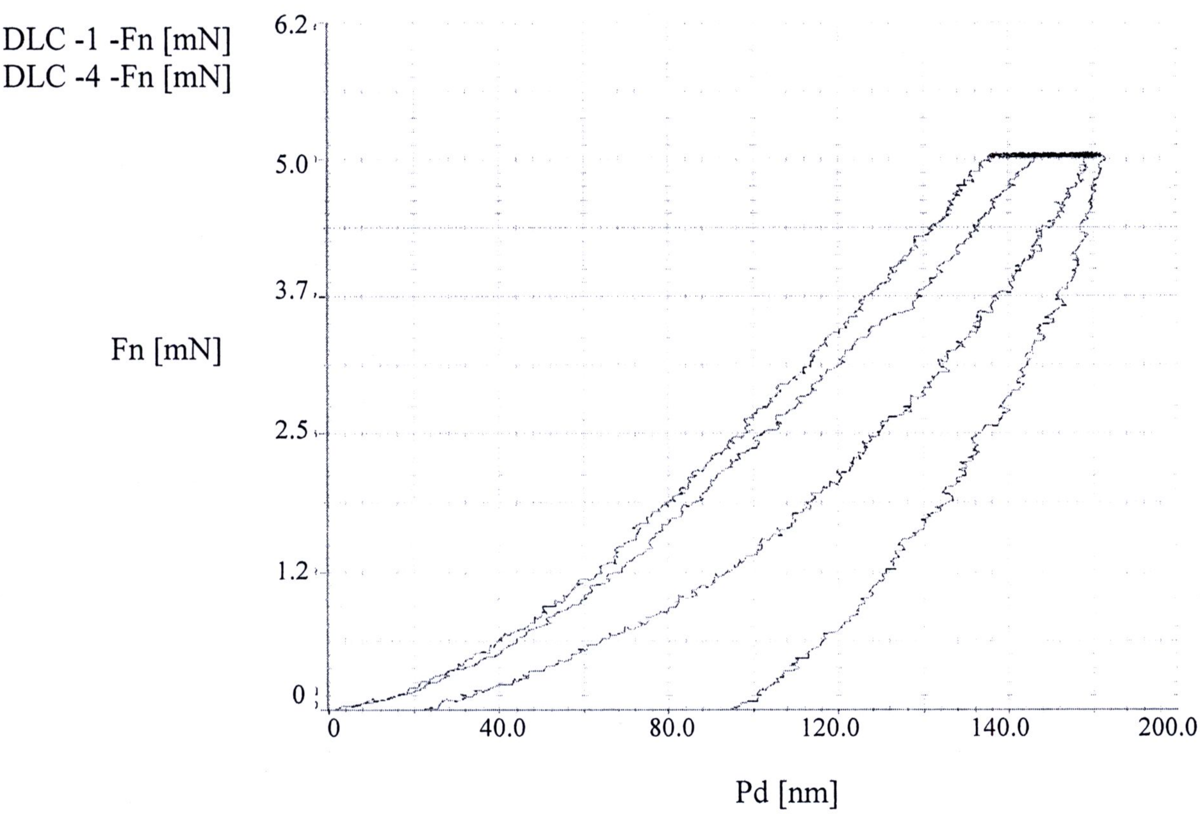

Figure B-8 Load-displacement curve of the DLC films deposited at deposition pressure of 50 torr.

B-1.3 The Nanoindenatation test data of the DLC films grown under various deposition times, CH_4 concentration of 1%, and deposition pressure of 30 torr.

Table B-10 The hardness of the DLC films grown at deposition time of 5 hr.

		DLC
Hit (O&P)	Data : 1	*12629.441*
[MPa]	Data : 2	*18952.854*
	Mean	15791.147
	Std Dev	4471.328
	Min	12629.441
	Max	18952.854
	N	2.000

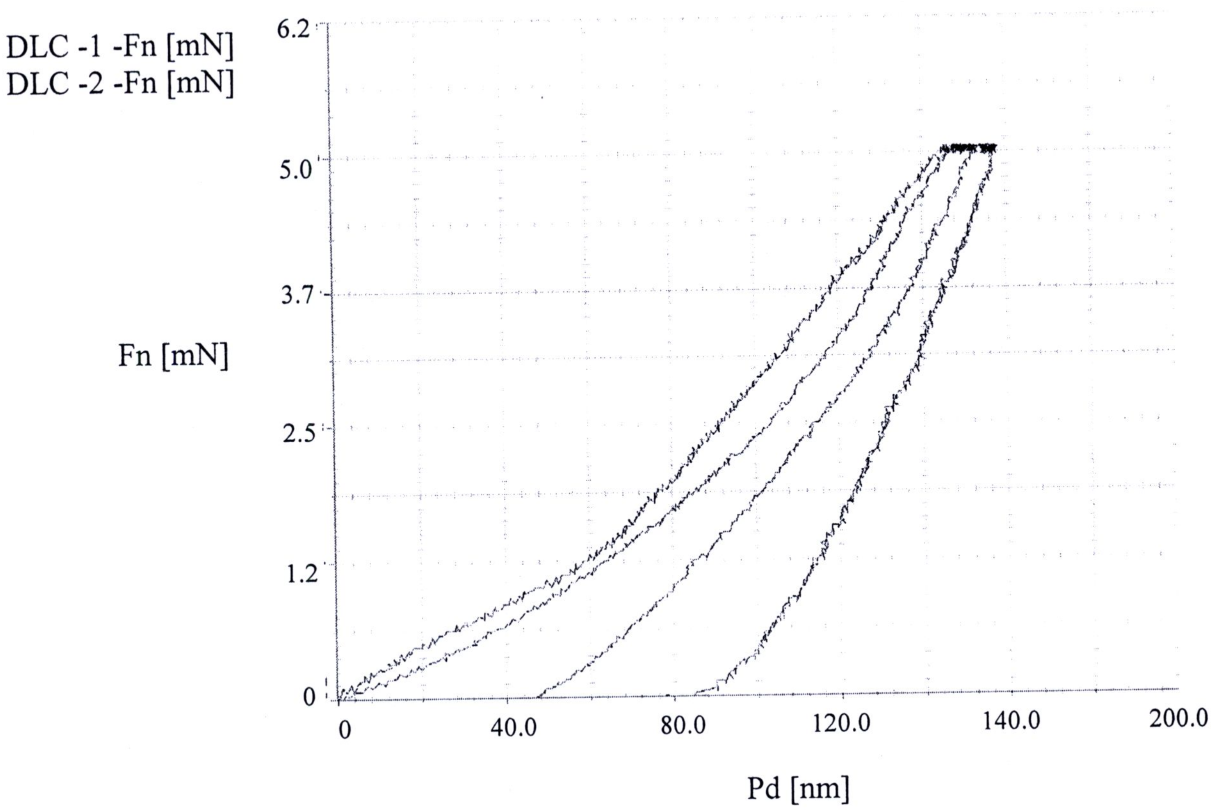

Figure B-9 Load-displacement curve of the DLC films deposited at deposition time of 5 hr.

Table B-11 The hardness of the DLC films grown at deposition time of 10 hr.

		DLC
Hit (O&P)	Data : 2	*29383.254*
[MPa]	Data : 3	*34358.152*
	Data : 4	*28263.406*
	Mean	30668.271
	Std Dev	3244.216
	Min	28263.406
	Max	34358.152
	N	3.000

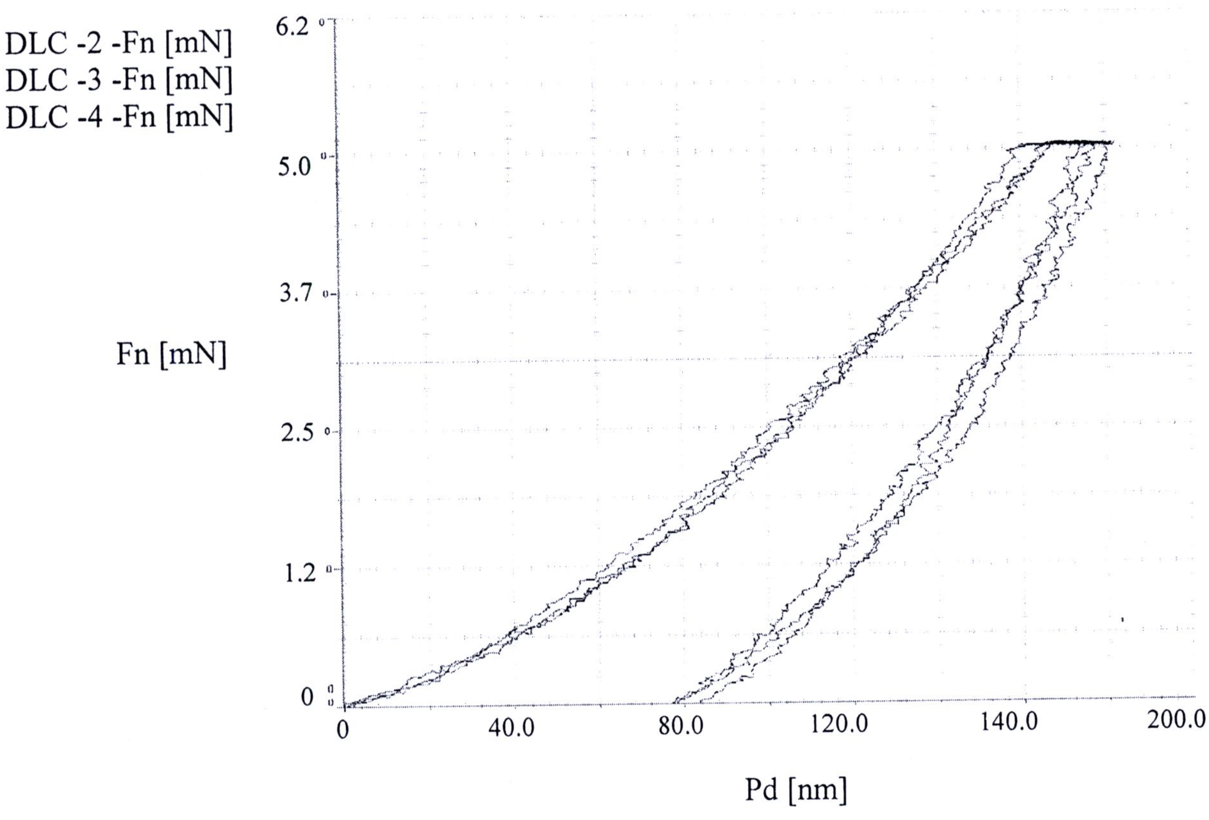

Figure B-10 Load-displacement curve of the DLC films deposited at deposition time of 10 hr.

Table B-12 The hardness of the DLC films grown at deposition time of 20 hr.

		DLC
Hit (O&P)	Data : 1	*36564.621*
[MPa]	Data : 4	*38050.203*
	Mean	37307.414
	Std Dev	1050.465
	Min	36564.621
	Max	38050.203
	N	2.000

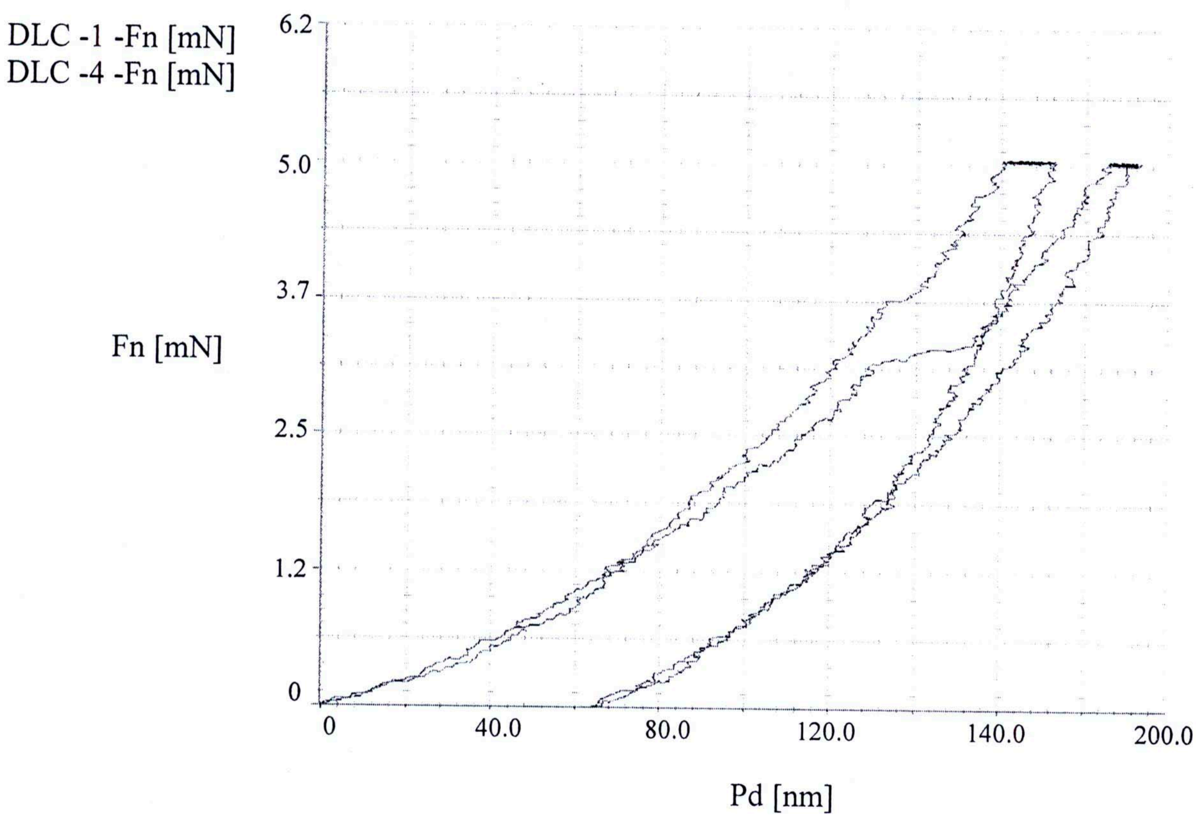

Figure B-11 Load-displacement curve of the DLC films deposited at deposition time of 20 hr.

VITAE

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Conferences:

C. Rattanasatien, N. Tonanon and B. Paosawatyanyong. Synthesis of diamond-like carbon thin film on alumina by microwave plasma enhanced chemical vapor deposition technique. 35th Congress on Science and Technology of Thailand, Thailand (October 15-17, 2009).

C. Rattanasatien, N. Tonanon and B. Paosawatyanyong. Growth of diamond-like carbon film on alumina by MW-PECVD technique. Pure and Applied Chemistry International Conference 2010, Thailand (January 21-23, 2010)

C. Rattanasatien, N. Tonanon and B. Paosawatyanyong. DLC coating on alumina by MW-PECVD technique. 2nd International Symposium on Advanced Plasma Science and its Applications for Nitrides and Nanomaterials, Meijo University, Nagoya, Japan (March 7-10, 2010)

C. Rattanasatien, N. Tonanon and B. Paosawatyanyong. DLC growth on alumina by microwave plasma enhanced chemical vapor deposition technique. Siam Physics Congress 2010, Thailand (March 25-27, 2010)

C. Rattanasatien, N. Tonanon and B. Paosawatyanyong. Coating of DLC nanofilm on alumina by MW-PECVD technique. Asian Conference on Nanoscience & Nanotechnology (AsiaNANO 2010), Tokyo, Japan (November 1-3, 2010)