REFERENCES

Barbetta, A. and Cameron, N.R. (2004) Morphology and surface area of emulsion-v derived (PolyHIPE) solid foams prepared with oil-phase soluble porogenic solvents: Span 80 as surfactant. Macromolecules, 37, 3188-3201.

Barbetta, A. and Cameron, N.R. (2004) Morphology and surface area of emulsion-derived (PolyHIPE) solid foams prepared with oil-phase soluble porogenic solvents: Three-component surfactant system. Macromolecules, 37, 3202-3213.

Barbieri, G., Brunetti, A., Scura, F., and Drioli, E. (2011) CO_2 separation by membrane technologies: Applications and potentialities. Chemical Engineering Transactions, 24, 775-780.

Cameron, N.R. (2005) High internal phase emulsion templating as a route to well-defined porous polymers. Polymer, 46(5), 1439-1449.

D'Alessandro, D.M.. Smit, B., and Long, J. (2010) Carbon dioxide capture: prospects for new materials. Angewandte Chemie International Edition, 49(35), 6058-6082.

Dey, D., Islam, M., Hussain, S., and Bhattacharjee, D. (2008) Layer by Layer (LbL) technique for fabrication of electrostatic Self assembled ultrathin films. International Journal of Pure and Applied Physics, 4(1), 39-44.

Dubas, S.T. and Schlenoff, J.B. (1999) Factors controlling the growth of polyelectrolyte multilayers. Macromolecules, 32(24), 8153-8160.

Erbay, E. and Okay, O. (1999) Pore memory of macroporous styrene–divinylbenzene copolymers. Journal of Applied Polymer Science, 71(7), 1055-1062.

Feuerabendt, F., Jindacharin, S., Pakeyangkoon, P., and Nithitanakul, M. (2014) The Effect of void size and level of interconnectivity of Poly (S/DVB)HIPEs on water adsorption and holding capacities. International Journal of Engineering Research and Reviews, 2, 22-29.

Fisher, J.C., Tanthana, J., and Chuang, S. (2009) Oxide-supported tetraethylene-pentamine for CO_2 capture. Environmental Progress & Sustainable Energy, 28(4), 589-598.

Gokmen, M.T., Van, C.W., Colver, P.J., Bon, S., and Du Prez, F.E. (2009) Fabrication of porous "clickable" polymer beads and rods through generation of high internal phase emulsion (HIPE) droplets in a simple microfluidic device. Macromolecules, 42(23), 9289-9294.

Gong, X. and Gao, C. (2009) Influence of salt on assembly and compression of PDADMAC/PSSMA polyelectrolyte multilayers. Physical Chemistry Chemical Physics, 11(48), 11577-11586.

Hamborg, E.S., Derks, P., Elk, E.P., and Versteeg, G.F. (2011) Carbon dioxide removal by alkanolamines in aqueous organic solvents. A method for enhancing the desorption process. Energy Procedia, 4, 187-194.

Hayward, A.S., Eissa, A.M., Maltman, D.J., Sano, N., Przyborski, S.A., and Cameron, N.R. (2013) Galactose-functionalized polyHipe scaffolds for use in routine three dimensional culture of mammalian hepatocytes. Biomacromolecules, 14(12), 4271-4277.

He, J., Zhang, Z.L., Kristiansen, H., Redford, K., Fonnum, G., and Modahl, G.I. (2013) Crosslinking effect on the deformation and fracture of monodisperse polystyrene-co-divinylbenzene particles. Express Polymer Letters, 7(4).

Iamsamai, C., Soottitantawat, A., Ruktanonchai, U., Hannongbua, S., and Dubas, S.T. (2011) Simple method for the layer-by-layer surface modification of multiwall carbon nanotubes. Carbon, 49(6), 2039-2045.

Jiang, B., Kish, V., Fauth, D.J., Gray, M.L., Pennline, H.W., and Li, B. (2011) Performance of amine-multilayered solid sorbents for CO_2 removal: effect of fabrication variables. International Journal of Greenhouse Gas Control, 5(5), 1170-1175.

Jiang, B., Wang, X., Gray, M.L., Duan, Y., Luebke, D., and Li, B.(2013) Development of amino acid and amino acid-complex based solid sorbents for CO_2 capture. Applied Energy, 109, 112-118.

Jin, J.M., Yang, S., Han, S.T., and Choe, S. (2006) Highly crosslinked poly (acrylamide-co-divinylbenzene) microspheres by precipitation polymerization. Journal of Industrial and Engineering Chemistry, 12(2), 268-274.

Kizling, J., Kronberg, B., and Eriksson, J.C. (2006) On the formation and stability of high internal phase O/W emulsions. Advances in Colloid and Interface Science, 123, 295-302.

Lan, J., Cao, D., Wang, W., and Smit, B. (2010) Doping of alkali, alkaline-earth, and transition metals in covalent-organic frameworks for enhancing CO_2 capture by first-principles calculations and molecular simulations. ACS Nano, 4(7), 4225-4237.

Li, B., Duan, Y., Luebke, D., and Morreale, B. (2013) Advances in CO_2 capture technology: a patent review. Applied Energy, 102, 1439-1447.

Liu, Y., Shi, J., Chen, J., Ye, Q., Pan, H., Shao, Z., and Shi, Y. (2010) Dynamic performance of CO_2 adsorption with tetraethylenepentamine-loaded KIT-6. Microporous and Mesoporous Materials, 134(1), 16-21.

Lumelsky, Y., Zoldan, J., Levenberg, S., and Silverstein, M.S. (2008) Porous polycaprolactone-polystyrene semi-interpenetrating polymer networks synthesized within high internal phase emulsions. Macromolecules, 41(4), 1469-1474.

Martín, A., García, R.A., Karaman, D.S., and Rosenholm, J.M. (2014) Polyethyleneimine-functionalized large pore ordered silica materials for poorly water-soluble drug delivery. Journal of Materials Science, 49(3), 1437-1447.

Medlyn, B. and Kauwe, D.M. (2013) Biogeochemistry: Carbon dioxide and water use in forests. Nature, 499(7458), 287-289.

Pakeyangkoon, P., Magaraphan, R., Malakul, P., and Nithitanakul, M. (2008) Effect of soxhlet extraction and surfactant system on morphology and properties of poly (DVB) polyHIPE. Macromolecular Symposia, 264, 149-156.

Pakeyangkoon, P., Magaraphan, R., Malakul, P., and Nithitanakul, M. (2009) Polymeric foam via polymerized high internal phase emulsion filled with organo-modified bentonite. Journal of Applied Polymer Science 114(5), 3041-3048.

Pakeyangkoon, P., Magaraphan, R., Malakul, P., and Nithitanakul, M. (2013) Surface modification of high internal phase emulsion foam as a scaffold for tissue engineering application via atmospheric pressure plasma treatment. Advances in Science and Technology, 77, 172-177.

Pipatsantipong, S., Rangsunvigit, P., and Kulprathipanja, S. (2012) Towards CO_2 adsorption enhancement via polyethyleneimine impregnation. World Academy of Science, 64, 405-410.

Plaza, M., Pevida, C., Arias, B., Fermoso, J., Arenillas, A., Rubiera, F., and Pis, J.J. (2008) Application of thermogravimetric analysis to the evaluation of aminated solid sorbents for CO_2 capture. Journal of Thermal Analysis and Calorimetry, 92(2), 601-606.

Pons, R., Solans, C., Stebe, M.J., Erra, P., and Ravey, J.C. (1992) Stability and rheological properties of gel emulsions. Trends in Colloid and Interface Science VI, 89, 110-113.

Qi, G., Wang, Y., Estevez, L., Duan, X., Anako, N., Park, A.H.A., Li, W., Jones, C.W., and Giannelis, E.P. (2011) High efficiency nanocomposite sorbents for CO_2 capture based on amine-functionalized mesoporous capsules. Energy & Environmental Science, 4(2), 444-452.

Quicker, G., Alper, E., and Deckwer, W.D. (1987) Effect of fine activated carbon particles on the rate of CO_2 absorption. AIChE Journal, 33(5), 871-875.

Rashidi, N.A., Yusup, S., and Lam, H.L. (2013) Kinetic studies on carbon dioxide capture using activated carbon. Chemical Engineering, 35, 361-366.

Saiwan, C., Muchan, P., and Tontiwachwutikul, P. (2014) New poly (Vinylbenzyl-chloride/Divinylbenzene) adsorbent for carbon dioxide adsorption. I. synthesis and parametric study. Energy Procedia, 63, 2312-2316.

Saiwan, C., Muchan, P., and Tontiwachwutikul, P. (2014) New poly (Vinylbenzyl-chloride/Divinylbenzene) adsorbent for carbon dioxide adsorption. II. effect of amine functionalization. Energy Procedia, 63, 2317-2322.

Silverstein, M.S. (2014) Emulsion-templated porous polymers: a retrospective perspective. Polymer, 55(1), 304-320.

Silverstein, M.S. , Ravisha, M., Ng, C.O., and Varun, V.L. (2005) PolyHIPE: IPNs, hybrids, nanoscale porosity, silica monoliths and ICP-based sensors. Polymer, 46(17), 6682-6694.

Somy, A., Mehrnia, M.R., Amrei, H.D., Ghanizadeh, A., and Safari, M. (2009) Adsorption of carbon dioxide using impregnated activated carbon promoted by zinc. International Journal of Greenhouse Gas Control, 3(3), 249-254.

Songolzadeh, M., Soleimani, M., Ravanchi, M.T., and Songolzadeh, R. (2014) Carbon dioxide separation from flue gases: A technological review emphasizing reduction in greenhouse gas emissions. The Scientific World Journal, 2014, 1-34.

Sumin, L., Youguang, M.A., Chunying, Z., Shuhua, S., Qing, H. (2009) The effect of hydrophobic modification of zeolites on CO_2absorption enhancement. Chinese Journal of Chemical Engineering, 17(1), 36-41.

Verykios, X.E., Stein, F., and Coughlin, R.W. (1980) Oxidation of ethylene over silver: Adsorption, kinetics, catalyst. Catalysis Reviews: Science and Engineering, 22(2), 197-234.

Williams, J.M., Gray, A.J., and Wilkerson, M.H. (1990) Emulsion stability and rigid foams from styrene or divinylbenzene water-in-oil emulsions. Langmuir, 6(2), 437-444.

Wu, N. (2009) Adsorption and diffusion of highly charged cationic polyelectrolyte into silica gel particles. M.S. Thesis, North Carolina State University, Raleigh, North Carolina.

Yue, M.B., Chun, Y., Cao, Y., Dong, X., and Zhu, J.H. (2006) CO_2 capture by as-prepared SBA-15 with an occluded organic template." Advanced Functional Materials, 16(13), 1717-1722.

Yue, M.B., Chun, Y., Cao, Y., Dong, X., and Zhu, J.H. (2008) Promoting the CO_2 adsorption in the amine-containing SBA-15 by hydroxyl group. Microporous and Mesoporous Materials, 114(1), 74-81.

Zhang, H. and Cooper, A.I. (2005) Synthesis and applications of emulsion-templated porous materials. Soft Matter, 1(2), 107-113.

APPENDICES

Appendix A Experimental-Data

Table A1 Multipoint BET surface area of polyHIPE filled with different S/DVB ratio

S/DVB 0:100					
P/Po	cc/g	P/Po	cc/g	P/Po	cc/g
0.0500907	55.7852	0.0474115	30.8194	0.05004	38.8511
0.0761042	64.2749	0.0778781	36.3143	0.075163	46.1183
0.102534	70.9662	0.104151	40.4328	0.102475	51.305
0.15062	79.7214	0.152581	45.8223	0.151233	57.6422
0.201126	87.9377	0.203342	50.33	0.200561	64.1723
0.252185	94.841	0.254334	53.85	0.252511	68.8734
0.302507	101.4364	0.304366	57.3617	0.302932	72.8718

S/DVB 20:80					
P/Po	cc/g	P/Po	cc/g	P/Po	cc/g
0.0506561	16.5063	0.0538238	21.7505	0.0535323	16.019
0.0793521	19.3037	0.0811327	24.7292	0.0796326	18.9911
0.0105278	21.4951	0.106733	26.9499	0.10628	20.7956
0.0153878	24.4798	0.155262	30.5099	0.153718	24.1835
0.0203920	27.2004	0.205524	33.64	0.20512	26.5848
0.0255452	29.0847	0.255607	36.4654	0.253826	29.6017
0.0304924	31.1343	0.305699	39.044	0.304939	31.8346

Table A1 Multipoint BET surface area of polyHIPE filled with different S/DVB ratio (con't)

S/DVB 80:20					
P/Po	cc/g	P/Po	cc/g	P/Po	cc/g
0.0557914	2.9684	0.0535935	3.8924	0.0549523	15.097
0.0831557	3.3771	0.0827345	4.4391	0.0811297	17.2509
0.0108387	3.6667	0.108109	4.7924	0.106615	19.0324
0.0157933	4.0756	0.157699	5.2483	0.155683	21.3216
0.0207598	4.4818	0.20769	5.5935	0.205459	23.884
0.0258251	4.7379	0.257484	5.998	0.256025	25.6286
0.0307694	4.9397	0.307522	6.3067	0.304458	28.2945

S/DVB 0:100 (Modified Surface)					
P/Po	cc/g	P/Po	cc/g	P/Po	cc/g
0.0475202	10.5305	0.0510009	58.0003	0.0525802	16.8793
0.0807148	12.98329	0.0762255	63.3577	0.0799709	19.6325
0.0107260	14.0959	0.102669	67.7096	0.106003	21.718
0.0205518	15.6801	0.149698	73.9324	0.153784	25.1259
0.0256715	19.0511	0.200591	79.4141	0.204662	27.879
0.0306533	20.3082	0.252221	83.611	0.254367	30.6669

S/DVB 20:80 (Modified Surface)					
P/Po	cc/g	P/Po	cc/g	P/Po	cc/g
0.0541064	38.2805	0.0498956	17.779	0.0498956	17.779
0.077449	42.5067	0.0791013	20.7403	0.0791013	20.7403
0.101104	47.3272	0.104642	23.2498	0.104642	23.2498
0.148911	53.4435	0.154069	26.1111	0.154069	26.1111
0.199441	59.0031	0.202983	29.4202	0.202983	29.4202
0.251018	63.586	0.254994	31.4997	0.254994	31.4997
0.301735	67.5821	0.302931	34.5615	0.302931	34.5615

Table A1 Multipoint BET surface area of polyHIPE filled with different S/DVB ratio (con't)

S/DVB 80:20 (Modified Surface)					
P/Po	cc/g	P/Po	cc/g	P/Po	cc/g
0.0544468	4.0718	0.0540944	4.2704	0.0573692	15.401
0.0831623	4.5493	0.0826983	4.962	0.0819143	17.3466
0.108249	4.884	0.107919	5.4605	0.106956	19.0609
0.157852	5.4419	0.15763	6.2363	0.15632	21.501
0.207682	5.9709	0.207919	6.7613	0.206179	23.7845
0.257543	6.3912	0.257411	7.1726	0.256342	25.8733
0.30769	6.601	0.307682	7.6451	0.306386	27.7214

Table A2 Universal testing machine of polyHIPE filled with differrant S/DVB ratio

S/DVB 0:100						
Speed (mm/min)	Height (cm)	Diameter (cm)	Maximum Load (N)	Area (mm^3)	Compressive Stress (MPa)	Young Modulus (MPa)
1.27	3.7	2.3	119.588432	415.47	0.287835	5.082627
1.27	3.5	2.3	117.187446	415.47	0.282056	5.082627
1.27	3	2.3	120.020724	415.47	0.288875	5.082627
1.27	3.5	2.3	146.197334	415.47	0.351879	5.082627
1.27	3.5	2.3	139.372794	415.47	0.335453	5.082627

S/DVB 20:80						
Speed (mm/min)	Height (cm)	Diameter (cm)	Maximum Load (N)	Area (mm^3)	Compressive Stress (MPa)	Young Modulus (MPa)
1.27	3	2.3	97.358393	452.39	0.215209	3.761881
1.27	3.2	2.3	104.38103	452.39	0.230732	3.792088
1.27	3.4	2.3	108.83524	452.39	0.240578	3.521111
1.27	2.7	2.3	95.021996	452.39	0.210044	3.264746
1.27	3.3	2.3	190.65934	452.39	0.421449	6.345202

S/DVB 80:20						
Speed (mm/min)	Height (cm)	Diameter (cm)	Maximum Load (N)	Area (mm^3)	Compressive Stress (MPa)	Young Modulus (MPa)
1.27	3.5	2.3	70.383266	452.39	0.155581	2.026694
1.27	3.9	2.3	73.036929	452.39	0.161447	2.371084
1.27	3.5	2.3	53.941690	452.39	0.119237	1.217273
1.27	2.5	2.3	56.712401	452.39	0.125362	1.532055

Appendix B Fourier Transform Infrared Spectroscopy (FTIR)

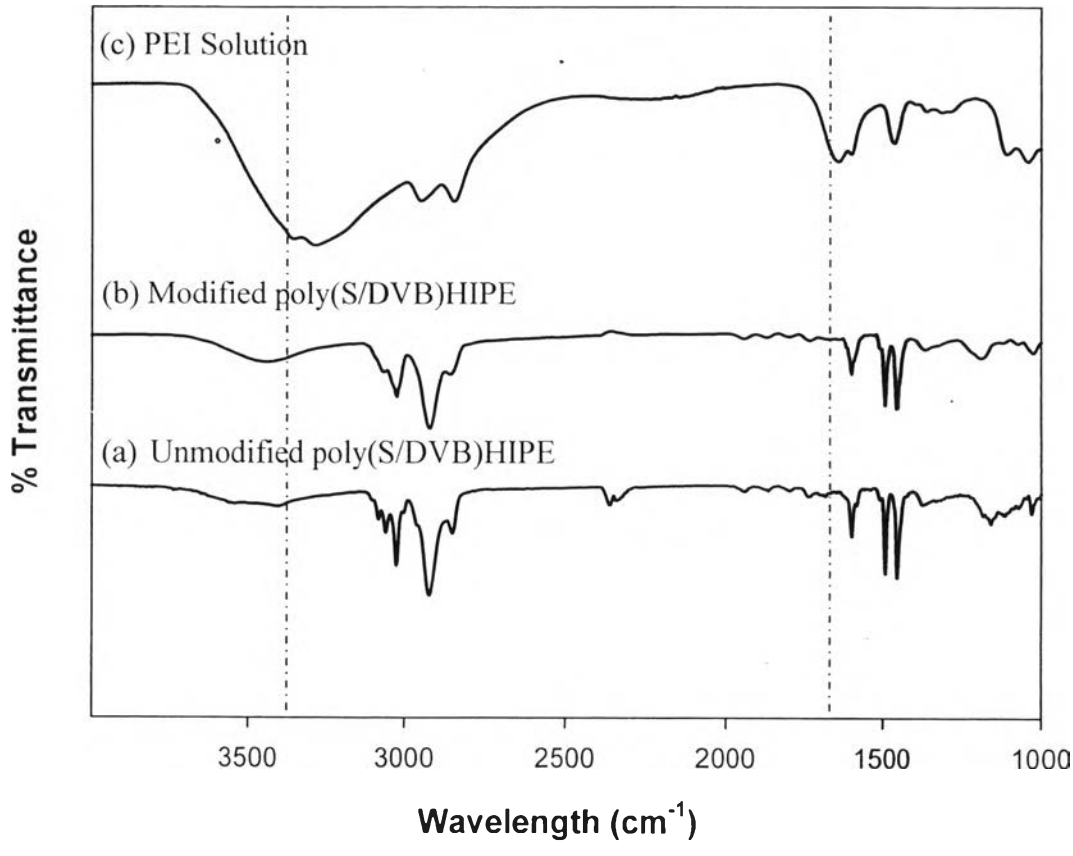

Figure B1 FTIR spectra of polyHIPE filled with different S/BVD of 0:100 (a) unmodified poly(S/DVB)HIPE (b) modified poly(S/DVB)HIPE with PEI solution (c) PEI solution and the spectra of N-H stretching at 3400-3380 cm^{-1} and N-H bend vibration at 1650-1550 cm^{-1}

Appendix C Calculation CO_2 Adsorption

$$Q_{ads} = \frac{FC_{in}t_{st}}{M}$$

$$t_{st} = \int_0^1 (1 - \frac{C_{ou}}{C_{in}})dt$$

$$F = \frac{P \times V}{R \times T}$$

Q_{ads} = Dynamic adsorption capacity, mmolCO_2/g

F = Total flow rate, mol/min

C_{in} = Theconcentration of CO_2 entering the reactor, vol%

M = The weight of the adsorbent, g

tst = The stoichiometric time corresponding to CO_2 stoichiometric adsorption capacity, min

Cou = The CO_2 concentration downstream of the reactor, vol%

t = The time at which the Cou reached its maximum permissible level, min

P = 1 atm = 0.1013 MPa

V = Volume (flow rate = 15 ml/min)

T = Temperature = 298 K

R = 8.314 cm^3 Mpa/ K mol

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Presentation

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