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APPENDICES

Appendix A Gas Permeability Analysis

Gas permeation experiments were obtained from Brugger Gas Permeability Tester. The sample films were cut into circular shape with 110 mm in diameter according to ASTM 1434-82. The thickness of the films was measured with the peacock digital thickness gauge model PDN 12N by reading ten points at random position over the entire test area and the results were averaged. The films were placed in a dessicator over NaCl and kept for not less than 3 days prior to test.

Gas trasmission rate (GTR)

$$GTR = \frac{\Delta M}{A \cdot \Delta t \cdot \Delta p}$$

Permeability (Q)

$$Q = \frac{\Delta M \cdot L}{A \cdot \Delta t \cdot \Delta p}$$

$$\therefore Q = GTR \times L$$

where:

$\dfrac{\Delta M}{\Delta t}$ = amount of gas passing through film in unit time (cm^3/s)

A = area (m^2)

Δp = the differential partial pressure of the permeate gas across the film (bar)

L = film thickness (mm)

The gas permeability rate, G, in units of $cm^3/(m^2.day.bar)$ is calculated from,

$$G = \frac{7.76 \times 10^7 \times V}{78.5K \times 29N}$$

where:

V = volume of the evacuation chamber

K = absolute temperature (degrees Kelvin)

N = the slope of the graph which is determined by dividing the time (s) by the scale divisions (mm) (If the detector is voltmeter, the scale divisions

are conversed from 0.01 V = 1 mm)

if the evacuation chamber volume, V, is 0.4370 cm^3 then this expression simplifies to,

$$G \; = \; \frac{1.49 \times 10^7}{KN} \quad cm^3 \,/(m^2 \cdot day \cdot bar)$$

According to ASTM D1434

Factor for converting gas permeability unit Q (ml(STP).mil/m^2.day.atm) from gas permeability rate G (cm^3/m^2.day.bar) is 7.725

Table A1 Time and scale divisions of PP

1st time		2nd time		3rd time	
Time (s)	Scale (mm)	Time (s)	Scale (mm)	Time (s)	Scale (mm)
0	97.4	0	99.2	0	97.5
60	96.5	60	98.3	60	96.8
300	93.5	300	95	480	91.4
600	89.8	960	86.5	720	88.5
900	86.3	1200	83.6	900	86.5
1200	82.8	1560	79.3	1200	83
1500	79.5	1800	76.6	1560	79.1
1800	76.3	2280	71.4	1800	76.5
2160	72.6	2460	69.5	2100	73.4
2400	70.1	2760	66.4	2400	70.4
2700	67	3240	61.6	2700	67.4
3000	64.2	3600	58.2	3000	64.6
3300	61.5	3900	55.4	3360	61.3
3600	58.8	4200	52.7	3600	59.1
3900	56.2	4500	50.1	3900	56.3
4200	53.5	4800	47.5	4260	53.4
4500	50.9	5100	45	4500	51.3
4860	48	5400	42.5	4740	49.4
5160	45.6	5700	40.1	5100	46.3
5460	43.2	6000	37.6	5400	44
5760	40.8	6300	35.4	5700	41.7
6000	39	-	-	6000	39.4
Temp = 297.5 K		Temp = 297.9 K		Temp = 297.6 K	
Thickness = 0.0299 mm		Thickness = 0.0278 mm		Thickness = 0.0290 mm	
Slope = 103.67		Slope = 99.985		Slope = 103.03	

Table A2 Time and scale divisions of PCH-9

1st time		2nd time		3rd time	
Time (s)	Scale (mm)	Time (s)	Scale (mm)	Time (s)	Scale (mm)
0	97.7	0	97.1	0	97.8
120	96.4	180	94.9	60	96.7
300	94.3	300	93.4	120	94.1
660	90.2	600	89.8	300	91.1
900	87.6	900	85.1	600	88.1
1260	83.8	1200	83.1	900	82.8
1500	81.4	1500	79.8	1200	81.4
1860	77.8	1860	76.1	1500	78.8
2160	74.9	2100	73.5	1800	74.9
2460	72.1	2400	70.6	2100	71.6
2700	70	2760	67.1	2400	70.5
3000	67.3	3000	64.9	2700	67.5
3300	64.7	3360	61.5	3000	64.1
3660	61.7	3600	60.3	3300	61.5
3960	59.2	4080	55.1	3600	59.8
4380	55.8	4440	52	3900	57.3
4500	54.9	4800	49.2	4230	55.2
4800	52.5	5100	46.5	4530	52.1
5220	49.3	5400	44.2	4800	49.1
5520	47	5730	41.6	5100	47.3
5880	44.4	6000	39.6	5400	45.9
6030	43.2	-	-	5820	42.6
Temp = 296.2 K		Temp = 298.2 K		Temp = 298.8 K	
Thickness = 0.0323 mm		Thickness = 0.0282 mm		Thickness = 0.0253 mm	
Slope = 113.37		Slope = 108.62		Slope = 114.35	

Table A3 Time and scale divisions of PCH-7

1st time		2nd time		3rd time	
Time (s)	Scale (mm)	Time (s)	Scale (mm)	Time (s)	Scale (mm)
0	97.9	0	97.7	0	97.7
60	96.7	120	95.3	300	90.7
180	94.2	240	92.9	600	84
300	91.8	420	89.3	900	78
600	86	1020	78.5	1200	72
990	78.9	1230	75	1500	66.4
1440	71.2	1500	70.5	1800	61
1530	67.9	1800	66	2100	56
1860	64.3	2190	60.1	2400	51.1
2100	60.7	2430	56.6	2700	46.4
2400	56.3	2760	52.1	3000	41.6
2700	52.1	2880	50.5	3300	37.3
3060	47.1	3270	45.4	3600	33
3390	42.7	3660	40.4	3900	28.8
3600	40	3960	38.3	4200	24.8
4320	31.2	4260	33.3	4500	20.9
4500	29.1	4560	29.9	4800	17.2
4890	24.6	4920	26	5160	12.8
5400	19.2	5340	21.5	5400	9.9
5700	16.1	5640	18.3	5700	6.5
6000	13	6000	14.8	6000	3.3
Temp = 298.3 K		Temp = 298.2 K		Temp = 298.2 K	
Thickness = 0.0216 mm		Thickness = 0.0242 mm		Thickness = 0.0200 mm	
Slope = 76.968		Slope = 78.072		Slope = 65.92	

Table A4 Time and scale divisions of PCH-5

1st time		2nd time		3rd time	
Time (s)	Scale (mm)	Time (s)	Scale (mm)	Time (s)	Scale (mm)
0	97.2	0	97.5	0	9.75
300	91.2	210	93.1	300	90.9
660	84.4	420	88.8	600	84.7
960	79.2	660	84.1	900	78.8
1230	74.6	900	79.6	1260	72.1
1500	70.5	1260	73.2	1620	66.7
1740	66.5	1500	69.9	1980	59.6
1860	64.8	1980	61.4	2100	57.6
2130	60.7	2400	54.9	2400	52.9
2520	55.2	2700	50.6	2700	50.9
2850	50.8	3060	45.6	3000	46.6
3090	47.7	3390	41	3300	42.3
3300	45	3780	36	3690	34
3630	40.9	4020	33	4020	29.6
4080	35.7	4200	31.9	4350	25.5
4200	34.9	4710	24.7	4830	19.4
4620	29.3	4800	23.4	5130	15.8
4800	27	5100	20.2	5400	12.7
5100	23.1	5400	15	5700	9.3
5400	19.1	5670	14	5910	7
6060	15	6000	10.6	6000	6.1
Temp = 298.0 K		Temp = 297.6 K		Temp = 298.0 K	
Thickness = 0.0217 mm		Thickness = 0.0198 mm		Thickness = 0.0191 mm	
Slope = 75.974		Slope = 70.896		Slope = 69.40	

Table A5 Time and scale divisions of PCH-3

1st time		2nd time		3rd time	
Time (s)	Scale (mm)	Time (s)	Scale (mm)	Time (s)	Scale (mm)
0	97.5	0	97.6	0	97.6
300	91.6	360	89.5	330	90.8
600	86	720	81.8	540	86.6
900	80.7	900	78.4	1020	77.7
1320	73.8	1200	71.5	1350	72.1
1500	70.9	1440	68.5	1650	67.1
1800	67	1800	63	1860	63.8
2070	62.2	2100	58.8	2220	58.3
2280	59.2	2400	52.8	2550	53.5
2580	55.1	2520	51	2940	48.1
3000	49.4	2790	47	3180	46.7
3300	45.6	3000	44	3390	42
3600	41.8	3180	41.4	3600	39.2
3960	37.5	3720	34.2	3930	35.3
4320	33.4	3960	31.2	4200	32.7
4500	31.9	4230	27.8	4500	28.6
4800	28	4500	24.6	4800	24.5
5280	23	4920	19.7	5040	22.5
5400	20.2	5160	17.1	5400	16.3
5640	19.3	5460	13.8	5700	12.2
6000	15.5	6000	8	6000	12.4
Temp = 298.35 K		Temp = 298.6 K		Temp = 298.1 K	
Thickness = 0.0211 mm		Thickness = 0.0191 mm		Thickness = 0.0206 mm	
Slope = 76.876		Slope = 71.02		Slope = 73.035	

Table A6 Time and scale divisions of HPCH-9

1st time		2nd time		3rd time	
Time (s)	Scale (mm)	Time (s)	Scale (mm)	Time (s)	Scale (mm)
0	99.9	0	97.8	0	97.8
120	98.2	120	93.4	240	94.4
300	95.9	750	87.4	660	88.7
600	92.4	1140	82.6	900	85.6
900	89	1200	81	1260	81.1
1200	85.7	1470	78.5	1530	77.8
1500	82.5	1860	74	1830	74.3
1800	79.5	2310	69	2100	71.8
2100	76.4	2400	68.7	2490	66.9
2400	73.6	2730	64.6	2790	63.8
2700	70.8	3000	61.9	3090	60.6
3060	67.5	3480	57.2	3300	59.7
3360	64.9	3720	56.2	3660	54.9
3600	62.8	3960	53.8	3930	52.4
3900	60.3	4260	50.9	4380	48.2
4200	57.8	4590	47	4680	45.9
4560	54.9	4800	45.6	4980	42.7
4800	53	5130	42.3	5280	40.1
5100	50.7	5490	39.4	5460	38.6
5460	48	5700	37.6	5700	36.6
5700	46.2	6000	35.3	6030	33.9
6000	44	-	-	-	-
Temp = 297.8 K		Temp = 298.7 K		Temp = 298.8 K	
Thickness = 0.0293 mm		Thickness = 0.0271 mm		Thickness = 0.0288 mm	
Slope = 112.10		Slope = 101.71		Slope = 99.627	

Table A7 Time and scale divisions of HPCH-7

1st time		2nd time		3rd time	
Time (s)	Scale (mm)	Time (s)	Scale (mm)	Time (s)	Scale (mm)
0	97.6	0	97.7	0	97.7
540	87.2	240	93.3	300	91
900	80.8	540	88.1	600	85
1200	73.2	930	81.7	930	78.8
1590	69.4	1260	76.6	1290	72.5
1920	64.6	1500	73	1590	67.3
2190	61.5	1980	66.2	1860	63
2400	59.1	2250	62.6	2280	56.6
2640	54.3	2400	60.5	2580	52.2
2880	50.9	2820	55.2	2820	50.3
3120	50.6	3060	53.8	3120	46.5
3480	44.2	3420	48	3210	43.5
3780	40.9	3750	44.1	3450	40.4
4080	37.7	4020	41.1	3720	38.7
4380	34.7	4380	37.2	4080	32.5
4500	32.9	4770	33.1	4560	27
5040	28.2	5160	29.1	4980	22.3
5340	25.4	5400	26.8	5160	20.4
5580	23.2	5760	23.3	5730	14.5
5760	21.6	6000	21.1	6000	11.8
6000	19.5	-	-	-	-
Temp = 298.1 K		Temp = 298.1 K		Temp = 299.2 K	
Thickness = 0.0258 mm		Thickness = 0.0229 mm		Thickness = 0.0233 mm	
Slope = 84.903		Slope = 84.031		Slope = 77.677	

Table A8 Time and scale divisions of HPCH-5

1st time		2nd time		3rd time	
Time (s)	Scale (mm)	Time (s)	Scale (mm)	Time (s)	Scale (mm)
0	97.6	0	97.8	0	97.8
600	85.3	240	93.6	240	92.5
810	81.3	660	86.4	600	85.5
1050	77.1	1080	77.9	960	79.4
1320	72.4	1380	74.4	1290	74.4
1560	68.4	1590	72.4	1560	70.7
1800	64.5	1860	68.5	2010	65.3
2100	59.9	2190	64.3	2400	61.1
2400	55.6	2520	60	2700	58.2
2700	51.3	2790	56.7	3000	59
3000	47.3	3090	53.1	3240	53.5
3300	43.4	3540	47.9	3600	53.7
3630	39.3	3660	46.6	3840	49.1
3900	36	3960	43.3	4200	46.6
4290	31.5	4320	39.6	4500	44.8
4500	29.1	4740	35.2	4800	43.1
4890	24.8	5040	32.2	5160	41.1
5220	21.4	5340	29.2	5400	39.9
5640	17	5700	25.6	5700	38.5
6000	13.4	6000	22.9	6000	37.1
Temp = 297.9 K		Temp = 297.6 K		Temp = 298.1 K	
Thickness = 0.0198 mm		Thickness = 0.0230 mm		Thickness = 0.0230 mm	
Slope = 77.684		Slope = 85.911		Slope = 112.83	

Table A9 Time and scale divisions of HPCH-3

1st time		2nd time		3rd time	
Time (s)	Scale (mm)	Time (s)	Scale (mm)	Time (s)	Scale (mm)
0	97.8	0	97.6	0	99.6
465	88.9	240	92.8	420	97.8
660	81	630	85.5	870	95.6
960	80.2	930	80.2	1080	94.3
1260	75.3	1410	72.2	1320	92.8
1560	70.7	1680	68.5	1440	89.9
1980	64.5	1890	64.9	1530	88.1
2160	61	2160	61	1980	79.8
2430	58.2	2550	55.5	2220	75.7
2730	54.2	2850	51.5	2400	72.7
3000	49.8	3000	50.9	2700	67.8
3240	47.6	3240	46.5	3120	61.3
3540	44	3690	41	3450	56.5
3780	41.1	4140	35.7	3690	53.1
4110	37.2	4530	31.4	3960	49.3
4260	33	4680	30.2	4320	44.6
4710	30.6	4950	26.8	4770	38.9
5040	27	5400	22.1	5130	34.5
5400	17.8	5730	18.9	5400	31.3
5640	20.9	6000	16.3	5760	27.2
6000	17.3	-	-	6000	24.7
Temp = 297.2 K		Temp = 297.7 K		Temp = 298.6 K	
Thickness = 0.0186 mm		Thickness = 0.0203 mm		Thickness = 0.0233 mm	
Slope = 74.994		Slope = 78.197		Slope = 72.768	

Appendix B Ethylene Adsorption

Gas chromatography with flame ionization detector was utilized to examine ethylene adsorption capacity of the porous clays. Ethylene adsorption was measured by placing each product in a jar (0.6 l), then sealing with a screw-cap lid. Ethylene was injected into a jar to give a specific concentration of 500 ppm. Ethylene concentration in the jar was measured periodically about once an hour. The ethylene adsorption was calculated by taking the difference between the amount of ethylene added and the amount of remaining in the headspace.

Table B1 Correlation between concentration and peak area of standard ethylene gas

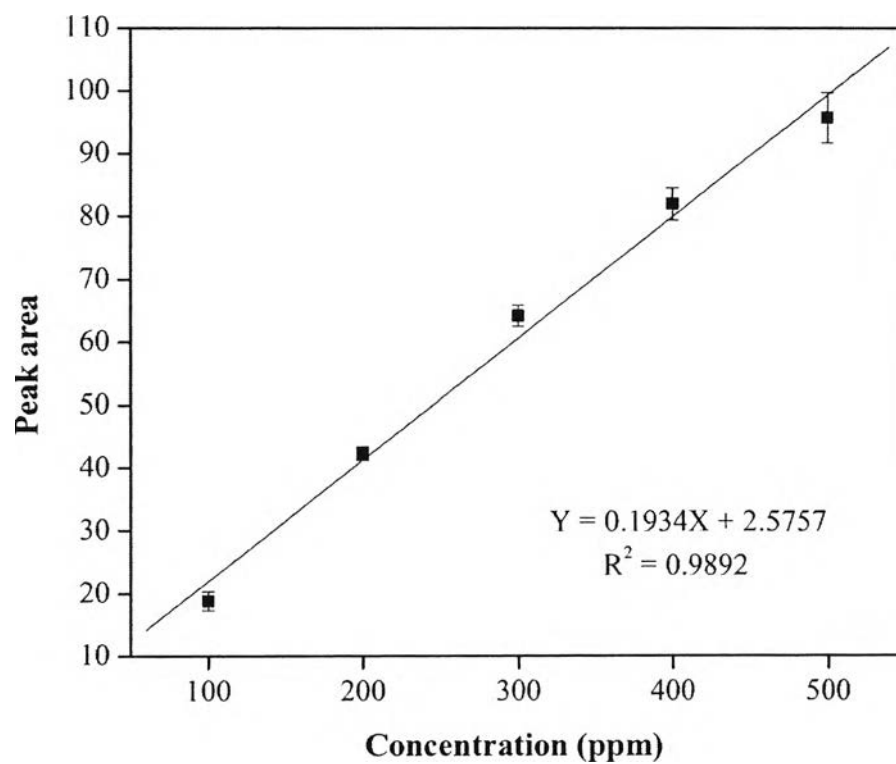| Concentration (ppm)	Peak area				
	1st time	2nd time	3rd time	Average	SD
100	20.5282	18.2045	17.7405	18.8244	1.4937
200	41.0931	42.7824	43.0126	42.2960	1.0481
300	63.1080	66.1258	63.3715	64.2018	1.6715
400	80.2008	84.8987	80.8095	81.9697	2.5548
500	94.3859	100.1810	92.4970	95.6880	4.0041

Figure B1 Standard curve of ethylene gas remaining in the headspace

Table B2 Ethylene adsorption of PCH-9

Time (hr)	Ethylene adsorption (mmol/g)		
	1st time wt = 16.00 g	2nd time wt = 15.70 g	Average
1	0.000052	0.000091	0.000071
2	0.000072	0.000126	0.000099
3	0.000206	0.000127	0.000166
4	0.000147	0.000221	0.000184
5	0.000256	0.000187	0.000222
6	0.000278	0.000277	0.000278
7	0.000255	0.000325	0.000290
8	0.000342	0.000352	0.000347
9	0.000335	0.000352	0.000343
10	0.000370	0.000387	0.000378
11	0.000399	0.000391	0.000395
12	0.000420	0.000355	0.000387

Table B3 Ethylene adsorption of PCH-7

Time (hr)	Ethylene adsorption (mmol/g)		
	1st time wt = 16.00 g	2nd time wt = 15.95 g	Average
1	0.000050	0.000056	0.000053
2	0.000107	0.000050	0.000079
3	0.000120	0.000102	0.000111
4	0.000176	0.000146	0.000161
5	0.000234	0.000162	0.000198
6	0.000242	0.000183	0.000213
7	0.000233	0.000233	0.000233
8	0.000251	0.000274	0.000262
9	0.000181	0.000366	0.000273
10	0.000202	0.000380	0.000291
11	0.000236	0.000355	0.000295
12	0.000219	0.000415	0.000317

Table B4 Ethylene adsorption of PCH-5

Time (hr)	Ethylene adsorption (mmol/g)		
	1st time wt = 14.22 g	2nd time wt = 14.09 g	Average
1	0.000075	0.000091	0.000083
2	0.000101	0.000124	0.000113
3	0.000133	0.000164	0.000148
4	0.000202	0.000163	0.000182
5	0.000263	0.000193	0.000228
6	0.000279	0.000188	0.000233
7	0.000225	0.000315	0.000270
8	0.000257	0.000296	0.000277
9	0.000275	0.000367	0.000321
10	0.000301	0.000309	0.000305
11	0.000407	0.000226	0.000317
12	0.000328	0.000375	0.000351

Table B5 Ethylene adsorption of PCH-3

Time (hr)	Ethylene adsorption (mmol/g)		
	1st time wt = 14.45 g	2nd time wt = 14.18 g	Average
1	0.000077	0.000098	0.000087
2	0.000094	0.000126	0.000110
3	0.000147	0.000154	0.000150
4	0.000197	0.000202	0.000200
5	0.000280	0.000119	0.000200
6	0.000288	0.000147	0.000217
7	0.000284	0.000235	0.000259
8	0.000383	0.000202	0.000293
9	0.000307	0.000280	0.000293
10	0.000311	0.000371	0.000341
11	0.000368	0.000311	0.000340
12	0.000342	0.000304	0.000323

Table B6 Ethylene adsorption of HPCH-9

Time (hr)	Ethylene adsorption (mmol/g)		
	1st time wt = 13.70 g	2nd time wt = 13.61 g	Average
1	0.00013	0.000143	0.000136
2	0.000191	0.000188	0.000189
3	0.000259	0.000259	0.000259
4	0.000291	0.000314	0.000303
5	0.000294	0.000364	0.000329
6	0.000268	0.000416	0.000342
7	0.000246	0.000485	0.000366
8	0.000322	0.000454	0.000388
9	0.00036	0.000435	0.000398
10	0.000389	0.000435	0.000412
11	0.000401	0.000405	0.000403
12	0.000389	0.000416	0.000402

Table B7 Ethylene adsorption of HPCH-7

Time (hr)	Ethylene adsorption (mmol/g)		
	1st time wt = 15.65 g	2nd time wt = 15.45 g	Average
1	0.00011	0.000131	0.000121
2	0.000141	0.000143	0.000142
3	0.000189	0.000218	0.000203
4	0.000175	0.000317	0.000246
5	0.000187	0.000357	0.000272
6	0.000276	0.000334	0.000305
7	0.000341	0.000304	0.000323
8	0.000375	0.000300	0.000337
9	0.00037	0.000333	0.000352
10	0.000393	0.000333	0.000363
11	0.000431	0.000299	0.000365
12	0.00047	0.000322	0.000396

Table B8 Ethylene adsorption of HPCH-5

Time (hr)	Ethylene adsorption (mmol/g)		
	1st time wt = 13.78 g	2nd time wt = 13.66 g	Average
1	0.000156	0.000118	0.000137
2	0.000131	0.000235	0.0001831
3	0.000188	0.000231	0.0002094
4	0.000164	0.000276	0.0002199
5	0.000222	0.000262	0.000242
6	0.000254	0.000276	0.000265
7	0.000258	0.000367	0.0003125
8	0.000239	0.000395	0.0003168
9	0.000293	0.000355	0.0003239
10	0.000294	0.00039	0.0003418
11	0.000338	0.000418	0.0003781
12	0.000156	0.000399	0.0003987

Table B9 Ethylene adsorption of HPCH-3

Time (hr)	Ethylene adsorption (mmol/g)		
	1st time wt = 14.95 g	2nd time wt = 14.42 g	Average
1	0.000129	0.000152	0.000141
2	0.000165	0.000211	0.000188
3	0.00025	0.000228	0.000239
4	0.000264	0.000251	0.000257
5	0.000246	0.000317	0.000282
6	0.000346	0.000232	0.000289
7	0.000376	0.000239	0.000308
8	0.000421	0.00021	0.000315
9	0.000416	0.000277	0.000346
10	0.000426	0.000267	0.000346
11	0.000401	0.000289	0.000345
12	0.000352	0.000343	0.000348

CIRRICULUM VITAE

Name: Ms. Kasinee Prakobna

Date of Birth: March 21, 1983

Nationality: Thai

University Education:

2001-2004 Bachelor Degree of Science in Chemistry, Faculty of Science, Chulalongkorn University, Bangkok, Thailand.

Presentations:

1. Prakobna, K., Luangsukrerk, S., Magaraphan, R., and Manuspiya, H. (2007, January 9-11) Effect of pH on the Formation of Porous Clay Heterostructures (PCHs) and Hybrid PCHs (HPCHs). Poster presented at IEEE-NEMs 2007, Bangkok, Thailand.

2. Prakobna, K., Magaraphan, R., and Manuspiya, H. (2007, April 9-13) Modification of Hybrid Organic-Inorganic Porous Clay Heterostructures for the Application in Entrapping System. Poster presented at Materials Research Society's 2007 Spring Meeting 2007, San Francisco, USA.