

Sixth Annual Conference on Carbon Capture & Sequestration

Capture and Sequestration / Advanced Concepts

**Adsorptive removal of carbon dioxide using advanced
mesoporous materials**

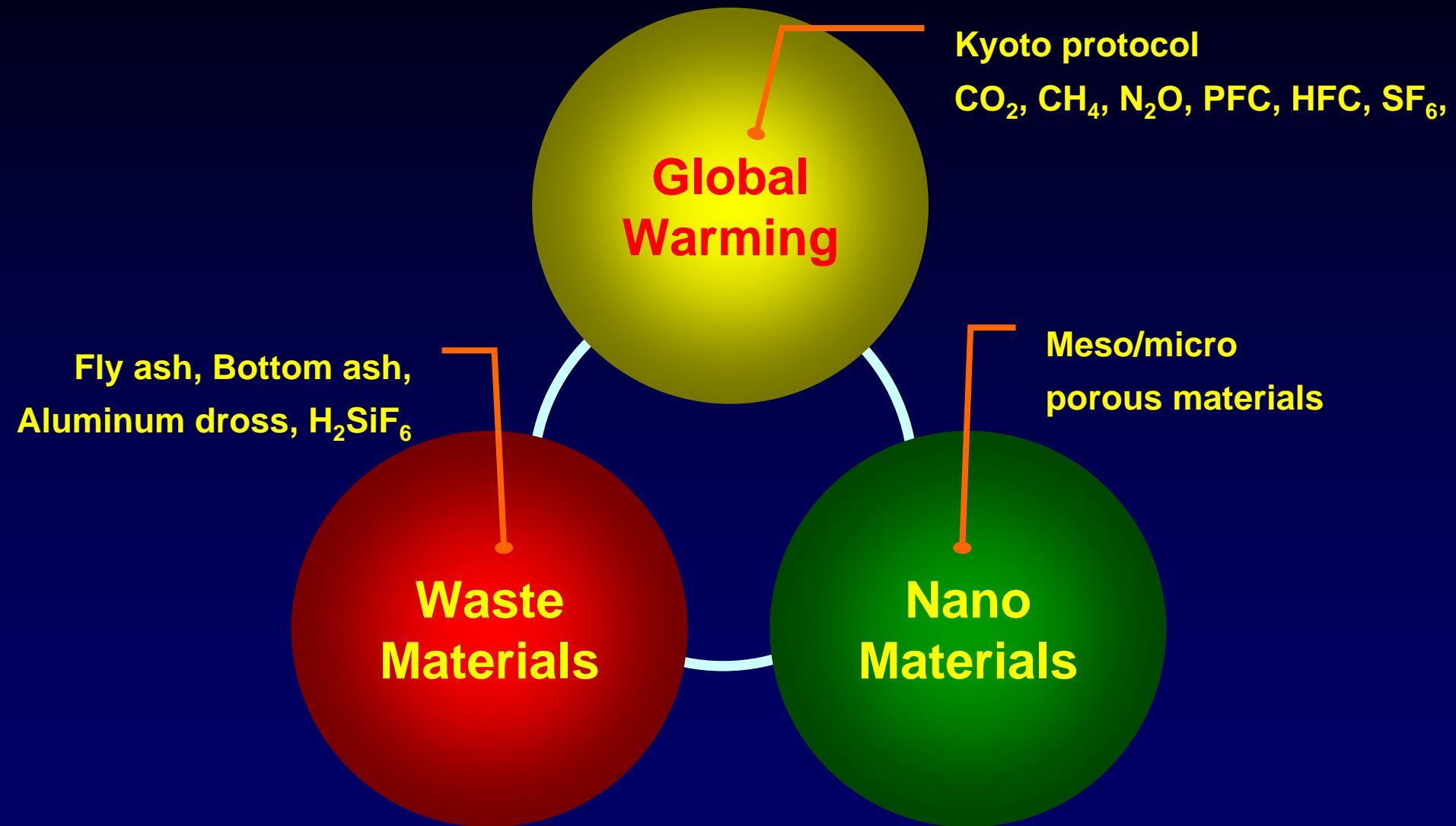
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May 7-10, 2007 • Sheraton Station Square • Pittsburgh, Pennsylvania

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INTRODUCTION



Research Scope

Carbon dioxide adsorption using nano porous materials

MOF

Zeolite
materials

Mesoporous
silica

Mesoporous
carbon

etc

- MOF-5
- MOF-177
- MIL-100
- MIL-101

- Zeolite 13X
- SAPOs

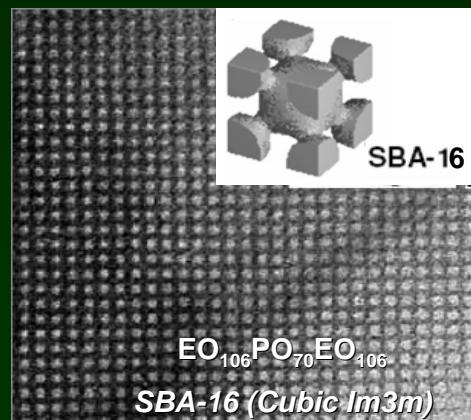
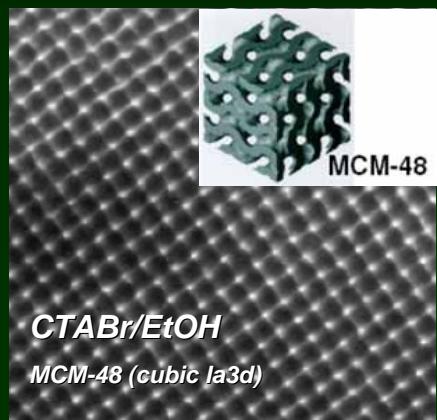
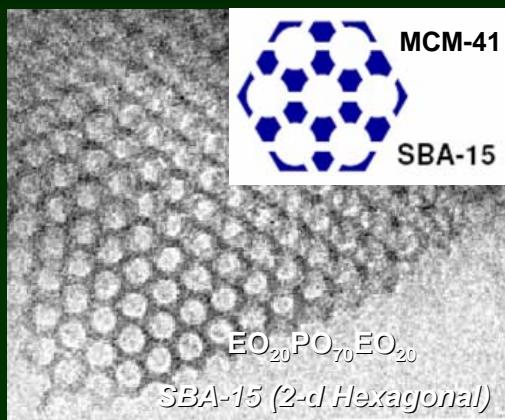
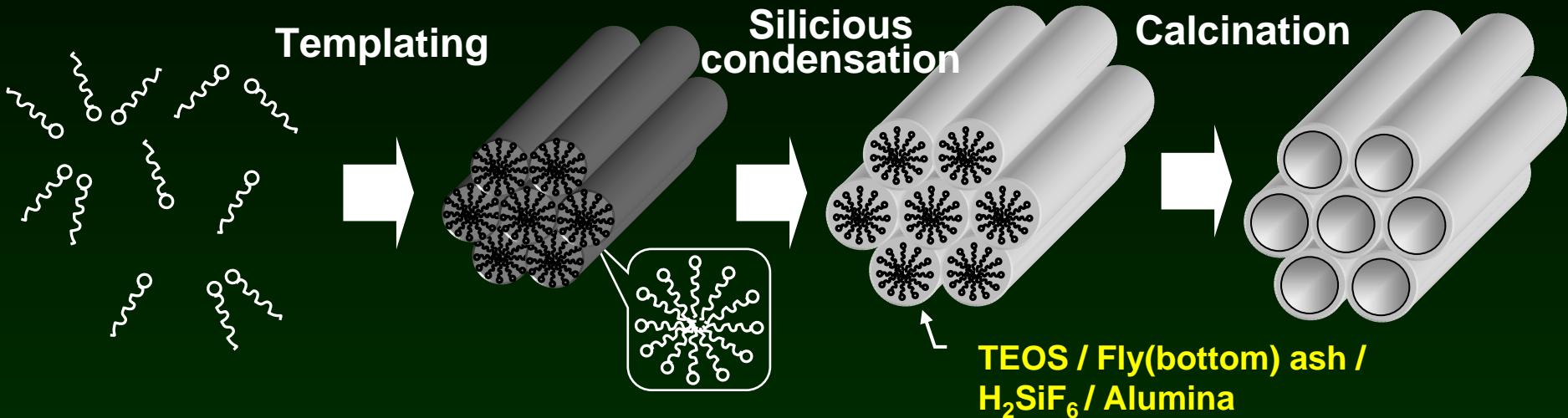
- PEI-
impregnation
(MCM-41/48,
SBA-15/16)
- AMS

- N-
incorporation
- H_3PO_4
treatment

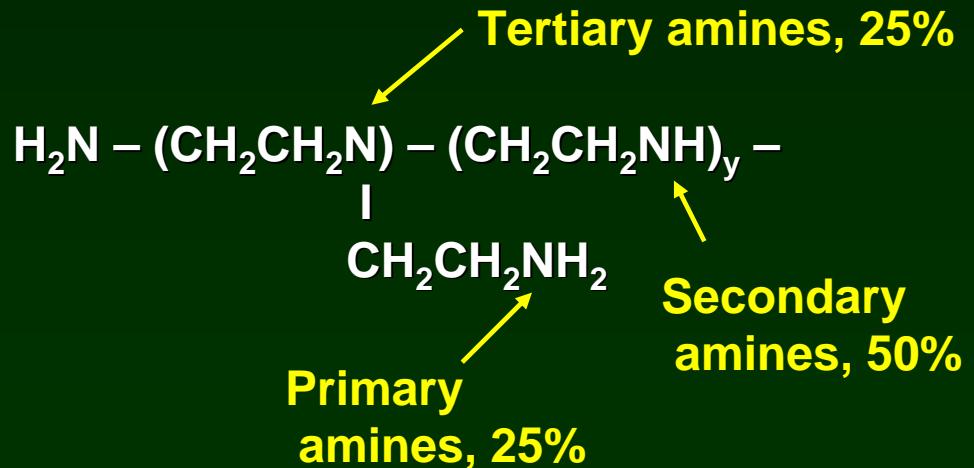
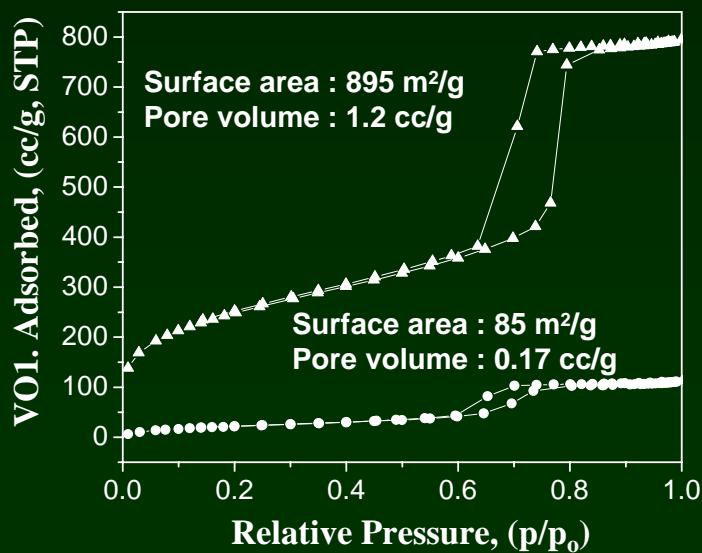
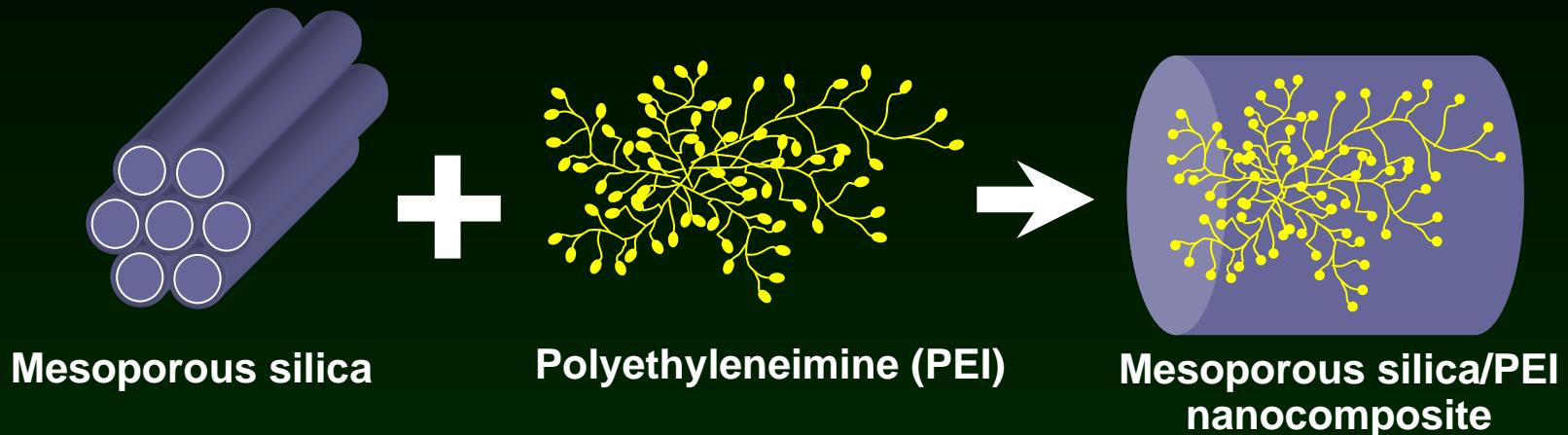
- Meso_alumina
- Meso_AIPO

Mesoporous Silica

❖ Synthesis mechanism

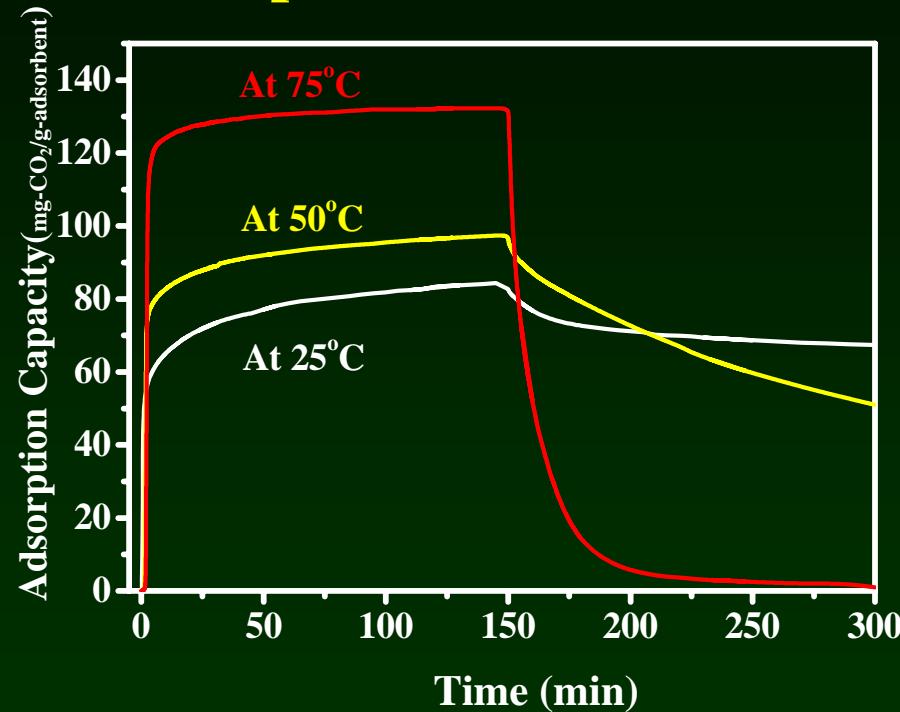


PEI impregnated Meso-silica

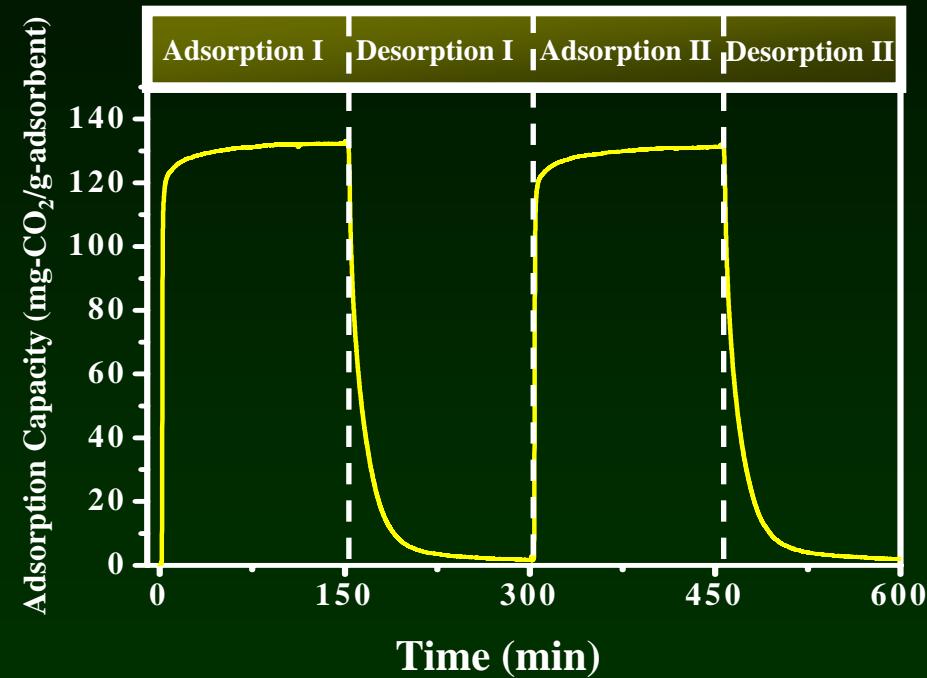


Adsorption of Carbon dioxide

Temperature



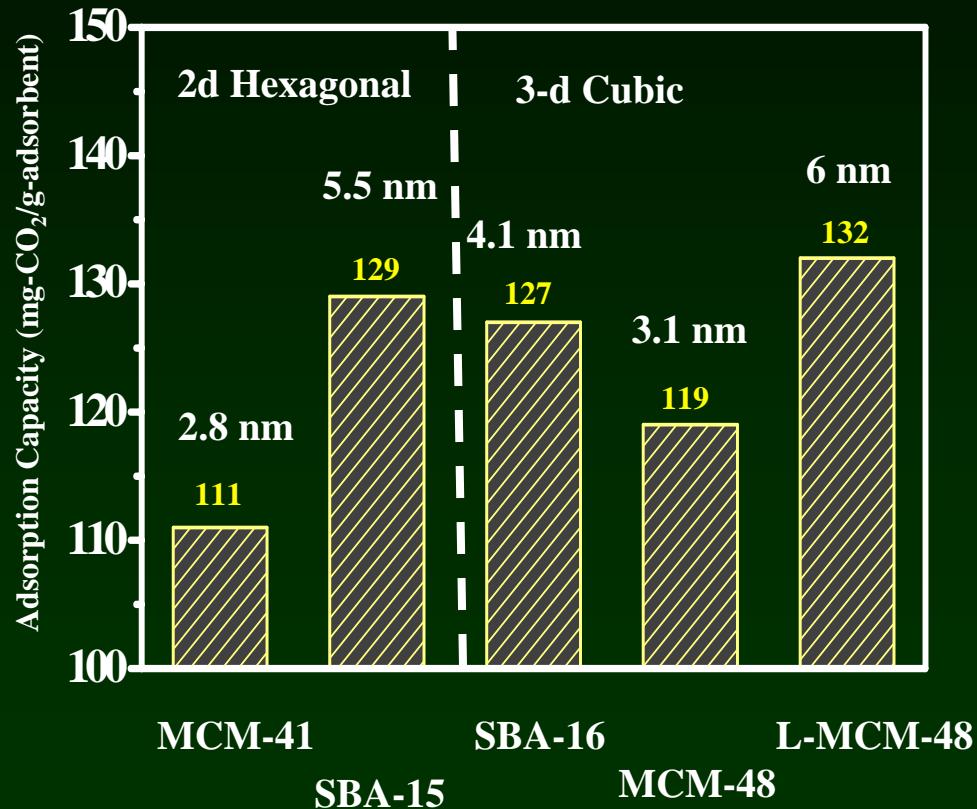
Recycle performance



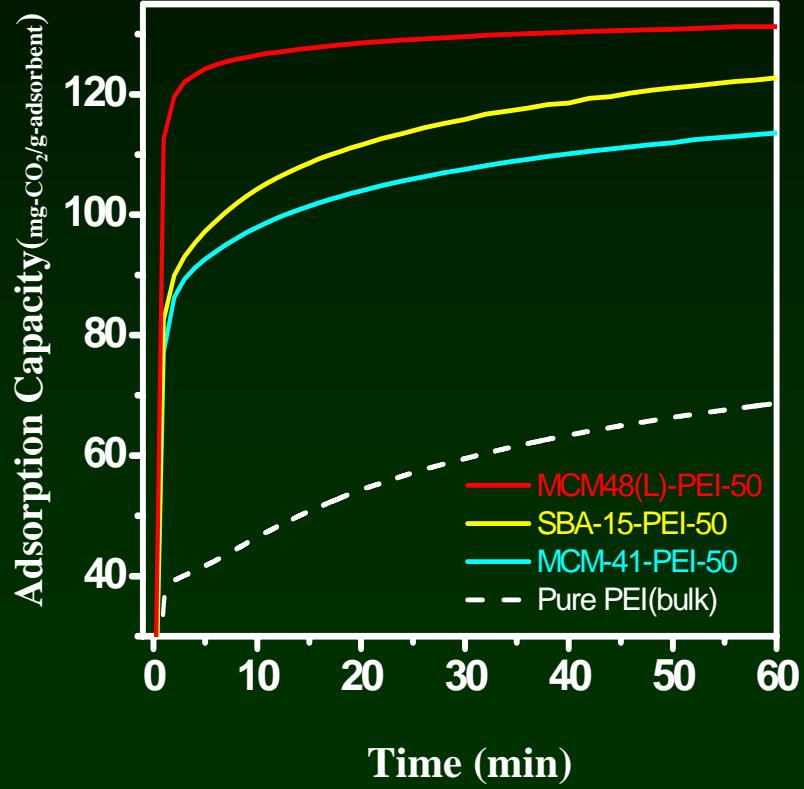
1. Pretreatment condition: Temperature : 100 °C, Time : 30 min
2. Adsorption/desorption: Temperature : 25 ~ 75 °C, Time : 150/150 min, Adsorption gas : CO₂ (5%, 100%)

Adsorption of Carbon dioxide

Adsorption capacity



Response time

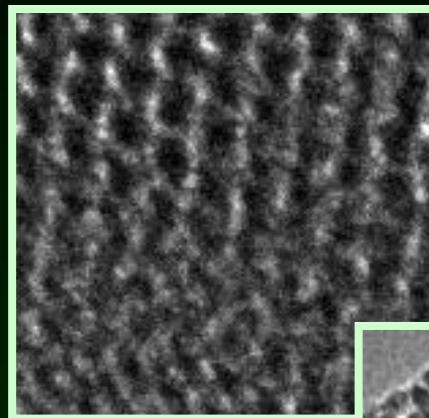
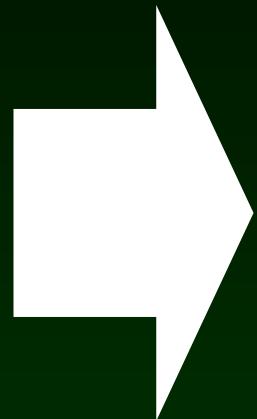


WTN (Wastes To Nano materials)

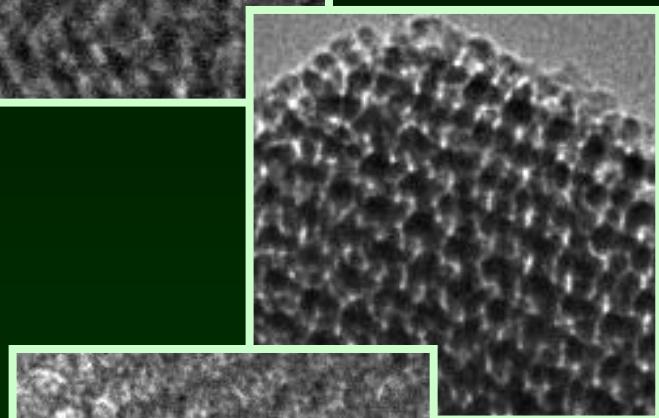
Power plant bottom ash



Grinding
Sieving
Alkali Dissolution



MCM-41

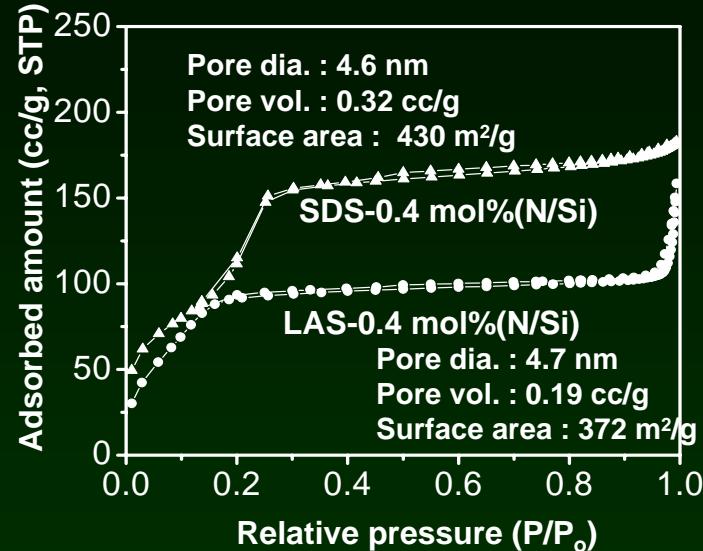
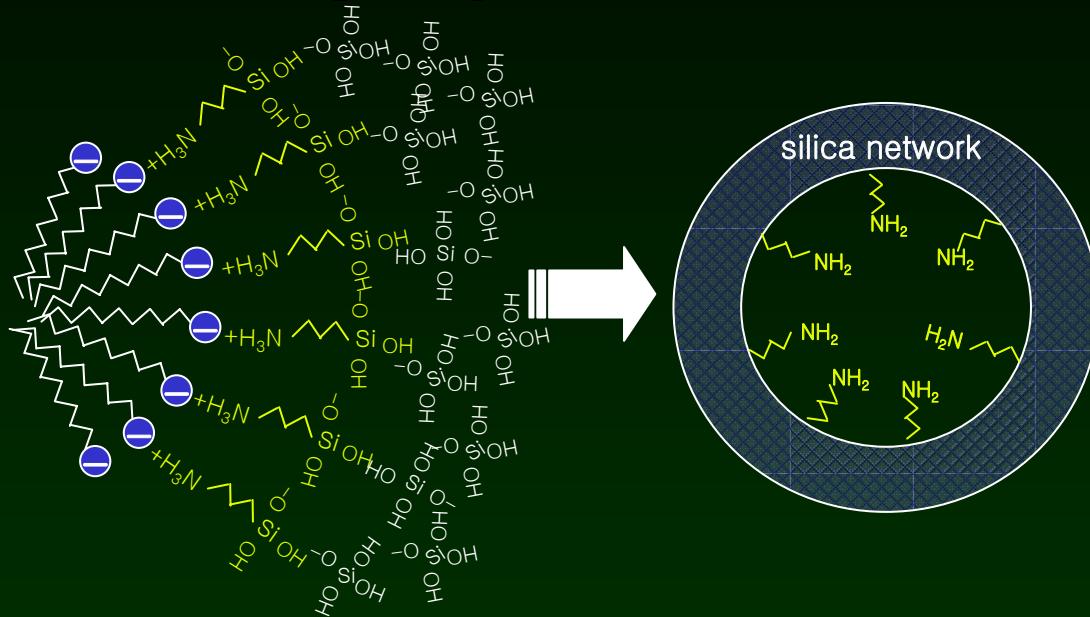


SBA-15

SBA-16

Anionic surfactant templated Mesoporous Silica

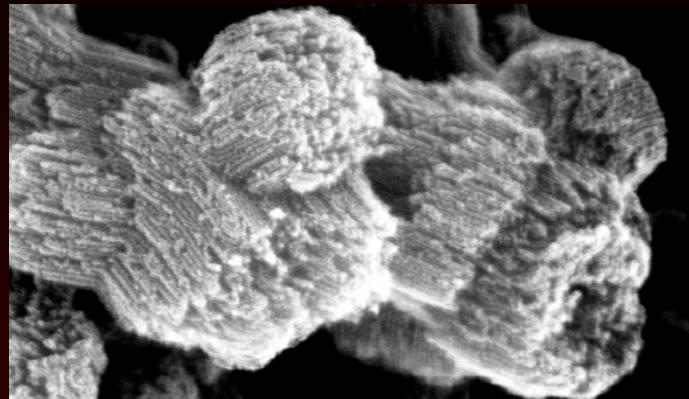
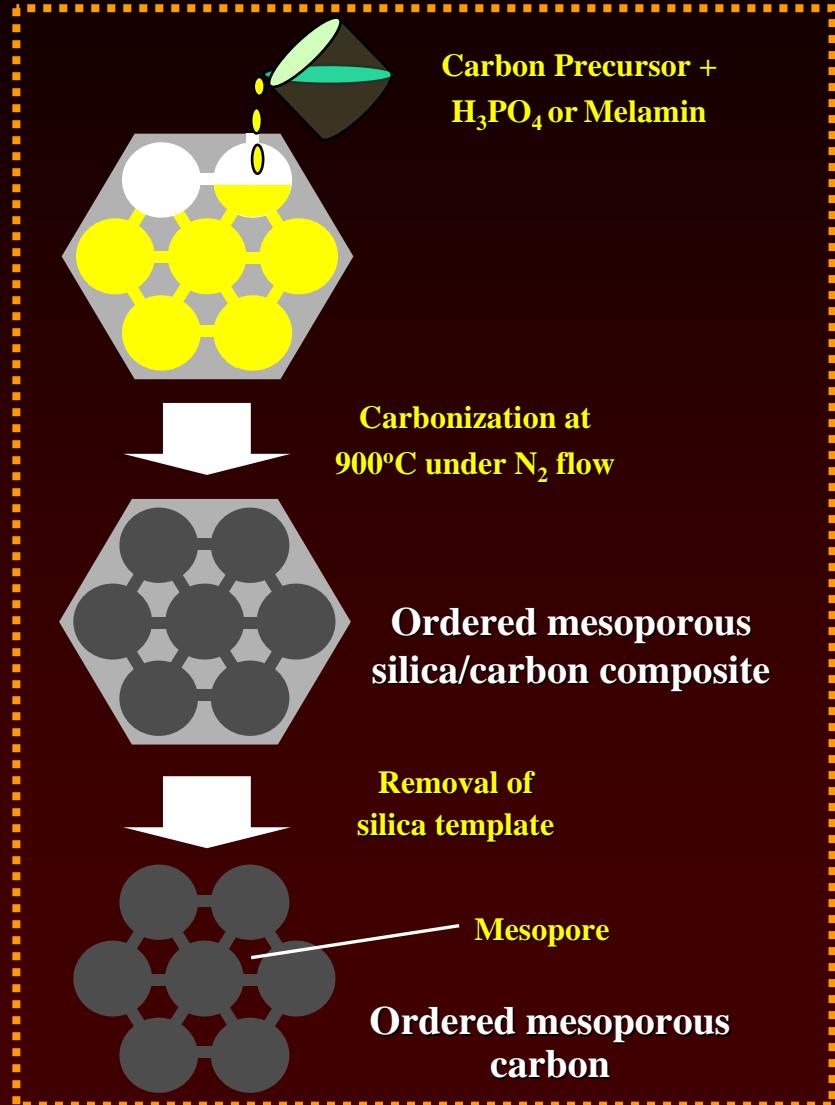
- Anionic templating routes



- CO_2 adsorption

	Amount grafted [mmol(N)/g]	Adsorption Amount [mg(CO_2)/g]	Adsorption Capacity [mmol(CO_2)/mmol(N)]
Lauric acid sodiumsalt-APS40%-TEOS60%	3.28	55	0.38
Sodium dodecyl sulfate-APS40%-TEOS60%	3.24	52	0.36

Meso-carbon

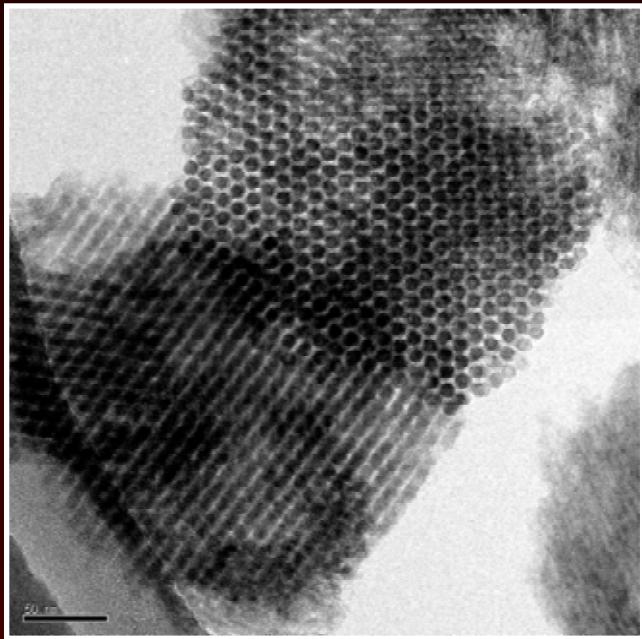


N incorporation CMK-3

	N=0%	N=5%	N=15%
BET Area (m^2/g)	801	915	706
Pore vol. (cc/g)	0.88	0.85	0.58

Meso-carbon

H₃PO₄ Treatment Meso-carbon



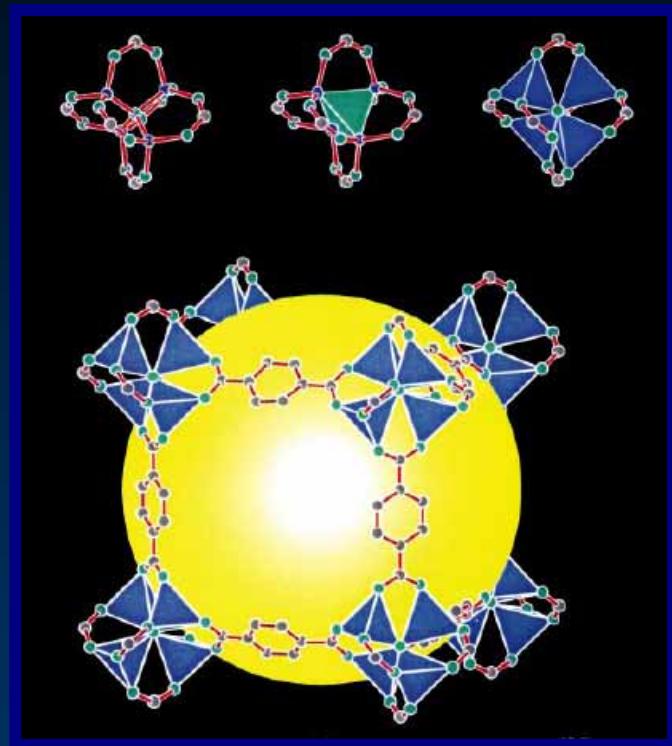
P=0% P=10% P=20% P=35%

BET Area (m ² /g)	1053	1260	1306	1370
Pore vol. (cc/g)	1.26	1.22	1.47	1.49

Samples	CO ₂ Partial Pressure (kPa)	Pret. Temp (°C)	Ad Temp (°C)	De Temp (°C)	Adsorbed CO ₂ (mg/g)
N0-CMK-3	101	100	25	25	52
N05-CMK-3	101	100	25	25	53
N15-CMK-3	101	100	25	25	73
P0-PC	101	100	25	25	64
	101	100	75	75	17
P10-PC	101	100	25	25	83
	101	100	75	75	-
P20-PC	101	100	25	25	88
	101	100	75	75	20
P35-PC	101	100	25	25	46
	101	100	75	75	10

MOF(Metal-Organic Framework)

MOF-5



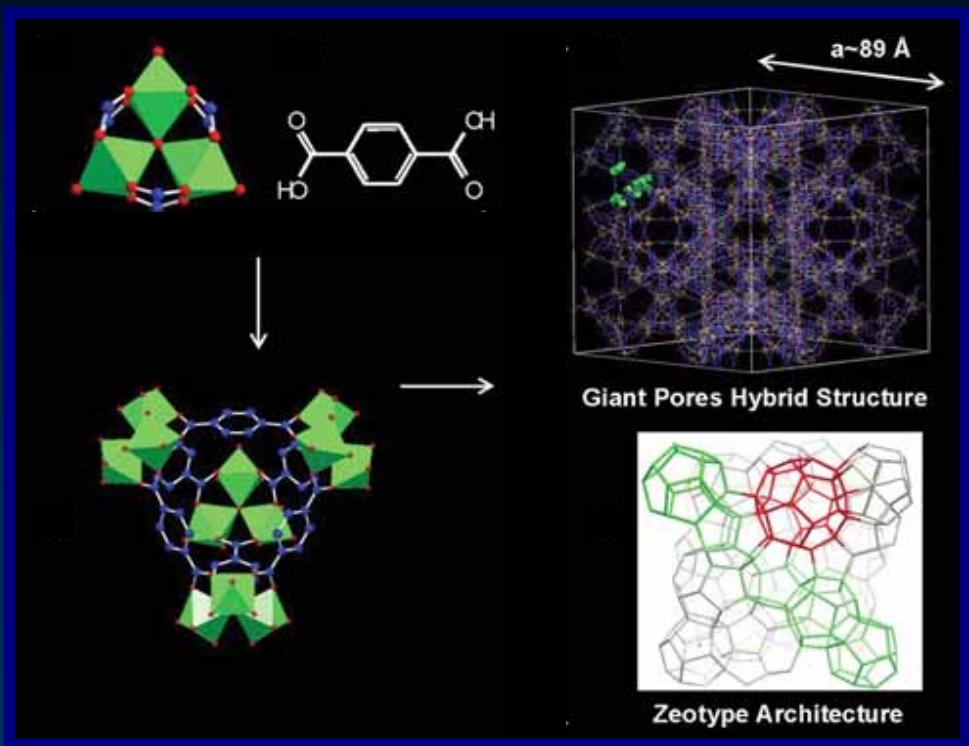
Langmuir surface area **2900 m²/g**

Pore volume **1.04 cc/g**

Pore size **12, 15 Å**

O. M. Yaghi et al., Nature, 402 (1999) 276

MIL-101



Langmuir surface area **5283 m²/g**

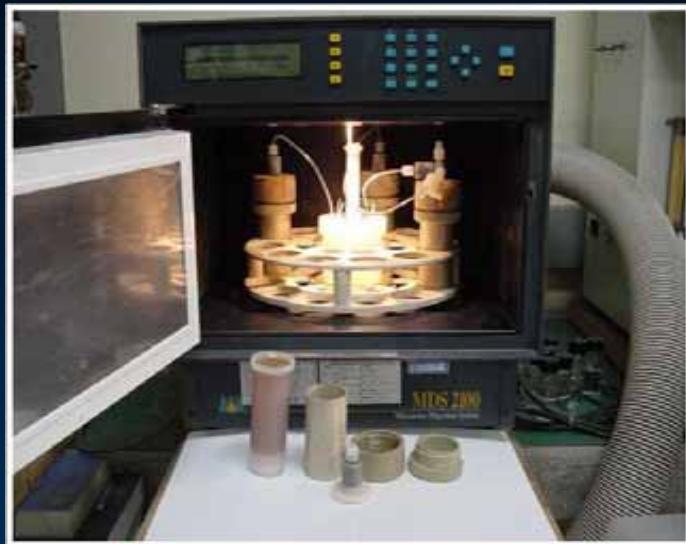
Pore volume **2.46 cc/g**

Pore size **28 Å**

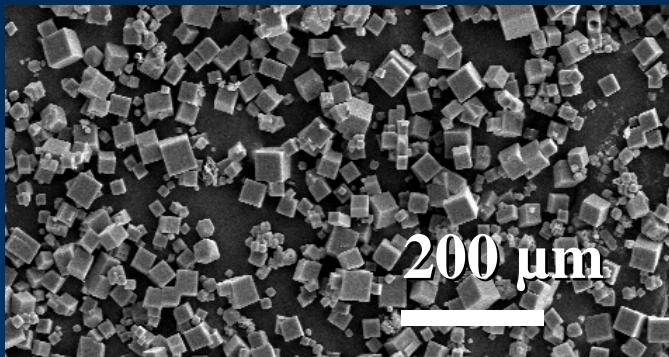
G. Ferey et al., Science, 309 (2005) 2040.

Synthesis method

Microwave synthesis



Within 30 min



Solvothermal synthesis

Organic Linker:

1,3-benzeneddicarboxylic acid

Metal Salt :

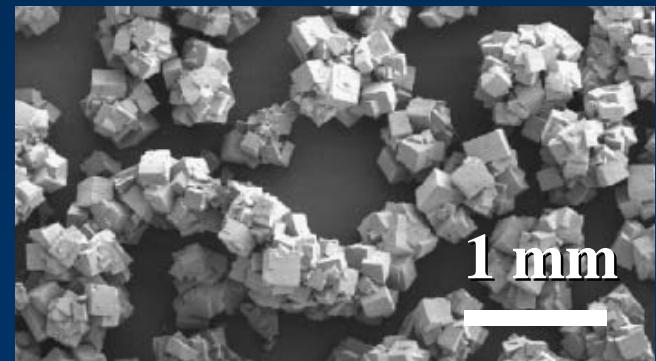
Zinc nitrate tetrahydrate

Solvents :

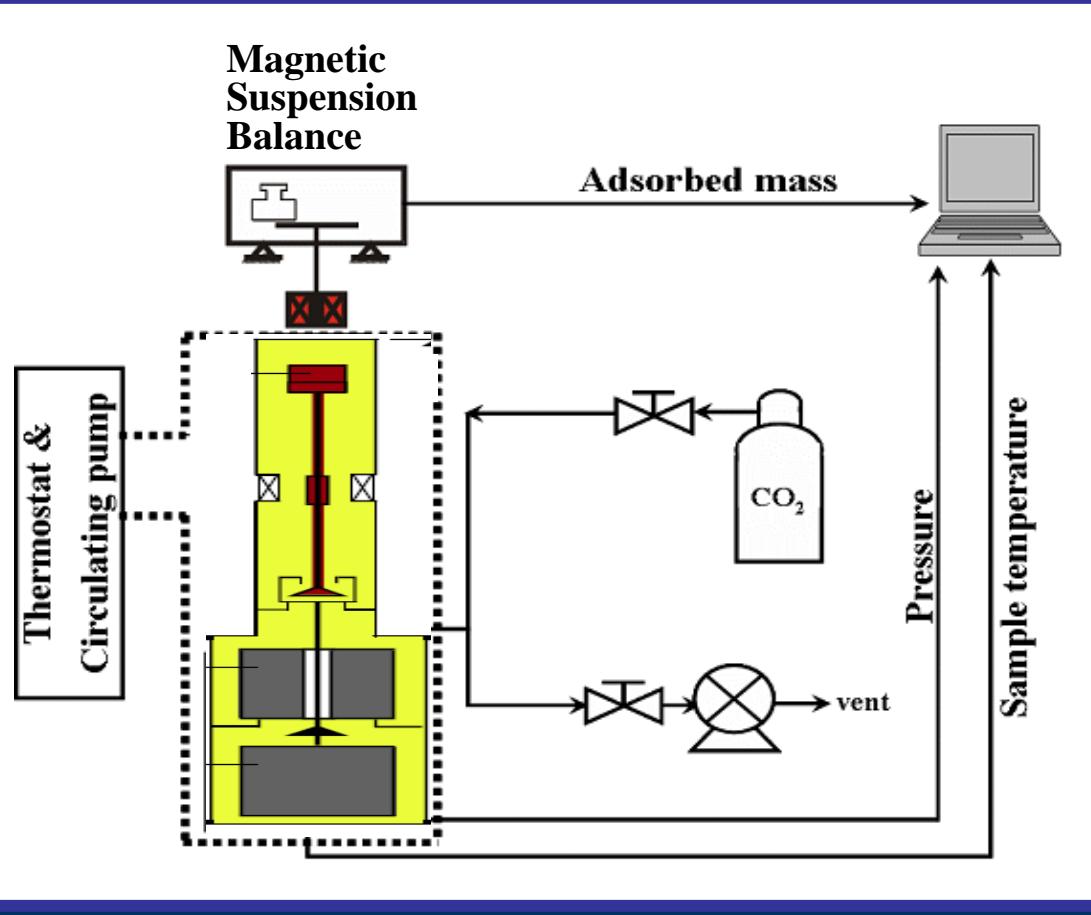
N-methyl-2-pyrrolidone(NMP)



1~2 days



High Pressure CO₂ Adsorption



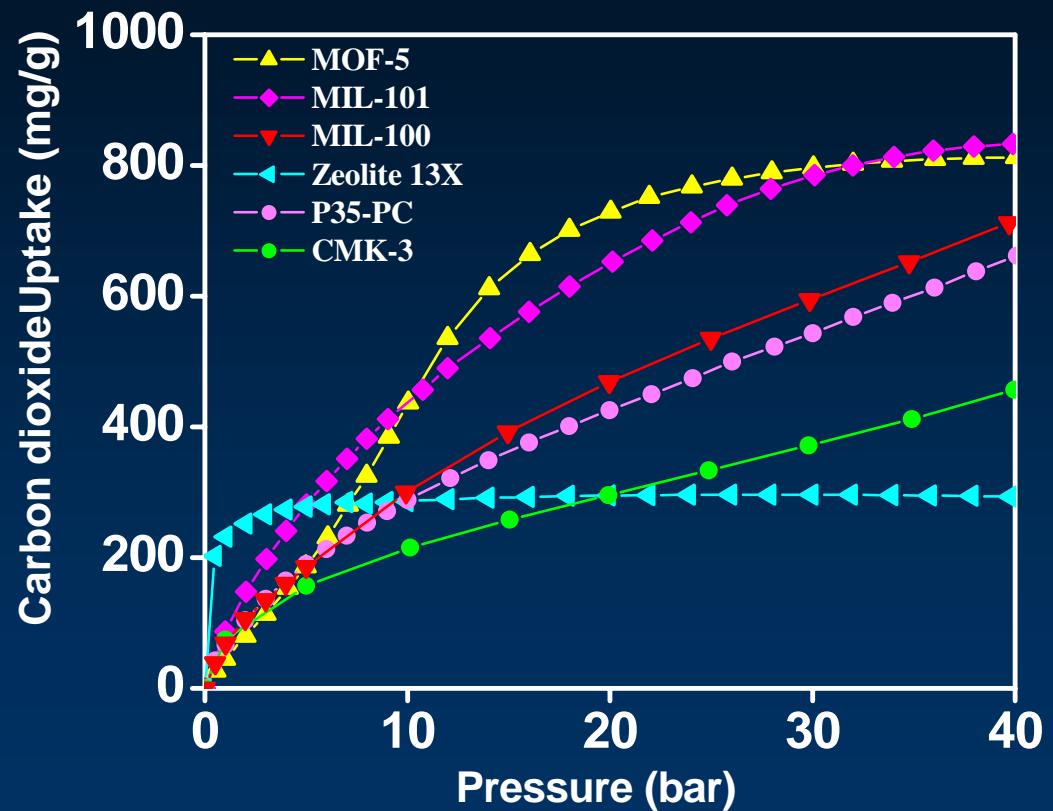
- Adsorption isotherm (1-40 bar, 25 °C) with in-situ measuring density

Rubotherm

Magnetic Suspension Balance

- Resolution : 10⁻⁵ g
- Max. Weight : 80 g

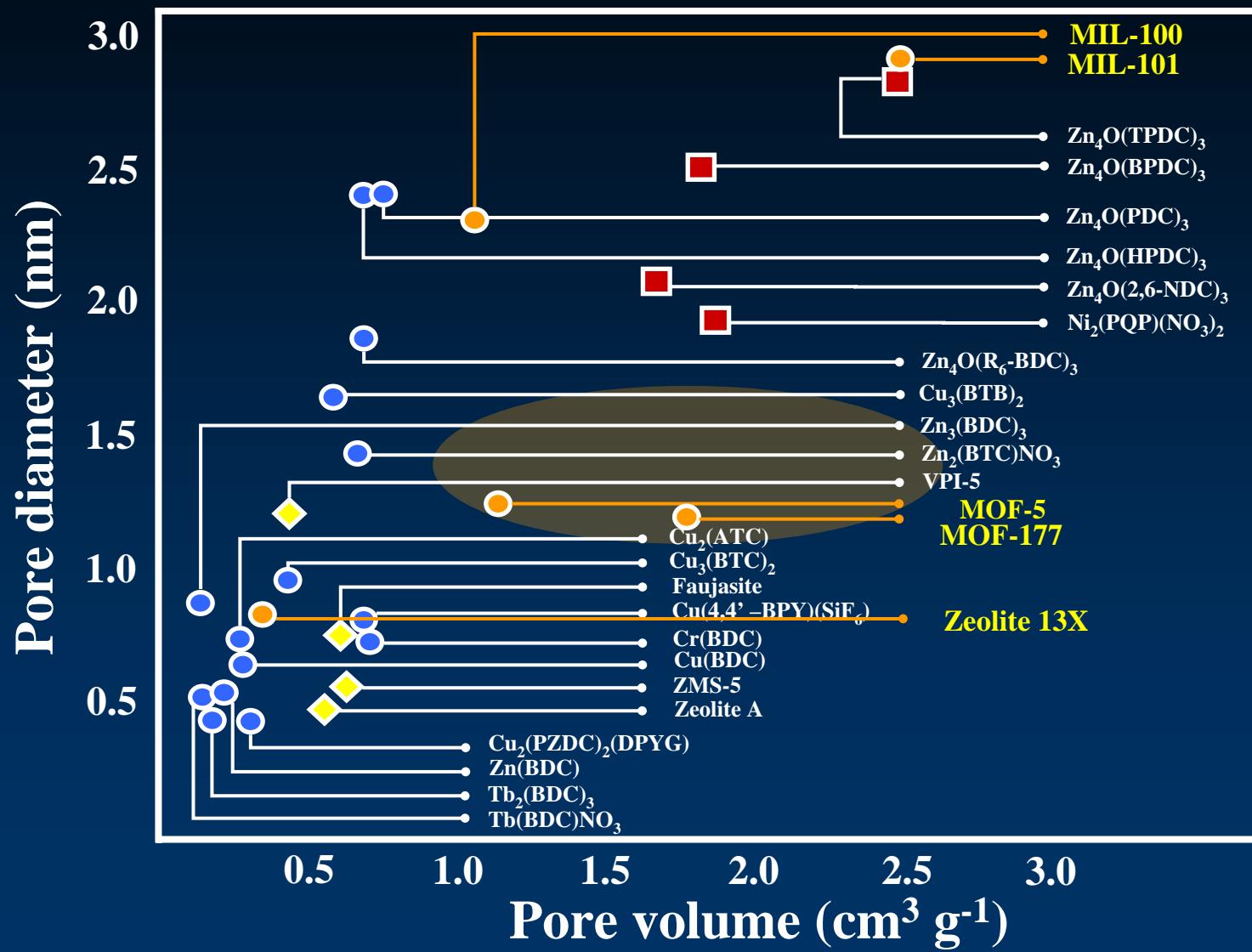
High Pressure CO₂ Adsorption



Samples	Langmuir Surface area (m ² /g)	Pore vol (cc/g)	Pore size (Å)
MW-MOF-5	3007 (2266)	1.14	11-15
MIL-101	5283 (3525)	2.46	28
MIL-100	3690 (1943)	1.16	24
Zeolite13X	- (470)	0.36	8
P35_PC	- (1370)	1.49	-
CMK-3	- (2227)	1.00	-

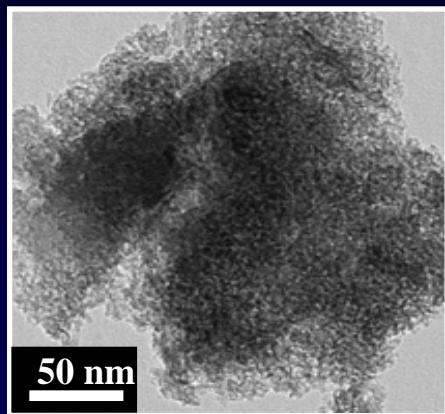
- CO₂ Storage capacity was measured based on gravimetric, Storage gas: 100% CO₂, Condition gas : 100% He

High Pressure CO₂ Adsorption



On going work

1. Alkali metal modified mesoporous alumina

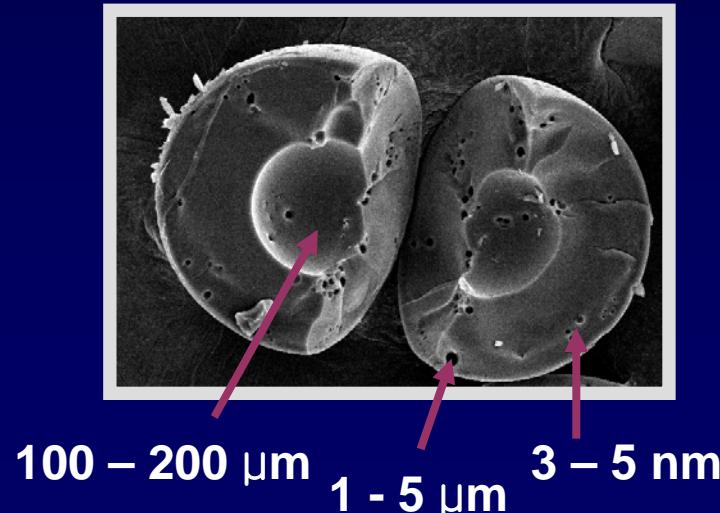
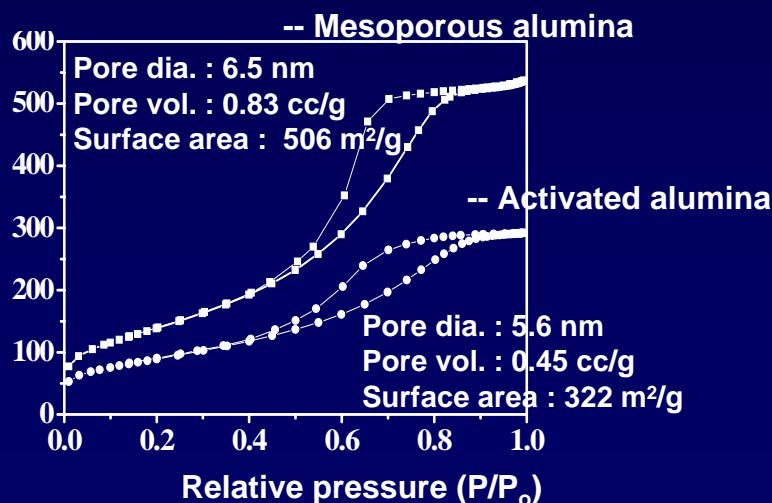
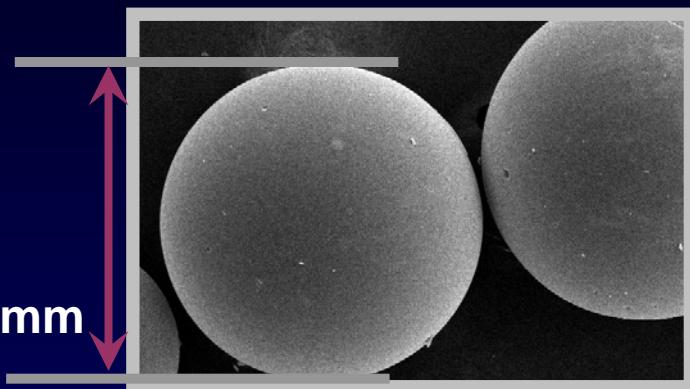


Alkali metal:

K_2CO_3 , CeNO_3 , $\text{Mg}(\text{NO}_3)_2$, NaNO_3

$200 \mu\text{m} - 2 \text{ mm}$

2. Triethanolamine impregnated mesoporous silica ball



On going work

3. N-functionalized materials prepared by sol-gel

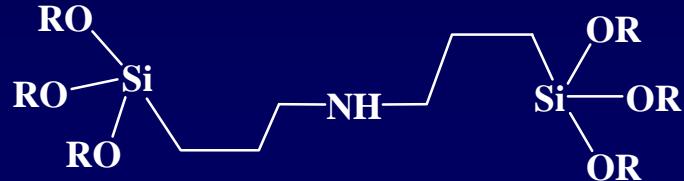
1.



2.



3.



Acknowledgments

- Carbon dioxide reduction & sequestration R&D center
Ph.D. Sang-Do Park
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Department of Chemistry
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