US007862647B2

(12) **United States Patent**
Hupp et al.

(10) **Patent No.: US 7,862,647 B2**
(45) **Date of Patent: Jan. 4, 2011**

(54) **GAS ADSORPTION AND GAS MIXTURE SEPARATIONS USING MIXED-LIGAND MOF MATERIAL**

(75) Inventors: **Joseph T. Hupp**, Northfield, IL (US); **Karen L. Mulfort**, Chicago, IL (US); **Randall Q. Snurr**, Evanston, IL (US); **Youn-Sang Bae**, Evanston, IL (US)

(73) Assignee: **Northwestern University**, Evanston, IL (US)

(*) Notice: Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 186 days.

(21) Appl. No.: **12/317,774**

(22) Filed: **Dec. 29, 2008**

(65) **Prior Publication Data**

US 2009/0178558 A1 Jul. 16, 2009

Related U.S. Application Data

(60) Provisional application No. 61/010,013, filed on Jan. 4, 2008.

(51) **Int. Cl.**
B01D 53/02 (2006.01)

(52) **U.S. Cl.** **95/139**; 95/96; 95/148; 95/900; 423/220; 423/230

(58) **Field of Classification Search** 95/96, 95/139, 148, 900; 423/220, 230
See application file for complete search history.

(56) **References Cited**

U.S. PATENT DOCUMENTS

5,648,508 A * 7/1997 Yaghi 556/9
6,491,740 B1 * 12/2002 Wang et al. 95/90
7,556,673 B2 * 7/2009 Schubert et al. 95/139
7,744,842 B2 * 6/2010 Farha et al. 423/282
2005/0124819 A1 * 6/2005 Yaghi et al. 556/148
2008/0121105 A1 * 5/2008 Schubert et al. 95/139
2009/0220400 A1 * 9/2009 Farha et al. 423/228
2010/0064888 A1 * 3/2010 Schubert et al. 95/139
2010/0170395 A1 * 7/2010 Farha et al. 95/139

OTHER PUBLICATIONS

Simone Cavenati, et al., Removal of Carbon Dioxide from Natural Gas by Vacuum Pressure Swing Adsorption, Energy & Fuels, 2006, 20,pp. 2648-2659.

Simone Cavenati, et al., Adsorption Equilibrium of Methane, Carbon Dioxide, and Nitrogen on Zeolite 13X at Hight Pressures, J. Chem. Eng. Data, 2004, 49, 1095-1101.

Min-Bae Kim, et al., Kinetic Separation of Landfill Gas by a Two-Bed Pressure Swing Adsorption Process Packed with Carbon Molecular Sieve: Nonisothermal Operation, Ind. Eng. Chem. Res., 2006, 45, pp. 5050-5058.

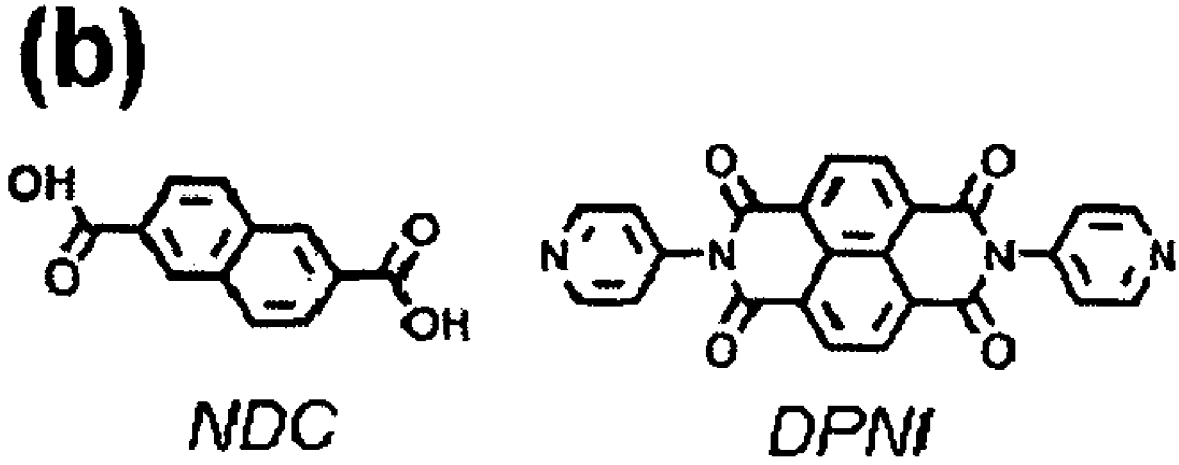
A. Kapoor and R.T. Yang, Kinetic Separation of Methane-Carbon Dioxide Mixture by Adsorption on Molecular Sieve Carbon, Chemical Engineering Science, 1989, 44, pp. 1723-1733.

Yi Li, et al., Novel Ag^+-Zeolite/Polymer Mixed Matrix Membranes with High CO_2/CH_4 Selectivity, AIChE Journal, 2007, 53, pp. 610-616.

(Continued)

Primary Examiner—Robert J Hill, Jr.
Assistant Examiner—Christopher P Jones

(57) **ABSTRACT**

A method of separating a mixture of carbon dioxiode and hydrocarbon gas using a mixed-ligand, metal-organic framework (MOF) material having metal ions coordinated to carboxylate ligands and pyridyl ligands.

12 Claims, 9 Drawing Sheets