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**Declarations under Rule 4.17:**

- as to applicant's entitlement to apply for and be granted a patent (Rule 4.17(ii))
- as to the applicant's entitlement to claim the priority of the earlier application (Rule 4.17(iii))
- of inventorship (Rule 4.17(iv))

**Published:**

- with international search report (Art. 21(3))

(88) Date of publication of the international search report:

24 October 2024 (24.10.2024)

(54) Title: SUBSTITUTED EPOXIDE MODIFIED SORBENTS, SYSTEMS INCLUDING SORBENTS, AND METHODS USING THE SORBENTS

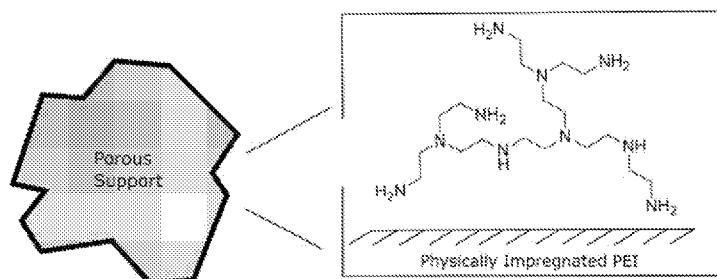


FIG. 1B

(57) Abstract: The present disclosure provides for substituted epoxide modified sorbents and contactors, methods of using sorbents and contactors to capture CO<sub>2</sub>, structures including the sorbent, and systems and devices using sorbents and contactors to capture CO<sub>2</sub>. The present disclosure provides for sorbents and contactors that can include a CO<sub>2</sub>-philic phase and a support. The CO<sub>2</sub>-philic phase can include a modified amine polymer that is the reaction product of an amine and a substituted epoxide.

## INTERNATIONAL SEARCH REPORT

International application No.

PCT/US2023/066670

## A. CLASSIFICATION OF SUBJECT MATTER

IPC(8) - INV. - B01J 20/26; B01D 53/04; B01J 20/34 (2023.01)  
ADD.

CPC - INV. - B01J 20/262; B01D 53/0407; B01J 20/3483 (2023.08)

ADD. - B01D 2253/202, 2257/504; B01J 2220/44 (2023.08)

According to International Patent Classification (IPC) or to both national classification and IPC

## B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

See Search History document

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

See Search History document

Electronic database consulted during the international search (name of database and, where practicable, search terms used)

See Search History document

## C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
Y	US 2016/0199810 A1 (UNIVERSITY OF SOUTHERN CALIFORNIA) 14 July 2016 (14.07.2016) entire document	1-16
Y	US 2012/0060686 A1 (KORTUNOV et al.) 15 March 2012 (15.03.2012) entire document	1-4, 7-14
Y	US 2019/0240613 A1 (SAUDI ARABIAN OIL COMPANY) 08 August 2019 (08.08.2019) entire document	1, 5, 6, 15, 16
A	CHOI et al., Epoxide-functionalization of polyethyleneimine for synthesis of stable carbon dioxide adsorbent in temperature swing adsorption, Nature Communications, Vol. 7, No. 12640, 30 August 2016 [retrieved on 09 August 2023]. Retrieved from the Internet: <URL: <a href="https://www.nature.com/articles/ncomms12640">https://www.nature.com/articles/ncomms12640</a> >. Pgs. 1-8	1-16
A	US 2019/0291077 A1 (GEORGIA TECH RESEARCH CORPORATION et al.) 26 September 2019 (26.09.2019) entire document	1-16

 Further documents are listed in the continuation of Box C. See patent family annex.

\* Special categories of cited documents:

"A" document defining the general state of the art which is not considered to be of particular relevance

"D" document cited by the applicant in the international application

"E" earlier application or patent but published on or after the international filing date

"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)

"O" document referring to an oral disclosure, use, exhibition or other means

"P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art

"&amp;" document member of the same patent family

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INTERNATIONAL SEARCH REPORT

International application No.

PCT/US2023/066670

Box No. II Observations where certain claims were found unsearchable (Continuation of item 2 of first sheet)

This international search report has not been established in respect of certain claims under Article 17(2)(a) for the following reasons:

- 1.  Claims Nos.:  
because they relate to subject matter not required to be searched by this Authority, namely:
  
- 2.  Claims Nos.:  
because they relate to parts of the international application that do not comply with the prescribed requirements to such an extent that no meaningful international search can be carried out, specifically:
  
- 3.  Claims Nos.: 17-28  
because they are dependent claims and are not drafted in accordance with the second and third sentences of Rule 6.4(a).

Box No. III Observations where unity of invention is lacking (Continuation of item 3 of first sheet)

This International Searching Authority found multiple inventions in this international application, as follows:

See extra sheet(s).

- 1.  As all required additional search fees were timely paid by the applicant, this international search report covers all searchable claims.
- 2.  As all searchable claims could be searched without effort justifying additional fees, this Authority did not invite payment of additional fees.
- 3.  As only some of the required additional search fees were timely paid by the applicant, this international search report covers only those claims for which fees were paid, specifically claims Nos.:
- 4.  No required additional search fees were timely paid by the applicant. Consequently, this international search report is restricted to the invention first mentioned in the claims; it is covered by claims Nos.:

1-16

Remark on Protest

- The additional search fees were accompanied by the applicant's protest and, where applicable, the payment of a protest fee.
- The additional search fees were accompanied by the applicant's protest but the applicable protest fee was not paid within the time limit specified in the invitation.
- No protest accompanied the payment of additional search fees.

Continued from Box No. III Observations where unity of invention is lacking

This application contains the following inventions or groups of inventions which are not so linked as to form a single general inventive concept under PCT Rule 13.1. In order for all inventions to be examined, the appropriate additional examination fees need to be paid.

Group I+: claims 1-16 are drawn to sorbents, and contactors thereof.

The first invention of Group I+ is restricted to a sorbent comprising: a CO<sub>2</sub>-philic phase and a support, wherein the CO<sub>2</sub>-philic phase includes the reaction product of a substituted epoxide and an amine, wherein the CO<sub>2</sub>-philic phase includes a structure selected from the first compound shown in claim 13 of the instant application PCT/US2023/066670, wherein R<sub>1</sub>, R<sub>2</sub>, R<sub>3</sub>, and R<sub>4</sub> are each independently hydrogen, and R' is hydrogen; and a contactor thereof. The first named invention has been selected based on the guidance set forth in section 10.54 of the PCT International Search and Preliminary Examination Guidelines. Specifically, the first named invention was selected based on the first listed structure presented in the claims (claim 13). It is believed that claims 1-16 read on this first named invention and thus these claims will be searched without fee to the extent that they read on the above embodiment.

Applicant is invited to elect additional formula(e) for each additional compound to be searched in a specific combination by paying an additional fee for each set of election. Each additional elected formula(e) requires the selection of a single definition for each compound variable. An exemplary election would be a sorbent comprising: a CO<sub>2</sub>-philic phase and a support, wherein the CO<sub>2</sub>-philic phase includes the reaction product of a substituted epoxide and an amine, wherein the CO<sub>2</sub>-philic phase includes a structure selected from the first compound shown in claim 13 of the instant application PCT/US2023/066670, wherein R<sub>1</sub>, R<sub>2</sub>, R<sub>3</sub>, and R<sub>4</sub> are each independently hydrogen, and R' is alkyl, wherein the alkyl is methyl unsubstituted; and a contactor thereof. Additional formula(e) will be searched upon the payment of additional fees. Applicants must specify the claims that read on any additional elected inventions. Applicants must further indicate, if applicable, the claims which read on the first named invention if different than what was indicated above for this group. Failure to clearly identify how any paid additional invention fees are to be applied to the "+" group(s) will result in only the first claimed invention to be searched/examined.

The inventions listed in Groups I+ do not relate to a single general inventive concept under PCT Rule 13.1, because under PCT Rule 13.2 they lack the same or corresponding special technical features for the following reasons:

The Groups I+ formulae do not share a significant structural element requiring the selection of alternatives for the structure and accordingly these groups lack unity a priori.

Additionally, even if Groups I+ were considered to share the technical features of a sorbent comprising: a CO<sub>2</sub>-philic phase and a support, wherein the CO<sub>2</sub>-philic phase includes the reaction product of a substituted epoxide and an amine; and a contactor, comprising a structure and a sorbent, these shared technical features do not represent a contribution over the prior art as disclosed by US 2016/0199810 A1 to University of Southern California.

US 2016/0199810 A1 to University of Southern California teaches a sorbent comprising: a CO<sub>2</sub>-philic phase and a support, wherein the CO<sub>2</sub>-philic phase includes the reaction product of a substituted epoxide and an amine (Para. [0025], sorbent for adsorbing carbon dioxide from a gas mixture, comprising a modified polyamine and a solid support. As disclosed herein, the modified polyamine is the reaction product of an amine and an epoxide; Para. [0049], 2,3-epoxybutane); and a contactor, comprising a structure and a sorbent (Para. [0025], solid sorbent for adsorbing carbon dioxide from a gas mixture, comprising a modified polyamine and a solid support).

The inventions listed in Groups I+ therefore lack unity under Rule 13 because they do not share a same or corresponding special technical feature.