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Declarations under Rule 4.17:

— as to the applicant's entitlement to claim the priority of the earlier application (Rule 4.17(iii))

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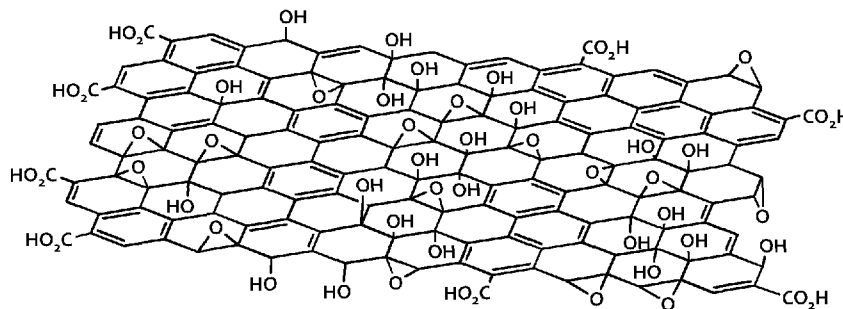
— with international search report (Art. 21(3))

— before the expiration of the time limit for amending the claims and to be republished in the event of receipt of amendments (Rule 48.2(h))

[Continued on next page]

(54) Title: HYDROCARBON TRANSFORMATIONS USING CARBOCATALYSTS

FIGURE 1



(57) Abstract: The disclosure relates to catalytically active carbocatalysts, e.g., a graphene oxide or graphite oxide catalyst suitable for use in a variety of high value chemical transformations.



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7 March 2013

A. CLASSIFICATION OF SUBJECT MATTER

C07C 5/333(2006.01)i, C07C 5/32(2006.01)i, C07C 11/08(2006.01)i, C07C 11/16(2006.01)i, B01J 21/18(2006.01)i, C01B 31/02(2006.01)i

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)

C07C 5/333

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

Korean utility models and applications for utility models

Japanese utility models and applications for utility models

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

eKOMPASS(KIPO internal) & Keywords: surface-modified, graphene oxide, graphite oxide, carbocatalyst, dehydrogenation, coupling, metathesis, cracking.

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	LIANG, CHENGDU et al., "Open-Cage Fullerene-like Graphitic Carbons as Catalysts for Oxidative Dehydrogenation of Isobutane", J. Am. Chem. Soc. 2009, Vol. 131, 7735-7741.	40-43
A	See Section 2.3 & 3.3; Figure 6.	1-34, 44-55
X	KUSHCH, S. D. et al., "Fullerene Black: Structure, Properties and Possible Applications", Russian Journal of General Chemistry, Feb. 2011, Vol. 81, 345-353.	40-43
A	See the Table in page 349.	1-34, 44-55
X	ALKHAZOV, T. G. et al., "Oxidative Dehydrogenation of Ethylbenzene over a Charcoal Catalyst", React. Kinet. Catal. Lett. 1979, Vol. 12, 189-193.	40-42
A	See the title, abstract and Figure 3.	1-34, 43-55
X	ZHANG, JIAN et al., "Surface-Modified Carbon Nanotubes Catalyze Oxidative Dehydrogenation of n-Butane", Science 2008, Vol. 322, 73-77.	40-43
A	See abstract & Figure 1.	1-34, 44-55

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

"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 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

"&" document member of the same patent family

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INTERNATIONAL SEARCH REPORT

International application No.

PCT/US2012/039143

C (Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT		
Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	ZHANG, AI MIN et al., "Synthesis and Catalytic Application of Ni-Supported Carbon Nanotubes for n-Heptane Cracking", Korean J. Chem. Eng. 2003, Vol. 20, 649-652.	40-43
A	See Table 3.	1-34,44-55
PA	CHAUHAN, SHIVE MURAT SINGH et al., "Use of Graphite Oxide and Graphene Oxide as Catalysts in the Synthesis of Dipyrromethane and Calix[4]pyrrole", Molecules 2011, Vol. 16, 7256-7266. (25 August 2011) See the whole document.	1-34,40-55
A	DREYER, DANIEL R. et al., "Graphene Oxide: A Convenient Carbocatalyst for Facilitating Oxidation and Hydration Reactions", Angewandte Chemie 2010, Vol. 122, 6965-6968. See the whole document.	1-34,40-55
A	ZHU, YANWU et al., "Graphene and Graphene Oxide: Synthesis, Properties, and Applications", Advanced Materials 2010, Vol. 22, 3906-3924. See the whole document.	1-34,40-55

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.: 37
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:

The above claim refers to a claim which is/are not drafted in accordance with the second and/or third sentence of Rule 6.4(a). Thus, no meaningful search could be carried out.

3. Claims Nos.: 35-36,38-39
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 the extra sheet.

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 an additional fee, this Authority did not invite payment of any additional fee.

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.:

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.

Box No. III

Invention group I (Claims 1-14, 22, 24-27, 30-34 & 40-55 to the extent that they relate to dehydrogenation):

A process for converting an alkane starting material (or a saturated hydrocarbon moiety on a hydrocarbon starting material) to an alkene product (or an unsaturated hydrocarbon moiety on a hydrocarbon product), comprising contacting the starting material with a catalytically active graphene oxide or graphite oxide (or carbocatalyst) to provide the corresponding product.

Invention group II (Claims 1-11, 15, 17-18, 33-34 & 40-55 to the extent that they relate to coupling):

A process for converting an alkane (or a hydrocarbon) starting material to one or more higher molecular weight alkane (or hydrocarbon) products, comprising contacting the starting material with a catalytically active graphene oxide or graphite oxide (or carbocatalyst) to provide the corresponding product.

Invention group III (Claims 1-11, 16, 28-29, 33-34 & 40-55 to the extent that they relate to metathesis):

A process for converting an alkane (or a hydrocarbon) starting material to one or more metathesis products, comprising contacting the starting material with a catalytically active graphene oxide or graphite oxide (or carbocatalyst) to provide the corresponding product.

Invention group IV (Claims 1-11, 19-24, 33-34 & 40-55 to the extent that they relate to cracking):

A process for converting a higher alkane (or hydrocarbon) starting material to one or more lower alkane (or hydrocarbon) products, comprising contacting the starting material with a catalytically active graphene oxide or graphite oxide (or carbocatalyst) to provide the corresponding product.

Invention group V (Claims 1-11 & 33-34 to the extent that they relate to cracking):

A process for converting a cycloalkane starting material to an alkane product or an alkene product or a combination thereof, comprising contacting the starting material with a catalytically active surface-modified graphene oxide or graphite oxide to provide the corresponding product.

The common technical feature linking invention groups I-V altogether is hydrocarbon reactions using catalytically active graphene oxide or graphite oxide (or carbocatalyst). However, the feature is already disclosed in several documents such as (1) DREYER, DANIEL R. et al., *Angewandte Chemie* 2010, Vol. 122, 6965-6968; (2) LIANG, CHENGDU et al., *J. Am. Chem. Soc.* 2009, Vol. 131, 7735-7741; (3) KUSHCH, S. D. et al., *Russian Journal of General Chemistry*, Feb. 2011, Vol. 81, 345-353; (4) ALKHAZOV, T. G. et al., *React. Kinet. Catal. Lett.* 1979, Vol. 12, 189-193; (5) ZHANG, JIAN et al., *Science* 2008, Vol. 322, 73-77; (6) ZHANG, AI MIN et al., *Korean J. Chem. Eng.* 2003, Vol. 20, 649-652. Thus, the invention groups I-V do not relate to a single general inventive concept under PCT Rule 13.1, because there is no common technical feature contributing over the prior art within the meaning of PCT Rule 13.2.

INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No.

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datePatent family
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date

None