

PATENT COOPERATION TREATY

From the
INTERNATIONAL SEARCHING AUTHORITY

PCT

To:

see form PCT/ISA/220

WRITTEN OPINION OF THE
INTERNATIONAL SEARCHING AUTHORITY
(PCT Rule 43*bis*.1)

Date of mailing
(day/month/year) see form PCT/ISA/210 (second sheet)

Applicant's or agent's file reference
see form PCT/ISA/220

FOR FURTHER ACTION
See paragraph 2 below

International application No.
PCT/B2018/051126

International filing date (day/month/year)
23.02.2018

Priority date (day/month/year)
28.02.2017

International Patent Classification (IPC) or both national classification and IPC
INV. B01J37/03 B01J23/42 B01J27/04 B01J35/00 C01B3/04 C25B1/00

Applicant
SABIC GLOBAL TECHNOLOGIES B.V.

1. This opinion contains indications relating to the following items:

- Box No. I Basis of the opinion
- Box No. II Priority
- Box No. III Non-establishment of opinion with regard to novelty, inventive step and industrial applicability
- Box No. IV Lack of unity of invention
- Box No. V Reasoned statement under Rule 43*bis*.1(a)(i) with regard to novelty, inventive step and industrial applicability; citations and explanations supporting such statement
- Box No. VI Certain documents cited
- Box No. VII Certain defects in the international application
- Box No. VIII Certain observations on the international application

2. **FURTHER ACTION**

If a demand for international preliminary examination is made, this opinion will usually be considered to be a written opinion of the International Preliminary Examining Authority ("IPEA") except that this does not apply where the applicant chooses an Authority other than this one to be the IPEA and the chosen IPEA has notified the International Bureau under Rule 66.1*bis*(b) that written opinions of this International Searching Authority will not be so considered.

If this opinion is, as provided above, considered to be a written opinion of the IPEA, the applicant is invited to submit to the IPEA a written reply together, where appropriate, with amendments, before the expiration of 3 months from the date of mailing of Form PCT/ISA/220 or before the expiration of 22 months from the priority date, whichever expires later.

For further options, see Form PCT/ISA/220.

Name and mailing address of the ISA:



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Date of completion of
this opinion

see form
PCT/ISA/210

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Box No. I Basis of the opinion

1. With regard to the **language**, this opinion has been established on the basis of:
 - the international application in the language in which it was filed.
 - a translation of the international application into , which is the language of a translation furnished for the purposes of international search (Rules 12.3(a) and 23.1 (b)).
2. This opinion has been established taking into account the **rectification of an obvious mistake** authorized by or notified to this Authority under Rule 91 (Rule 43bis.1(a))
3. With regard to any **nucleotide and/or amino acid sequence** disclosed in the international application, this opinion has been established on the basis of a sequence listing:
 - a. forming part of the international application as filed:
 - in the form of an Annex C/ST.25 text file.
 - on paper or in the form of an image file.
 - b. furnished together with the international application under PCT Rule 13ter.1(a) for the purposes of international search only in the form of an Annex C/ST.25 text file.
 - c. furnished subsequent to the international filing date for the purposes of international search only:
 - in the form of an Annex C/ST.25 text file (Rule 13ter.1(a)).
 - on paper or in the form of an image file (Rule 13ter.1(b) and Administrative Instructions, Section 713).
4. In addition, in the case that more than one version or copy of a sequence listing has been filed or furnished, the required statements that the information in the subsequent or additional copies is identical to that forming part of the application as filed or does not go beyond the application as filed, as appropriate, were furnished.
5. Additional comments:

Box No. V Reasoned statement under Rule 43bis.1(a)(i) with regard to novelty, inventive step or industrial applicability; citations and explanations supporting such statement

1. Statement

Novelty (N)	Yes: Claims	<u>5, 9-20</u>
	No: Claims	<u>1-4, 6-8</u>
Inventive step (IS)	Yes: Claims	
	No: Claims	<u>1-20</u>
Industrial applicability (IA)	Yes: Claims	<u>1-20</u>
	No: Claims	

2. Citations and explanations

see separate sheet

Box No. VIII Certain observations on the international application

The following observations on the clarity of the claims, description, and drawings or on the question whether the claims are fully supported by the description, are made:

see separate sheet

Re Item V

Reasoned statement with regard to novelty, inventive step or industrial applicability; citations and explanations supporting such statement

Reference is made to the following documents:

- D1 S. R. Lingampalli ET AL: "Highly efficient photocatalytic hydrogen generation by solution-processed ZnO/Pt/CdS, ZnO/Pt/Cd_{1-x}Zn_xS and ZnO/Pt/CdS_{1-x}Se_x hybrid nanostructures",
Energy & Environmental Science,
vol. 6, no. 12, 1 January 2013 (2013-01-01), page 3589, XP055464536,
Cambridge
ISSN: 1754-5692, DOI: 10.1039/c3ee42623h ; & S. R Lingampalli ET AL:
"Highly efficient photocatalytic hydrogen generation by solution-processed ZnO/Pt/CdS, ZnO/Pt/Cd_{1-x}Zn_xS and ZnO/Pt/CdS_{1-x}Se_x hybrid nanostructures",
Energy & Environmental Science,
1 January 2013 (2013-01-01), page 3589, XP055464533,
DOI: 10.1039/c3ee42623h
Retrieved from the Internet:
URL:<http://www.rsc.org/suppdata/ee/c3/c3ee42623h/c3ee42623h.pdf>
- D2 MOLINARI RAFFAELE ET AL: "Photocatalytic membrane reactors for hydrogen production from water",
INTERNATIONAL JOURNAL OF HYDROGEN ENERGY,
vol. 39, no. 14 , pages 7247-7261, XP028644524,
ISSN: 0360-3199, DOI: 10.1016/J.IJHYDENE.2014.02.174
- D3 ZHU J ET AL: "Nanostructured materials for photocatalytic hydrogen production",
CURRENT OPINION IN COLLOID AND INTERFACE SCIENCE,
LONDON, GB,
vol. 14, no. 4, 1 August 2009 (2009-08-01), pages 260-269,
XP026251191,
ISSN: 1359-0294, DOI: 10.1016/J.COCIS.2009.05.003
[retrieved on 2009-05-14]

Novelty

- 1 The present application does not meet the criteria of Article 33(1) PCT, because the subject-matter of claims 1-4 and 6-8 is not new in the sense of Article 33(2) PCT.
- 2 D1 discloses (abstract) a water splitting photoelectrochemical catalyst comprising metal positioned between a $\text{Cd}_{0.8}\text{Zn}_{0.2}\text{S}$ semiconductor and a ZnO semiconductor to form a Z-scheme catalyst having the structure ZnO/Pt/ $\text{Cd}_{0.8}\text{Zn}_{0.2}\text{S}$.
- It is noted that the process of preparation of the catalyst of D1 (see the supporting information) is identical to the process of preparation of the ZnO/Pt/ $\text{Cd}_{0.8}\text{Zn}_{0.2}\text{S}$ catalyst used in the present application, which means that the catalyst of D1 inherently has all the features of the catalysts claimed in the present invention even without explicitly disclosing them.
- 3 Thus, D1 is novelty destroying for the subject-matter of claims 1-4 and 6-8.

4 Inventive step

- 5 The present application does not meet the criteria of Article 33(1) PCT, because the subject-matter of claims 5 and 9-20 does not involve an inventive step in the sense of Article 33(3) PCT.
- 6 Claim 10
- 7 Any of the photocatalytic reactors (in particular of figures 8 and 9), which are shown to be the state of the art in D2, could be regarded as reactors prior art closest to the subject-matter of claim 10. These reactors have an inlet for feeding water or aqueous solution to a reactor chamber, the reaction chamber comprising:
- (i) a photo electrochemical (PEC) assembly comprising a PEC photocatalyst;
 - (ii) a H₂ gas product outlet; and
 - (iii) O₂ gas product outlet.
- 8 The subject-matter of claim 10 therefore differs from the reactors of D2 in that the PEC catalyst is the specific catalyst as defined in claims 1 to 8 in the present application.

- 9 However, no unexpected technical effect resulting from the use of the known catalysts of claims 1 to 8 in the known reactors of D2 was shown by the applicants.
- 10 The problem to be solved by the present invention may therefore be regarded as a provision of an alternative photocatalytic reactor.
- 11 However, it is obvious to the skilled person to use a known photocatalyst in a known, rather conventional photocatalytic reactor.
- 12 The subject-matter of claim 10 therefore can not involve an inventive step.
- 13 Claim 19
- 14 D2 is considered to be the prior art closest to the subject-matter of claim 19 and discloses (figures 8 and 9) a method of producing hydrogen comprising irradiating a photo electrochemical (PEC) thin film comprising photocatalyst with light in the presence of water.
- 15 The subject-matter of claim 19 therefore differs from the method of D2 in that the PEC catalyst is the specific catalyst as defined in claims 1 to 9 in the present application.
- 16 However, no unexpected technical effect resulting from the use of the known catalysts of claims 1 to 9 in the known method of D2 was shown by the applicants.
- 17 The problem to be solved by the present invention may therefore be regarded as a provision of an alternative method of producing hydrogen.
- 18 However, it is obvious to the skilled person to use a known photocatalyst in a known, rather conventional method.
- 19 Dependent claims 5,9,11-18 and 20 do not appear to contain any additional features which, in combination with the features of any claim to which they refer, meet the requirements of the PCT in respect of inventive step, the reasons being as follows:
- 20 Claim 5: core-shell nanoparticles are known to the skilled person. The experimental data on file show only results for Pt containing catalyst, so there is no support for any technical effect resulting from the use of core-shell nanoparticles.

- 21 Claim 9: the experimental data on file show only performance of ZnO/Pt/ $\text{Cd}_{0,8}\text{Zn}_{0,2}\text{S}$ catalyst system. There is no support for any technical effect resulting from the use of catalysts having the composition as specified in claim 9.
- 22 Claims 11-18: That semiconductor is deposited on a conductive support appears to be a known design of photo electrochemical assemblies in the art (see figure 11 of D2 or figure 3 of D3). The therein used conductive support can be a metal substrate such as Al, Fe, Pd, Pt, Ti and Zr (see D3, page 263, right hand column), or Cu as is the case in D2 (figure 11).
"Hydrogen catalyst" (Pt) is present in the systems of both, D2 and D3.
Further features, such as the use of two metals in the ratio specified in claim 13 or the presence of hole transporting film or co-catalysts, appear to be known options to the skilled person and it appears that no particular technical effect is attributed to them in the present invention.
- 23 Claim 20: the catalyst of D1 contains Pt nanoparticles, so the claim lacks an inventive step for the same reasons like claim 19 (see above).

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Re Item VIII

Certain observations on the international application

- 24 The term "nanostructures" used in the claims is vague and unclear and leaves the reader in doubt as to the meaning of the technical feature to which it refers, thereby rendering the definition of the subject-matter of the claims concerned unclear, Article 6 PCT.
- 25 The term "hydrogen catalyst" used in claim 12 is also unclear.