(54) Title: METASTABLE CERAMIC FUEL CELL AND METHOD

(57) Abstract: A solid oxide fuel cell has anode, cathode and electrolyte layers each formed essentially of a multi-oxide ceramic material and having a far-from-equilibrium, metastable structure from the group consisting of nanocrystalline, nanocomposite and amorphous. The electrolyte layer has a matrix of the ceramic material, and is impervious and serves as a fast oxygen ion conductor. The electrolyte layer has a matrix of the ceramic material and a dopant dispersed therein in an amount substantially greater than its equilibrium solubility in the ceramic matrix. The anode layer includes a continuous surface area metallic phase in which electron conduction is provided by metallic phase and the multi-oxide ceramic matrix provides ionic conduction.
INTERNATIONAL SEARCH REPORT

A. CLASSIFICATION OF SUBJECT MATTER

IPC: H01M 8/12(2006.01), 4/86(2006.01); B05D 5/12(2006.01)

USPC: 429/32,33,45; 427/115

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)

U.S.: 429/32,33,45; 427/115

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

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

C. DOCUMENTS CONSIDERED TO BE RELEVANT

<table>
<thead>
<tr>
<th>Category</th>
<th>Citation of document, with indication, where appropriate, of the relevant passages</th>
<th>Relevant to claim No.</th>
</tr>
</thead>
<tbody>
<tr>
<td>X</td>
<td>WO 00/24676 (Virkar et al.) 4 May 2000 (04.05.2000), page 2, line 9, page 4, line 16 and page 8, lines 9-16</td>
<td>1</td>
</tr>
<tr>
<td>Y</td>
<td>US 5,543,239 (Virkar et al.) 6 August 1996 (06.08.1996), column 4, lines 57 and 65, column 5, line 7 and line 40, column 6, line 38, column 7, lines 25-28 and example 3</td>
<td>2, 3, 5-11, 13-17 19-25</td>
</tr>
<tr>
<td>Y</td>
<td>U.S. 5,431,967 (Manthiram et al.) 11 July 1995 (11.07.1995), whole document</td>
<td>1, 4, 12, 18, 22 and 25</td>
</tr>
<tr>
<td>Y</td>
<td>U.S. 2003/0124050 (Yadav et al.) 3 July 2003 (03.07.2003), paragraphs [0008], [0041] and [0046]-[0049]</td>
<td>18-25</td>
</tr>
</tbody>
</table>

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

Date of the actual completion of the international search
13 September 2007 (13.09.2007)

Date of mailing of the international search report
01 OCT 2007

Name and mailing address of the ISA/US
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Authorized officer
Robert Hodge
DEBORAH A. THOMAS
PARALEGAL SPECIALIST

form PCT/ISA/210 (second sheet) (April 2005)
INTERNATIONAL SEARCH REPORT

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.:
   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:
Please See Continuation 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 additional fees, this Authority did not invite payment of any 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.:

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.

Form PCT/ISA/210 (continuation of first sheet(2)) (April 2005)
BOX 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 must be paid.

Group I, claim(s) 1-17, drawn to a solid oxide fuel cell.

Group II, claim(s) 18-25, drawn to a method of making a solid oxide fuel cell.

This application contains claims directed to more than one species of the generic invention. These species are deemed to lack unity of invention because they are not so linked as to form a single general inventive concept under PCT Rule 13.1.

In order for more than one species to be examined, the appropriate additional examination fees must be paid. The species are as follows:

Species 1, nanocrystalline
Species 2, nanocomposite
Species 3, amorphous

The following claim(s) are generic: claim 1.

The inventions listed as Groups I and II 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 special technical feature related to the two disclosed inventions is a metastable structure, listed as either, nanocrystalline, nanocomposite and amorphous, all of the structures have been found in the prior art related to solid oxide fuel cells and therefore they lack unity. Related patents that discuss the above structures are U.S Patent Nos. 4,830,780, 5,431,967 and 5,905,000.

The species listed above do not relate to a single general inventive concept under PCT Rule 13.1 because, under PCT Rule 13.2, the species lack the same or corresponding special technical features for the following reasons: the special technical feature related to the three disclosed species is that they are all metastable structures, all of the structures have been found in the prior art related to solid oxide fuel cells and therefore they lack unity. Related patents that discuss the above structures of the listed species are U.S Patent Nos. 4,830,780, 5,431,967 and 5,905,000.