Molybdenum disulfide powders include substantially spherically-shaped particles of molybdenum disulfide that are formed from agglomerations of generally flake-like sub-particles. The molybdenum disulfide powders are flowable and exhibit uniform densities. Methods for producing a molybdenum disulfide powder may include the steps of: providing a supply of molybdenum disulfide precursor material; providing a supply of a liquid; providing a supply of a binder; combining the molybdenum disulfide precursor material with the liquid and the binder to form a slurry; feeding the slurry into a stream of hot gas; and recovering the molybdenum disulfide powder, the molybdenum disulfide powder including substantially spherically-shaped particles of molybdenum disulfide formed from agglomerations of generally flake-like sub-particles.
Published: 2012/1 48984 A 3

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

Date of publication of the international search report: 23 January 2014
INTERNATIONAL SEARCH REPORT

International application No.
PCT/US 12/34942

A. CLASSIFICATION OF SUBJECT MATTER
IPC(8) - C01G 39/00, 39/06 (201 2.01)
USPC - 508/1 67

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)
IPC(8)- C01G 39/00, 39/06 (2012.01);
USPC- 508/167

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched
Patents aPd NPL (classification, keyword; search terms below)

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)
PubWest (US Pat, PgPub, EPO, JPO), GoogleScholar (PL, NPL), FreePatentsOnline (US Pat, PgPub, EPO, JPO, WIPO, NPL);
search terms: molydbenum, disulfide, MoS2, powder, particle, nanoparticle, D50, D99, Hall, flowability, Fisher, number, surface, coating, polyvinyl alcohol, agglomerate, flake, spherical, solid, hollow

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>US 2011/00255203 A1 (MOSLEH et al.) 07 October 2003 (07.10.2003), para [0017], [0018], [0023]-[0029], [0033]</td>
<td>1, 2, 15, 16</td>
</tr>
<tr>
<td></td>
<td></td>
<td>3-14, 16</td>
</tr>
<tr>
<td>Y</td>
<td>US 2009/0098010 A1 (JOHNSON et al.) 16 April 2009 (16.04.2009), para [0003], [0007], [0043], [0058], [0063], [0120], [0122], [0142]</td>
<td>3-9, 16</td>
</tr>
<tr>
<td>Y</td>
<td>US 2010/01 19188 A1 (HSUEH et al.) 13 May 2010 (13.05.2010), para [0070], [0100], [0104]</td>
<td>10, 11</td>
</tr>
<tr>
<td>Y</td>
<td>WO 2010/057667 A1 (SKORB et al.) 27 May 2010 (27.05.2010), pg 5, para 1; pg 5, para 4; pg 8, para 3</td>
<td>13, 14</td>
</tr>
<tr>
<td>Y</td>
<td>US 6,355,207 B1 (KEYES) 12 March 2002 (12.03.2002), col 2-7</td>
<td>1-16</td>
</tr>
</tbody>
</table>

Further documents are listed in the continuation of Box C.

* 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 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
"G" document member of the same patent family

Date of the actual completion of the international search
20 August 2012 (20.08.2012)

Date of mailing of the international search report
01 OCT 2012

Name and mailing address of the ISA/US
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Authorized officer:
Lee W. Young
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PCT OSP: 571-272-7774

Form PCT/ISA/210 (second sheet) (July 2009)
## 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:

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, claims 1-16: A molybdenum disulfide powder comprising substantially spherically-shaped particles of molybdenum disulfide formed from agglomerations of generally flake-like sub-particles.

- Group II, claims 17-21: A molybdenum disulfide powder comprising a plurality of generally spherically-shaped particles that are themselves formed from smaller flake-like particles that are adhered together.

- Please see 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 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:

Continued from Box No. I (i):

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, claims 1-16: a molybdenum disulfide powder comprising substantially spherically-shaped particles of molybdenum disulfide formed from agglomerations of generally flake-like sub-particles.

Group II, claims 17-21: a molybdenum disulfide powder comprising a plurality of generally spherically-shaped particles that are themselves formed from smaller flake-like particles that are adhered together.

Group III, claims 22-30: a method for producing a molybdenum disulfide powder, comprising: providing a supply of molybdenum disulfide precursor material; providing a supply of a liquid; providing a supply of a binder; combining said molybdenum disulfide precursor material with the liquid and the binder to form a slurry; feeding said slurry into a stream of hot gas; and recovering the molybdenum disulfide powder, said molybdenum disulfide powder comprising substantially spherically-shaped particles of molybdenum disulfide formed from agglomerations of generally flake-like sub-particles.

Group IV, claims 31-38: a coated article, surface coating, and method of producing a surface coating, comprising: an article; a surface coating on at least a portion of said article formed by depositing individual particles of a molybdenum disulfide spherical powder on said article so that individual particles of said molybdenum disulfide spherical powder bonds with said article, said molybdenum disulfide spherical powder comprising substantially spherically-shaped particles of molybdenum disulfide formed from agglomerations of generally flake-like subparticles.

Groups I, III, and IV do not share smaller flake-like particles that are adhered together.

Group II does not share agglomerations of generally flake-like subparticles.

Groups I, II, and IV do not share a method for producing a molybdenum disulfide powder, comprising providing a supply of a binder.

Groups I, II, and III do not share a coated article or surface coating, comprising a surface coating on at least a portion of said article formed by depositing individual particles of a molybdenum disulfide spherical powder on said article.

The inventions listed as Groups I, II, III, IV, and V do not relate to a single inventive concept under PCT Rule 13.2 because, under PCT Rule 13.2, they lack the same or corresponding special technical features for the following reasons:

The inventions of Groups I-V share the special technical feature of particles of molybdenum disulfide. However, this special technical feature does not represent a contribution over the prior art of US 2010/0255203 A1 to Mosleh, et al. (hereinafter 'Mosleh'), 07 October 2010 (07.10.2010). Mosley discloses a molybdenum disulfide powder comprising substantially spherically-shaped particles of molybdenum disulfide formed from agglomerations of generally flake-like sub-particles (para [0017], [0029], and [0033]); wherein said particles adhered together (para [0025]); and wherein said particles forming a coating on an article (para [0027]).

Groups I-IV therefore lack unity under PCT Rule 13 because they do not share a same or corresponding special technical feature.