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Published:

— *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))*

(88) Date of publication of the international search report:
26 May 2016

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(54) Title: PROTECTIVE COATINGS FOR ELECTRONIC DEVICES AND ATOMIC LAYER DEPOSITION PROCESSES FOR FORMING THE PROTECTIVE COATINGS

(57) Abstract: A protective coating for an electronic device, such as a coating that is substantially impermeable to moisture and oxygen, comprises an ultra-thin film comprising a plurality of sub-layers formed by atomic layer deposition (ALD) processes. Low temperature ALD processes may be used to form the sub-layers of the protective coating. The density of the protective film may be enhanced with energy, to which the protective coating or sub-layers thereof may be exposed during deposition or intermittently during the deposition process. ALD apparatuses that are equipped to perform the disclosed processes are also disclosed, as are electronic devices that include the disclosed protective coatings.

INTERNATIONAL SEARCH REPORT

International application No.
PCT/US2015/035892

A. CLASSIFICATION OF SUBJECT MATTER
IPC(8) - H01L 21/31 (2015.01)
CPC - H01L 21/02238 (2015.04)
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) - C23C 16/48; H01L 21/31, 21/469 (2015.01)
USPC - 427/584, 585, 593; 438/759, 763, 771, 906

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched
CPC - C23C 16/18; H01L 21/02238, 21/31662 (2015.04) (keyword delimited)

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)
Orbit, Google Patents, ProQuest.
Search terms used: atomic layer deposition, reaction chamber, substrate, low temperature, UV, TMA, contaminants, aluminum oxide, ultrasonic energy

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	US 2005/0175789 A1 (HELMS, JR. et al) 11 August 2005 (11.08.2005) entire document	1, 3-5, 7-8, 12-13, 15-16, 28-30
X	US 2001/0031379 A1 (TERA et al) 18 October 2001 (18.10.2001) entire document	1-5, 7-8, 11, 15, 18-20, 22-27
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Y		6, 9-10, 14, 17, 21
Y	US 2012/0201860 A1 (WEIMER et al) 09 August 2012 (09.08.2012) entire document	6, 21
Y	US 2011/0159204 A1 (DICKEY et al) 30 June 2011 (30.06.2011) entire document	9
Y	US 2004/0087141 A1 (RAMANATHAN et al) 06 May 2004 (06.05.2004) entire document	10, 14
Y	US 6,395,650 B1 (CALLEGARI et al) 28 May 2002 (28.05.2002) entire document	17
A	US 2007/0281105 A1 (MOKHLESI et al) 06 December 2007 (06.12.2007) entire document	1-30
A	US 2010/0178481 A1 (GEORGE et al) 15 July 2010 (15.07.2010) entire document	1-30

☐ 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 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
"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
30 September 2015	29 MAR 2016
Name and mailing address of the ISA/ Mail Stop PCT, Attn: ISA/US, Commissioner for Patents P.O. Box 1450, Alexandria, Virginia 22313-1450 Facsimile No. 571-273-8300	Authorized officer Blaine Copenheaver PCT Helpdesk: 571-272-4300 PCT OSP: 571-272-7774

INTERNATIONAL SEARCH REPORT

International application No.
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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:

See last page

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.:

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.

INTERNATIONAL SEARCH REPORT

International application No.
PCT/US2015/035892

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 1-17,28-30, drawn to an atomic layer deposition process and apparatus.
Group II, claims 18-27, drawn to an electronic device.

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 of the Group I invention: introducing reactants into the reaction chamber at a temperature of 150 oC or less to enable a product to be formed as a film on the substrate as claimed therein is not present in the invention of Group II. The special technical feature of the Group II invention: an electronic device assembly including a plurality of electronic components and electrical coupling elements between the plurality of electronic components, the electronic device assembly lacking thermally induced defects or damage as claimed therein is not present in the invention of Group I.

Groups I and II lack unity of invention because even though the inventions of these groups require the technical feature of electronic device comprising atomic layers, this technical feature is not a special technical feature as it does not make a contribution over the prior art. Specifically, US 2010/0178481 A1 (GEORGE et al) 15 July 2010 (15.07.2010) teaches electronic device comprising atomic layers (flexible organic electronic devices comprising silica and alumina films with thicknesses of 100-300 Å, Paras. 2 and 4).

Since none of the special technical features of the Group I or II inventions are found in more than one of the inventions, unity of invention is lacking.