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(54) Title: PHOTSENSITIVE, INORGANIC LIGAND-CAPPED INORGANIC NANOCRYSTALS

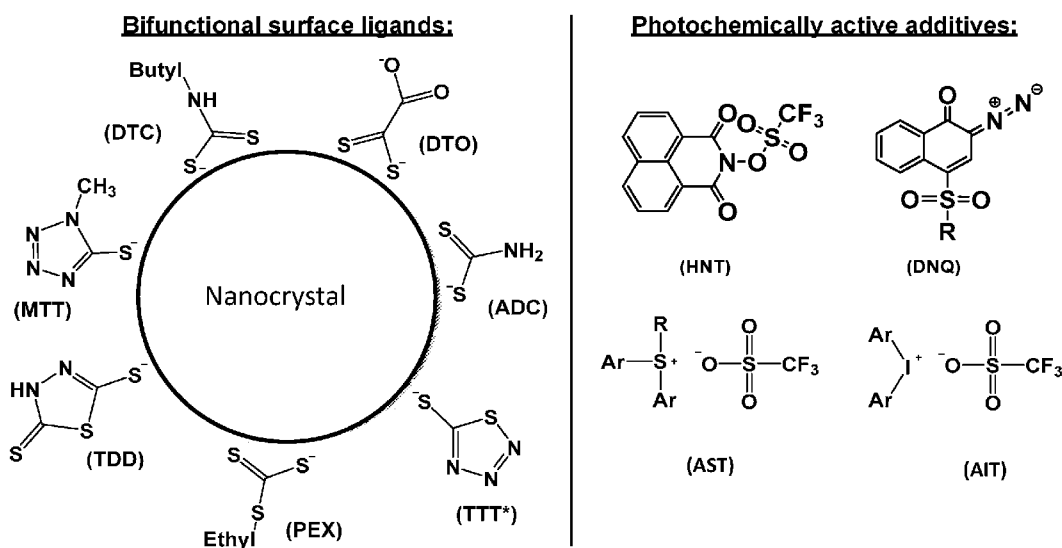


FIG. 3A

(57) **Abstract:** Ligand-capped inorganic particles, dispersions of the ligand-capped inorganic particles, and films composed of the ligand-capped inorganic particles are provided. Also provided are methods of patterning the films and electronic, photonic, and optoelectronic devices that incorporate the films. The ligands include bifunctional ligands and two-component ligand systems that include a photosensitive group, cation, or molecule.



TM), European (AL, AT, BE, BG, CH, CY, CZ, DE, DK, EE, ES, FI, FR, GB, GR, HR, HU, IE, IS, IT, LT, LU, LV, MC, MK, MT, NL, NO, PL, PT, RO, RS, SE, SI, SK, SM, TR), OAPI (BF, BJ, CF, CG, CI, CM, GA, GN, GQ, GW, KM, ML, MR, NE, SN, TD, TG).

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- *with international search report (Art. 21(3))*
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INTERNATIONAL SEARCH REPORT

International application No.

PCT/US 19/55784

A. CLASSIFICATION OF SUBJECT MATTER

IPC - H01L 21/02; H01L 21/027; H01L 21/033 (2020.01)

CPC - C09K 11/025; C09K 11/58; C09K 11/70

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)

See Search History document

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

See Search History document

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

See Search History document

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	US 2011/0059264 A1 (Park et al.) 10 March 2011 (10.03.2011); para [0009], [0058], [0060]	1-12
A	- Zhang et al. "Colloidal Nanocrystals with Inorganic Halide, Pseudohalide, and Halometallate Ligands" ACS Nano. 02 July 2014 (02.07.2014) vol 8, pg. 7359-7369; pg. 7359, abstract, para 1	1-12
A	- Erathodiyil et al. "Functionalization of Inorganic Nanoparticles for Bioimaging Applications" Accounts of Chemical Research. 07 June 2011 (07.06.2011) vol 44, pg. 925-935; pg. 926, Table 1, pg. 927, Figure 1, pg. 929, Figure 2	1-12
A	US 2014/0322898 A1 (Tangirala et al.) 30 October 2014 (30.10.2014); entire document	1-12
P, X	WO 2018/195143 A1 (THE UNIVERSITY OF CHICAGO) 25 October 2018 (25.10.2018); entire document	1-12

☐ 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

"D" document cited by the applicant in the international application

"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

29 June 2020

Date of mailing of the international search report

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INTERNATIONAL SEARCH REPORT

International application No.

PCT/US 19/55784

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 supplemental 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.:
1-12

- 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

Information on patent family members

International application No.

PCT/US 19/55784

--continued from Box No. III--

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 searched, the appropriate additional search fees must be paid.

Group I: Claims 1-12, directed to a ligand-capped inorganic crystals comprising: photosensitive cations or photosensitive non-ionic molecules associated with the inorganic crystals.

Group II: Claims 13-26, directed to a ligand-capped inorganic crystals comprising: photosensitive anions bound to the surfaces of the inorganic crystals.

The group of inventions listed above 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:

Special Technical Features:

Group I includes the technical feature of a ligand-capped inorganic crystals comprising: photosensitive cations or photosensitive non-ionic molecules associated with the inorganic crystals, which is not required by any other invention of Group II.

Group II includes the technical feature of a ligand-capped inorganic crystals comprising: photosensitive anions bound to the surfaces of the inorganic crystals, which is not required by any other invention of Group I.

Common technical features:

The inventions of Groups I and II share the technical feature of a ligand-capped inorganic crystals comprising a photosensitive moiety bound directly or indirectly to the surface.

These shared technical features, however, do not provide a contribution over the prior art, as being obvious over US 2011/0059264 A1 to Park et al. (hereinafter Park). Park discloses a ligand-capped (para [0009]: attaching a plurality of photoactive linker to nanoparticles to obtain photoactive nanoparticles) inorganic nanoparticles (para [0054]: inorganic nanoparticles include...cadmium-selenide) comprising a photosensitive moiety bound directly or indirectly to the surface (para [0058]: the nanoparticles can include or be functionalized with photoactive linkers that becomes activated upon exposure to photons and react with reactive groups that are on the surface of the substrate; para [0060]: a "photoactive linker" includes at least a photoactive group and a binding group), but does not disclose wherein the nanoparticle is crystalline. However, it would have been obvious to one with skill in the art to prepare nanoparticles disclosed as pure compounds of the disclosed materials (CdSe) which are expected to form crystalline structures (as evidenced by instant specification, para [0024]).

As said compound was known in the art at the time of the invention, these cannot be considered special technical features that would otherwise unify the inventions of Groups I or II. The inventions of Group I and II thus lack unity under PCT Rule 13.