ABSTRACT

The present disclosure relates to a process for preparing zinc indium sulfide nanoparticles, said process comprising the steps of reacting $Zn(NO_3)_2.6H_2O$, In(NO3)3.5H2O, thiourea and triethylamine for a time period ranging between 0.5 hour and 1.0 hours followed by treating hydrothermally at a temperature ranging between 100 °C and 200 °C for a time period ranging between 12 hours and 48 hours to obtain a precipitate followed by separating and iteratively washing the precipitate with a solvent to obtain zinc indium sulfide nanoparticles, wherein the concentration of the triethylamine ranges between 100 and 1000 ppm.

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WE CLAIM:

1. A process for preparing zinc indium sulfide nanoparticles, said process comprising the following steps:
   a. reacting $Zn(NO_3)_2.6H_2O$, $In(NO_3)_3.5H_2O$, thiourea and triethylamine for a time period ranging between 0.5 hour and 1.0 hours followed by treating hydrothermally at a temperature ranging between 100 °C and 200 °C for a time period ranging between 12 hours and 48 hours to obtain a precipitate; and
   b. separating and iteratively washing the precipitate with a solvent to obtain zinc indium sulfide nanoparticles,
   wherein the concentration of the triethylamine ranges between 100 and 1000 ppm.

2. The process as claimed in claim 1, wherein the solvent used for washing is at least one selected from the group consisting of methanol, ethanol, propanol, isopropanol and butanol.

3. The process as claimed in claim 1, wherein the molar ratio of $Zn(NO_3)_2.6H_2O$ to $In(NO_3)_3.5H_2O$ ranges between 1:1 and 1:2.

4. The process as claimed in claim 1, wherein the molar ratio of $Zn(NO_3)_2.6H_2O$ to thiourea ranges between 1:1 and 1:8.

5. The process as claimed in claim 1, wherein the molar ratio of $In(NO_3)_3.5H_2O$ to thiourea ranges between 1:2 and 1:8.

6. The zinc indium sulfide nanoparticles prepared by the process as claimed in claim 1, wherein the zinc indium sulfide nanoparticles are characterized by at least one of the following properties:
   a. band gap ranging between 2.3 and 2.5 eV;
   b. particle size ranging between 50 nm and 70 nm;

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c. dimensions a=3.85A^0 and c= 24.68 A^0; and

d. crystalline hexagonal structure.

7. The zinc indium sulfide nanoparticles prepared by the process as claimed in claim 1, characterized in that said zinc indium sulfide nanoparticles produce hydrogen at the rate of about 4,000 µmol/hour/half gram and 5,500 µmol/hour/half on irradiating with hydrogen sulfide at a wattage ranging between 200 W and 500 W in the presence of the aqueous alkaline solution.

8. A process for generating hydrogen, said process comprising the following steps:

   a. reacting $Zn(NO_3)_2.6H_2O$, $In(NO_3)_3.5H_2O$, thiourea and triethylamine for a time period ranging between 0.5 hour and 1.0 hours followed by treating hydrothermally at a temperature ranging between 100 °C and 200 °C for a time period ranging between 12 hours and 48 hours to obtain a precipitate;

   b. separating and iteratively washing the precipitate with at least one solvent selected from the group consisting of methanol, ethanol, propanol, isopropanol and butanol to obtain zinc indium sulfide nanoparticles; and

   c. adding zinc indium sulfide nanoparticles into a reactor containing an aqueous alkaline solution saturated with hydrogen sulfide and irradiating using visible light at a wattage ranging between 200 W and 500 W,

   wherein the concentration of the triethylamine ranges between 100 and 1000 ppm and said process generates hydrogen at the rate of about 4,000 to 5,500 µmol/h/half gram of zinc indium sulfide nanoparticles.

Dated this 30th day of January, 2014

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APPLICANTS' PATENT ATTORNEY

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FIELD OF THE DISCLOSURE:

The present disclosure relates to zinc indium sulfide nanoparticles, a process for its preparation and uses thereof.

BACKGROUND:

Nanostructured materials have received great interest in the field of biomedical, catalysis and electronic devices due to their size and shape dependent optical and electrical properties. Therefore, a large amount of work is being carried out to effectively control the size, shape and structure of inorganic nanomaterials to improve their physical and chemical properties. Currently, semiconducting materials of ternary chalcogenide AB_2X_4 wherein A= Cu, Ag, Zn and Cd; B=Al, Ga and In; and X= S, Se and Te, have gained much attention because they display tunable electronic and optical properties. A number of oxide semiconductors, have also been reported as a photocatalysts for hydrogen production via water splitting. However, these oxide semiconductors have a wide band gap and shows activity under UV light (λ <389 nm). This limits the applicability of these photocatalysts under solar radiation, as solar light contains only 5 % UV light. To utilize the solar energy for various purposes it is necessary to develop visible light active photocatalyst.

Recently, a new class of multi-component sulphides has also been reported to show high photocatalytic efficiency. ZnS is a wide band gap semiconductor and it is well-known for its photocatalytic activity under UV light. In this context, $ZnIn_2S_4$ has immense importance as a stable visible light photocatalyst and therefore, has attracted considerable attention because of its outstanding electrical and optical properties.

$ZnIn_2S_4$ is an important semiconducting material of ternary chalcogenides with a layered structure in the AB_2X_4 family. It has a wide application in different fields such as charge storage, thermoelectricity, photo-catalysis and the like and therefore has attracted considerable attention of the scientific community. Further, $ZnIn_2S_4$ is a

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visible light active photo-absorber material having an indirect band gap in the range of 1.8 to 2.1 eV and substantial chemical stability which makes it more promising candidate for solar energy applications. In addition to this, the shape, size and structure of $ZnIn_2S_4$ semiconductors also play a pivotal role in their optical and photo-catalytic properties. Therefore, scientific community is continuously exploring this inherent relationship to enhance their application in photo-catalysis.

For instance, JP2009066529 synthesized a photo-catalyst consisting of a catalytic substance which is a composite metal sulfide $ZnIn_2S_4$ in the crystal lattice form. It further discloses the use of the photo-catalyst for producing hydrogen from an aqueous solution containing a sulfur-based reactant by irradiating it with visible light.

A method for the preparation of $ZnIn_2S_4$ is described by Masoud Salavati-Niasari in "Journal of Inorganic and Organometallic Polymers and Materials." Masoud Salavati-Niasari specifically describes a facile microwave approach to react zinc acetate, $InCl_3$ and thiourea.

Another article authored by Shengjie Peng in "CrystEngComm, 2013,15, 1922-1930", titled Size and shape controlled synthesis of $ZnIn_2S_4$ nanocrystals with high photocatalytic performance, describes a method for the preparation of $ZnIn_2S_4$ nanocrystals. The process described in the article employs oleylamine as the ligand, noncoordinating octadecene as the solvent and thiourea as the sulfur source. Further, it manipulates the reaction temperature to achieve required size of $ZnIn_2S_4$ nanocrystals.

Zhi Xin Chen et. al in an article titled "Synthesis of $ZnIn_2S_4$ via a Surfactant-Assisted Hydrothermal Method and their Visible Light Photocatalytic Properties of MO Degradation" published in the periodical "Applied Mechanics and Materials (Volumes 217 - 219)" discloses a series of $ZnIn_2S_4$ photo-catalysts synthesis via a surfactant-assisted hydrothermal method at 120 °C for 6h.

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Zhi Xin Chen et. al in another article "A Simple Synthesis of Marigold-like $ZnIn_2S_4$ Microspheres and Visible Light Photocatalytic Degradation of Methyl Orange" has synthesized marigold-like $ZnIn_2S_4$ microspheres by means of a facile thermal solution method at 353 K without using templates, catalysts, surfactants and organic solvents.

Yet another article authored by Ming Xing Guo discloses a method for the preparation of $ZnIn_2S_4$. According to the method of Ming Xing Guo, $ZnIn_2S_4$ crystals are synthesized in one step at a temperature of 45 °C-65 °C by using hydrothermal method.

Various morphologies of $ZnIn_2S_4$ such as tubes, ribbons, wires, porous submirospheres, flowering-cherry- like microspheres and micropeony have also been reported earlier. However, the processes reported in the prior art do not effectively control size and shape of the zinc indium sulfide nanoparticles. Further, the nanoparticles prepared by the reported processes are not uniform.

The present disclosure also addresses some of the problems faced by the refinery industry. It is well-known that the refineries produce a huge amount of H_2S which is used to produce sulphur and water using the "Claus" process. This process is not economically viable due to the high cost of chemicals employed. Further, the Claus process creates acute environmental problems.

In view of the above, there is felt a need for the development of a simple, inexpensive and efficient process for the preparation of $ZnIn_2S_4$ nanostructured compound. Further, there is also a need for a process that converts H_2S into H_2 by obviating the prior art issues.

OBJECTS:

Some of the objects of the present disclosure which at least one embodiment herein satisfies are as follows;

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It is an object of the present disclosure to provide a simple and economic process for preparing zinc indium sulfide nanoparticles.

It is another object of the present disclosure to provide a process for preparing zinc indium sulfide nanoparticles which regulates and controls the size and shape of zinc indium sulfide nanoparticles.

It is still another object of the present disclosure to provide a process for preparing zinc indium sulfide nanoparticles which produces highly crystalline and uniform zinc indium sulfide nanoparticles.

It is still another object of the present disclosure to provide a process for preparing zinc indium sulfide nanoparticles which produces zinc indium sulfide nanoparticles having desired band gap and chemical stability.

It is yet another object of the present disclosure to provide a process for preparing zinc indium sulfide nanoparticles which employs inexpensive and non-toxic reagents.

It is yet another object of the present disclosure to provide zinc indium sulfide nanoparticles which can be effectively applied for hydrogen generation through H_2S splitting under solar light irradiation.

Other objects and advantages of the present disclosure will be more apparent from the following description when read in conjunction with the accompanying figures, which are not intended to limit the scope of the present disclosure.

SUMMARY:

In accordance with one aspect of the present disclosure there is provided a process for preparing zinc indium sulfide nanoparticles, said process comprising the following steps:

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a. reacting $Zn(NO_3)_2.6H_2O$, $In(NO_3)_3.5H_2O$, thiourea and triethylamine for a time period ranging between 0.5 hour and 1.0 hours followed by treating hydrothermally at a temperature ranging between 100 °C and 200 °C for a time period ranging between 12 hours and 48 hours to obtain a precipitate; and

b. separating and iteratively washing the precipitate with a solvent to obtain zinc indium sulfide nanoparticles,

wherein the concentration of the triethylamine ranges between 100 and 1000 ppm.

Typically, the solvent used for washing is at least one selected from the group consisting of methanol, ethanol, propanol, isopropanol and butanol.

Typically, the molar ratio of $Zn(NO_3)_2.6H_2O$ to $In(NO_3)_3.5H_2O$ ranges between 1:1 and 1:2.

Typically, the molar ratio of $Zn(NO_3)_2.6H_2O$ to thiourea ranges between 1:1 and 1:8.

Typically, the molar ratio of $In(NO_3)_3.5H_2O$ to thiourea ranges between 1:2 and 1:8.

In accordance with another aspect of the present disclosure there is provided zinc indium sulfide nanoparticles prepared by the process of the present disclosure, wherein the zinc indium sulfide nanoparticles are characterized by at least one of the following properties:

a. band gap ranging between 2.3 and 2.5 eV;
b. particle size ranging between 50 nm and 70 nm;
c. dimensions a=3.85A^0 and c= 24.68 A^0; and
d. crystalline hexagonal structure.

Typically, the zinc indium sulfide nanoparticles prepared by the process of the present disclosure is characterized in that said zinc indium sulfide nanoparticles produce

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hydrogen at the rate of about 4,000 µmol/hour/half gram and 5,500 µmol/hour/half on irradiating with hydrogen sulfide at a wattage ranging between 200 W and 500 W in the presence of the aqueous alkaline solution.

In accordance with yet another aspect of the present disclosure there is provided a process for generating hydrogen, said process comprising the following steps:

a. reacting $Zn(NO_3)_2.6H_2O$, $In(NO_3)_3.5H_2O$, thiourea and triethylamine for a time period ranging between 0.5 hour and 5.0 hours followed by treating hydrothermally at a temperature ranging between 100 °C and 200 °C for a time period ranging between 12 hours and 48 hours to obtain a precipitate;
b. separating and iteratively washing the precipitate with at least one solvent selected from the group consisting of methanol, ethanol, propanol, isopropanol and butanol to obtain zinc indium sulfide nanoparticles; and
c. adding zinc indium sulfide nanoparticles into a reactor containing an aqueous alkaline solution saturated with hydrogen sulfide and irradiating using visible light at a wattage ranging between 200 W and 500 W,

wherein the concentration of the triethylamine ranges between 100 and 1000 ppm and said process generates hydrogen at the rate of about 4,000 to 5,500 µmol/h/half gram of zinc indium sulfide nanoparticles.

BRIEF DESCRIPTION OF ACCOMPANYING DRAWINGS:

The disclosure will now be described with reference to accompanying drawings.

Fig.1 illustrates the UV-Visible spectra (a-d) of samples prepared in accordance with the process of the present disclosure, wherein

(a) without capping agent (S1),
(b) TEA 810.325 ppm (S2),
(c) TEA 162.285 ppm (S3), and
(d) TEA 243.077 ppm (S4).

Fig.2 illustrates the XRD analysis of samples (a-d) prepared in accordance with the

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process of the present disclosure, wherein a-d has the same meaning as in Fig. 1, and **Fig.3** illustrates the surface morphology of $ZnIn_2S_4$ using FE-SEM technique, wherein (a-b) is FESEM and (c) is TEM of sample S3 TEA and (d) is ED pattern.

DETAILED DESCRIPTION OF THE INVENTION:

The present disclosure relates to a process for preparing zinc indium sulfide nanoparticles using metal salts, at least one sulfur source and at least one capping agent. The inventors of the present disclosure after extensive research found that by using the process of the present disclosure and by varying the synthetic parameters and conditions, the morphology of zinc indium sulfide nanoparticles can be controlled in a reproducible manner. Particularly, the inventors have developed a hydrothermal process for preparing zinc indium sulfide nanoparticles and its application for the production of H_2.

In accordance with one aspect of the present disclosure there is provided a process for preparing zinc indium sulfide nanoparticles.

In the first step, $Zn(NO_3)_2.6H_2O$, In(NO3)3.5H2O, thiourea and triethylamine are mixed and stirred for a time period ranging between 0.5 hour and 1.0 hours to obtain a homogeneous mixture.

This homogeneous mixture is then hydrothermally treated at a temperature ranging between 100 °C and 200 °C for a time period ranging between 12 hours and 48 hours to obtain a precipitate. The polar solvent added to the stirred mixture is water.

The precipitate is separated by, for example filtration, and washed with a suitable solvent to obtain zinc indium sulfide nanoparticles. The suitable solvent used for washing is at least one selected from the group consisting of methanol, ethanol, propanol, isopropanol and butanol.

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The zinc indium sulfide nanoparticles prepared by the process of the present disclosure is characterized by at least one of the following properties:

a. band gap ranging between 2.3 and 2.5 eV;
b. particle size ranging between 50 nm and 70 nm;
c. dimensions a=3.85A^0 and c= 24.68 A^0; and
d. crystalline hexagonal structure.

The molar ratio of one ingredient to other ingredient plays a vital role in deciding the efficiency of the process in controlling the morphological properties of zinc indium sulfide nanoparticles. The inventors of the present disclosure after conducting several experiments found that the use of a particular molar ratio of one ingredient with respect to the other ingredient gives desired results. For instance, the molar ratio of $Zn(NO_3)_2.6H_2O$ to $In(NO_3)_3.5H_2O$ ranges between 1:1 and 1:2.

The sulfur in the catalyst provides desired band gap and photocatalytic activity under UV light. Therefore, the source and amount of thiourea used in the process for preparing zinc indium sulfide nanoparticles plays a vital role in deciding the yield of zinc indium sulfide nanoparticles. The molar ratio of $Zn(NO_3)_2.6H_2O$ to thiourea ranges between 1:1 and 1:8 whereas the molar ratio of $In(NO_3)_3.5H_2O$ to thiourea ranges between 1:2 and 1:8.

The effect of triethylamine on the morphology and other properties was also studied by varing its concentration. The results of the study indicated that the concentration of triethylamine ranging between 100 and 1000 ppm in the reaction mixture attributes enhanced morphological and other properties to the zinc indium sulfide nanoparticles.

The zinc indium sulfide nanoparticles prepared by the process of the present disclosure are characterized in that said nanoparticles produce hydrogen at the rate of about 4,000 µmol/hour/half gram and 5,500 µmol/hour/half on irradiating with hydrogen sulfide at a wattage ranging between 200 W and 500 W in the presence of the aqueous alkaline solution.

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In yet another aspect of the present disclosure there is provided a process for generating hydrogen.

In the first step, $Zn(NO_3)_2.6H_2O$, $In(NO_3)_3.5H_2O$, thiourea and triethylamine are mixed and stirred for a time period ranging between 0.5 hour and 1.0 hours to obtain a homogeneous reaction mixture. This homogeneous mixture is hydrothermally treated at a temperature ranging between 100 °C and 200 °C for a time period ranging between 12 hours and 48 hours to obtain a precipitate. The precipitate is separated by, for example filtration, and washed with a suitable solvent to obtain zinc indium sulfide nanoparticles. The suitable solvent used for washing is at least one selected from the group consisting of methanol, ethanol, propanol, isopropanol and butanol.

In the final step, zinc indium sulfide nanoparticles are added into a reactor containing an aqueous alkaline solution saturated with hydrogen sulfide which is then irradiated using visible light at a wattage raging 200 W and 500 W. The irradiation is carried out till hydrogen evolution ceases. The hydrogen generating capacity of the zinc indium sulfide nanoparticles ranges between 4,000 μmol/h/half gram and 5,500 μmol/h/half gram.

The zinc indium sulfide nanoparticles prepared in accordance with the present disclosure is used for hydrogen generation, optical and electrical applications.

The present disclosure is further described in light of the following non-limiting examples which are set forth for illustration purpose only and are not to be construed for limiting the scope of the disclosure.

EXAMPLE 1

$Zn(NO_3)_2.6H_2O$, $In(NO_3)_3.5H_2O$ and thiourea were mixed in the ratio of 1:2:8 and diluted to 100 ml to obtain a mixture. The mixture was then transferred into a Teflon lined stainless steel reactor of capacity 200 ml. To this mixture, TEA (100 to 1000

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ppm) was added as a capping agent and stirred for 30 min. The final volume of the reactor was adjusted to 150 ml using distilled water. The reactor was then kept in an oven maintained at a temperature of 150 ^{0}C for 30 hours to obtain a yellow precipitate. The yellow precipitate obtained was then filtered and washed with ethanol and dried at 70 ^{0}C.

The effect of the capping agent on the morphology and other properties was studied by varying the amount of the capping agent between 100 ppm and 1000 ppm.

The $ZnIn_2S_4$ nanoplates were also characterized using XRD, FESEM, TEM, UV-DRS and XPS for its structural and optical properties.

Fig.1 shows the UV-Visible spectra (a-d) of samples prepared

- (a) without capping agent (S1),
- (b) TEA 810.325 ppm (S2),
- (c) TEA 162.285 ppm (S3), and
- (d) TEA 243.077 ppm (S4).

A careful observation of the UV spectra suggests that, there is a blue shift in the absorption edge of $ZnIn_2S_4$ when the capping agent (TEA) is used and the extent of the blue shift in the absorption edge is concentration dependent, i.e., as concentration of TEA is increased the absorption edge shifts further to a shorter wavelength (UV side). This may be attributed to the decrease in the particle size of $ZnIn_2S_4$ with increase in the concentration of the capping agent.

The structural analysis (XRD) of samples is shown in Fig.2. The XRD pattern confirms a hexagonal crystal structure with dimensions a=3.85A^0, c= 24.68 A^0.

The surface morphology of $ZnIn_2S_4$ obtained by using FE-SEM technique shows the formation of nanoplates (Fig.3), which is further confirmed from TEM. FESEM images clearly show nanoplates and nanostrips stacked into bundles with the size ranging from 100-500 nm. The thickness of the nanopetals is observed to be in the

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range of 50-70 nm.

EXAMPLE 2

The $ZnIn_2S_4$ nanoparticles synthesized in Example1 was tested for its applicability as a photocatalyst. The photocatalytic study was carried out by using a quartz photoreactor designed and fabricated in-house.

The cylindrical quartz photochemical thermostatic reactor was filled with 700 ml 0.25 M aqueous KOH and purged with argon for 1h. Hydrogen sulphide (H_2S) was bubbled through the solution for about 1 hour at the rate of 2.5 ml min^{-1} at a temperature of 298 K. The hydrogen sulphide escaping the reactor was trapped in a scrubber of NaOH solution. $ZnIn_2S_4$ (0.5 g) was introduced into the reactor and the reactor was irradiated with visible light source using Xe-lamp (Oriel, 300 W) with constant stirring. The amount of hydrogen evolved was measured using a graduated gas burette and was analyzed using a Gas Chromatograph (Model Shimadzu GC-14B, MS-5 Å column, TCD, Ar carrier).

The photocatalytic study shows that in the absence of a photocatalyst, no evolution of hydrogen gas was observed from 0.25 M KOH solution flushed with H_2S gas under visible light irradiation. However, $ZnIn_2S_4$ photocatalyst prepared by the process of the present disclosure shows excellent photocatalytic activity for decomposition of H_2S into H_2. Table 1 shows the hydrogen evolution rate from the photodecomposition of H_2S using the synthesized $ZnIn_2S_4$ samples i.e. S1, S2, S3, S4 (all prepared in example 1) and CdS.

Table 1. Photocatalytic activity of $ZnIn_2S_4$ samples for hydrogen evolution.

Sample	$ZnIn_2S_4$ (S1)	$ZnIn_2S_4$ (S2)	$ZnIn_2S_4$ (S3)	$ZnIn_2S_4$ (S4)	CdS

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H_2/ µmol/h	4011	4491	5287	4374	847

The $ZnIn_2S_4$ sample S1 (without TEA) showed hydrogen evolution rate around 4011 µmol h^{-1}, while sample S2 (810.325 ppm TEA), S3 (162.285 ppm), S4 (243.077 ppm) and CdS showed 4491 µmol h^{-1}, 5287 µmol h^{-1}, 4375 µmol h^{-1} and 847 µmol h^{-1} respectively. It is noteworthy that among all the $ZnIn_2S_4$ samples, S3 shows significant hydrogen evolution rate without any promoters, which is about six times higher than the earlier reported values and bulk CdS.

TECHNICAL ADVANCEMENT:

The process of the present disclosure for the preparation of zinc indium sulphide nanoparticles is:

- simple and economic.
- efficient in regulating and controlling the size and shape of zinc indium sulphide nanoparticles.
- capable of producing zinc indium sulphide having desired band gap and chemical stability.
- devoid of expensive and toxic reagents.
- capable of producing hydrogen at a higher rate.

Throughout this specification the word "comprise" or variations such as "comprises" or "comprising", will be understood to imply the inclusion of a stated element, integer or step, or group of elements, integers or steps, but not the exclusion of any other element, integer or step, or group of elements, integers or steps.

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The use of the expression "at least" or "at least one" suggests the use of one or more elements or ingredients or quantities, as the use may be in the embodiment of the invention to achieve one or more of the desired objects or results.

Any discussion of documents, acts, materials, devices, articles or the like that has been included in this specification is solely for the purpose of providing a context for the invention. It is not to be taken as an admission that any or all of these matters form part of the prior art base or were common general knowledge in the field relevant to the invention as it existed anywhere before the priority date of this application.

The numerical values mentioned for the various physical parameters, dimensions or quantities are only approximations and it is envisaged that the values higher/lower than the numerical values assigned to the parameters, dimensions or quantities fall within the scope of the disclosure, unless there is a statement in the specification specific to the contrary.

While considerable emphasis has been placed herein on the product and the process, it will be appreciated that alterations can be made and that many modifications can be made in the preferred embodiment departing from the principles of the disclosure. These and other changes in the preferred product and the process of the disclosure will be apparent to those skilled in the art from the disclosure herein, whereby It is to be distinctly understood that the foregoing descriptive matter is to be interpreted merely as illustrative of the disclosure and not as a limitation.

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WE CLAIM:

1. A process for preparing zinc indium sulfide nanoparticles, said process comprising the following steps:
   a. reacting $Zn(NO_3)_2.6H_2O$, $In(NO_3)_3.5H_2O$, thiourea and triethylamine for a time period ranging between 0.5 hour and 1.0 hours followed by treating hydrothermally at a temperature ranging between 100 °C and 200 °C for a time period ranging between 12 hours and 48 hours to obtain a precipitate; and
   b. separating and iteratively washing the precipitate with a solvent to obtain zinc indium sulfide nanoparticles,
   wherein the concentration of the triethylamine ranges between 100 and 1000 ppm.

2. The process as claimed in claim 1, wherein the solvent used for washing is at least one selected from the group consisting of methanol, ethanol, propanol, isopropanol and butanol.

3. The process as claimed in claim 1, wherein the molar ratio of $Zn(NO_3)_2.6H_2O$ to $In(NO_3)_3.5H_2O$ ranges between 1:1 and 1:2.

4. The process as claimed in claim 1, wherein the molar ratio of $Zn(NO_3)_2.6H_2O$ to thiourea ranges between 1:1 and 1:8.

5. The process as claimed in claim 1, wherein the molar ratio of $In(NO_3)_3.5H_2O$ to thiourea ranges between 1:2 and 1:8.

6. The zinc indium sulfide nanoparticles prepared by the process as claimed in claim 1, wherein the zinc indium sulfide nanoparticles are characterized by at least one of the following properties:
   a. band gap ranging between 2.3 and 2.5 eV;
   b. particle size ranging between 50 nm and 70 nm;

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c. dimensions a=3.85A^0 and c= 24.68 A^0; and

d. crystalline hexagonal structure.

7. The zinc indium sulfide nanoparticles prepared by the process as claimed in claim 1, characterized in that said zinc indium sulfide nanoparticles produce hydrogen at the rate of about 4,000 µmol/hour/half gram and 5,500 µmol/hour/half on irradiating with hydrogen sulfide at a wattage ranging between 200 W and 500 W in the presence of the aqueous alkaline solution.

8. A process for generating hydrogen, said process comprising the following steps:

   a. reacting $Zn(NO_3)_2.6H_2O$, $In(NO_3)_3.5H_2O$, thiourea and triethylamine for a time period ranging between 0.5 hour and 1.0 hours followed by treating hydrothermally at a temperature ranging between 100 °C and 200 °C for a time period ranging between 12 hours and 48 hours to obtain a precipitate;

   b. separating and iteratively washing the precipitate with at least one solvent selected from the group consisting of methanol, ethanol, propanol, isopropanol and butanol to obtain zinc indium sulfide nanoparticles; and

   c. adding zinc indium sulfide nanoparticles into a reactor containing an aqueous alkaline solution saturated with hydrogen sulfide and irradiating using visible light at a wattage ranging between 200 W and 500 W,

   wherein the concentration of the triethylamine ranges between 100 and 1000 ppm and said process generates hydrogen at the rate of about 4,000 to 5,500 µmol/h/half gram of zinc indium sulfide nanoparticles.

Dated this 30th day of January, 2014

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