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(71) Applicant: **RHODIA OPERATIONS** [FR/FR]; 25, rue de Clichy, F-75009 Paris (FR).

(72) Inventor: **NI, Xiao**; 402-48 3828 Nong Yindu Rd, Minhang, Shanghai 201108 (CN).

(74) Agent: **CHINA PATENT AGENT (H.K.) LTD.**; 22/F., Great Eagle Center, 23 Harbour Road, Wanchai, Hong Kong (CN).

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(54) Title: METHOD FOR RECOVERING FINE PARTICLES FROM AQUEOUS SLURRY

(57) Abstract: A process for separating a hydrophobic particulate material from an aqueous slurry containing the same is provided, which comprises the steps of: (a) mixing an aqueous slurry containing a hydrophobic particulate material with an oil having a greater density than water, to form a liquid mixture; (b) introducing a gas into the liquid mixture to produce a froth containing the hydrophobic particulate material, by flotation; and (c) recovering said froth to obtain said hydrophobic particulate material.



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Description**METHOD FOR RECOVERING FINE PARTICLES FROM AQUEOUS SLURRY****Technical Field**

[0001] This invention relates to a method for recovering hydrophobic particles from an aqueous slurry and, more particularly, to a method for recovering fine hydrophobic particles from an aqueous slurry by froth flotation.

Background Art

[0002] For years flotation procedures have been widely used to recover various particles from suspension. Flotation is based on the principle that introducing a gas into a liquid containing different solid particles suspended therein causes selective adherence of some gas to certain suspended particles, making the gas-adhered solid particles float to the top of the liquid. In a typical flotation recovery process, flotation agents and other optional additives are added to the particle-containing suspension, and the thus treated particles are then brought into contact with air bubbles to buoy or lift the particles to the surface, which are subsequently recovered.

[0003] This flotation recovery technique is widely used in mining application, oil sand refining operation and pulp and paper industries, which often consume a large amount of water and generate plentiful aqueous slurry where particles of value are suspended. However, conventional air flotation recovery procedures usually do not work well for recovering fine particles with diameters of $<10\mu\text{m}$, since these light, low-inertia particles tend to get trapped in the liquid streamlines that flow around the rising air bubbles, instead of contacting the air bubbles, let alone getting attached thereto for the desired upward movement.

[0004] To improve fine particle recovery from aqueous suspension, a technique called agglomeration-flotation has been developed. In most cases, this technique involves contacting the target fine particles in aqueous suspension with a non-polar mineral oil intensively mixed therein, so that the oil may act as a bridging liquid to selectively agglomerate the

hydrophobic fine particles into larger pellets. These pellets can then be readily separated from the suspension by conventional flotation equipment, as demonstrated in **COLEMAN, Richard D., et al.**

Agglomeration-flotation: recovery of hydrophobic components from oil sands fine tailing. *Fuel*. 1995, vol.74, no.8, p.1156-1161. and **CA 2172028** A 19/09/1997 . However, as the non-polar mineral oil (e.g. light fuel oil, kerosene, heptane) applied in these prior art has a lighter density than water, it necessarily requires high-level agitation to be “intensively mixed” with the immiscible aqueous phase, to reach a reasonable collision rate with the air bubbles and fine particles suspended near the bottom. The practical problems associated with such high-level agitation include the correspondingly high energy consumption and equipment requirement during the operation.

- [0005] In an attempt to address these problems, **LIU, J., et al.** Fundamental study of reactive oily-bubble flotation. *Minerals Engineerings*. 2002, vol.15, p.667-676. proposed a modified microflotation cell characterized by having a bottom chamber fully filled with kerosene (see Fig. 1). In this particular configuration, oily bubbles could be produced by bubbling a compressed nitrogen gas through the oil phase in the bottom chamber, and then passing through a fritted glass disk into the aqueous slurry phase to collect fine particles. The limitation of this configuration, however, is the complexity to apply the same in an industrial scale, since a conventional flotation cell is designed to have the oil added from its top opening and not equipped with a separate oil inlet conduit or liquid chamber near its bottom.
- [0006] Therefore, there remains a need to provide a modified particle flotation method or system that efficiently separates and recovers fine particles from various aqueous slurries containing the same, using minimized mechanical energy input and basic flotation cells already applied in industry.

Summary of invention

- [0007] The present invention provides a process for separating a hydrophobic particulate material from an aqueous slurry containing the same, the process comprising the steps of:
- (a) mixing an aqueous slurry containing a hydrophobic particulate material with an oil having a greater density than water [Oil (H)], to form a liquid mixture;
 - (b) introducing a gas into the liquid mixture to produce a froth containing the hydrophobic particulate material, by flotation; and
 - (c) recovering said froth to obtain said hydrophobic particulate material.
- [0008] Advantageously, by the use of an oil with a greater density than water, the flotation process of this invention could effectively collect hydrophobic fine particles from an aqueous slurry, and even achieve a high particle recovery rate by mild agitation. As an additional advantage over the prior art, the invented flotation process also eliminates the necessity of adding collectors to the aqueous phase, thereby minimizing the undesired contamination in the recovered products.
- [0009] As used herein, the term "particulate material" refers to solid materials in the physical form of distinct particles, including but not limited to finely divided minerals, and particulate products chemically synthesised from minerals.
- [0010] The term "hydrophobic", as used herein, refers to a tendency to not dissolve or otherwise associate readily in water. Particularly, when used herein with respect to particulate materials, the term "hydrophobic" shall mean that the surfaces of such particles prefer to bond or associate with other hydrophobic moieties or molecules, thereby excluding water molecules. For the purpose of the present invention, a hydrophobic surface refers to one that generates a contact angel of greater than 90° with water, and a hydrophobic material refers to a material having a contact angle with water of greater than 90° when the material is shaped into a flat plate.
- [0011] Notably, the hydrophobic particulate material amenable to the present invention include, but are not limited to coal particles and minerals, particularly including coal, base-metal oxide type metallic minerals,

platinum group metals, ferrous metals, rare earth minerals, non-metallic minerals, phosphate minerals and clays.

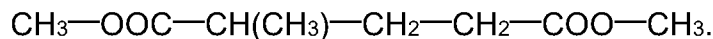
- [0012] In one preferred embodiment, the hydrophobic particulate material is talc. As used herein, the term "talc" denotes a composition consisting entirely or almost entirely of hydrated magnesium silicate. Talc may generally be described by either of the following formulas: $\text{H}_2\text{Mg}_3(\text{SiO}_3)_4$ or $\text{Mg}_3\text{Si}_4\text{O}_{10}(\text{OH})_2$. One preferred form of talc is talcum powder.
- [0013] In another preferred embodiment, the hydrophobic particulate material is coal. By way of illustration, anthracite coal, semi-anthracite coal, medium and high-volatile bituminous coal, sub-bituminous coal, lignite coal, and biocoal such as charcoal or torrefied biomass (e.g. torrefied wood and the like) can be advantageously used to practice this invention.
- [0014] Advantageously, the hydrophobic particulate material amenable to the present invention could include a substantive portion of fine particulate materials, which are composed of particles having an average diameter D_{50} of between 0.1 and 500 μm , preferably between 0.1 and 100 μm , and more preferably between 3 and 20 μm . As used herein, the term "a substantive portion" can mean at least 25%, at least 50%, at least 70%, and/or at least 90% of the hydrophobic particulate material.
- [0015] In a specific embodiment of the present invention, the hydrophobic particulate material provides the size distribution as follows in the aqueous slurry:
- D_{10} between 1 and 30 μm ,
 - D_{50} between 0.1 and 100 μm , preferably between 3 and 20 μm , and
 - D_{90} between 50 and 200 μm .
- [0016] Such an average diameter may be obtained by wet or dry grinding, notably in a grinding mill, for instance a tumbling mill, which can be done in either a batch or continuous mode. A tumbling mill is any horizontally mounted cylindrical mill which tumbles its contents when rotating. The preferred tumbling mill used in this invention is a ball mill.
- [0017] Particle size distribution of the hydrophobic particulate material and notably its average diameter D_{50} may be determined by laser diffraction sensors, sedimentometer or a scanning electron microscope (SEM).

- [0018] The term “aqueous slurry” is used herein to refer to any water-based dispersion of a hydrophobic particulate material. Optionally, an aqueous slurry amenable to the present invention may further comprise hydrophilic particles, notably as contaminant. As used herein, the term “hydrophilic” refers to a tendency of water affinity. For the purpose of the present invention, a hydrophilic material refers to a material having a contact angle with water of 90° or less when the material is shaped into a flat plate. Typical hydrophilic contaminants in an aqueous slurry may include, for example, silica and clay.
- [0019] Aqueous slurry of the present invention may comprise from 0.5 to 50 % by weight of the hydrophobic particulate material, preferably from 1 to 40 % by weight, and more preferably from 20 to 30% by weight.
- [0020] The term “oil” as used herein means an organic solvent. The expression of “Oil (H)”, as used throughout the specification and claims, refers to an oil or oils having a greater density than water.
- [0021] Notably, examples of Oil (H) include solvents of linear dicarboxylic acid diester type. Preferably, Oil (H) comprises a diester solvent of formula (I):
- $$\text{R}^1\text{—OOC—A—COO—R}^2 \quad (\text{I})$$
- wherein
- the R¹ and R² groups, which are identical or different, represent a linear or branched, cyclic or noncyclic, C₁-C₂₀ alkyl, aryl, alkylaryl or arylalkyl group, and
- the A group represents a linear or branched divalent alkylene group.
- [0022] It is noted that according to one embodiment of the present invention, the Oil (H) may be a mixture of different dicarboxylic acid diesters of formula (I).
- [0023] In the formula (I), the groups R¹ and R², either identical or different may notably be selected from a group consisting of methyl, ethyl, n-propyl, isopropyl, benzyl, phenyl, n-butyl, isobutyl, cyclohexyl, hexyl, n-hexyl, isooctyl, and 2-ethylhexyl. They correspond to the alcohols of formulas R¹—OH and R²—OH, either identical or different.

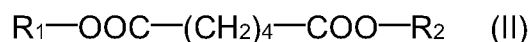
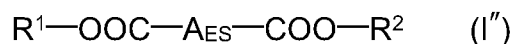
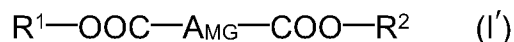
- [0024] In the present application, this dicarboxylic acid diester of formula (I) may be designated by “diester”, “particular diester”, or “diester used in the invention”.
- [0025] The group A is a divalent alkylene group. The corresponding acid is the compound of formula HOOC—A—COOH .
- [0026] According to a first alternative of the invention, A is a linear divalent alkylene group of formula $(\text{CH}_2)_r$, wherein r is an average number comprised between 2 and 4 inclusive.
- [0027] Preferably, A is selected so that the Oil (H) may be a mixture of adipate diesters ($n=4$), glutarate diesters ($r+3$), and succinate diesters ($r=2$).
- [0028] Advantageously, Oil (H) comprises one or more diesters selected from
- dimethyl adipate;
 - a mixture of dimethyl adipate (for example from 9 to 17% by weight, as determined by gas chromatography), of dimethyl glutarate (for example from 59 to 67% by weight), and of dimethyl succinate (for example from 20 to 28% by weight), for example marketed by Solvay under the name of Rhodiasolv® RPDE;
 - diisobutyl adipate; and
 - a mixture of disobutyl adipate (for example from 9 to 17% by weight, as determined by gas chromatography), of diisobutyl glutarate (for example from 59 to 67% by weight), and of diisobutyl succinate (for example from 20 to 28% by weight), for example marketed by Solvay under the name of Rhodiasolv® DIB.
- [0029] According to a second alternative of the present invention, the Oil (H) comprises a dicarboxylic acid diester of formula (I) wherein the group A is a branched divalent C3-C10 alkylene group. In the present application, this diester of a dicarboxylic acid may be designated as “branched diester”.
- [0030] In the branched diester comprised in Oil (H), the group A may notably be a C3, C4, C5, C6, C7, C8, C9 group or a mixture thereof. Preferably it is a C4 group.
- [0031] In the branched diester comprised in Oil (H), the group A is preferably selected from the following groups:

- the group A_{MG} of formula $—CH(CH_3)—CH_2—CH_2$, (corresponding to 2-methyl glutaric acid)
- the group A_{ES} of formula $—CH(C_2H_5)—CH_2$, (corresponding to 2-ethyl succinic acid), and
- mixtures thereof.

[0032] Advantageously, the branched diester comprised in Oil (H) is the dimethyl ester of 2-methyl glutaric acid fitting the following formula:



[0033] According to a preferred embodiment, the particular Oil (H) appears as a mixture comprising the diesters of dicarboxylic acids of the following formulae (I'), (I'') and optionally (II):



wherein:

A_{MG} is a group of formula $—CH(CH_3)—CH_2—CH_2$,

A_{ES} is a group of formula $—CH(C_2H_5)—CH_2$.

[0034] In these formulae (I') (I'') and (II), the groups R^1 and R^2 may notably be methyl, ethyl or isobutyl groups.

[0035] According to a more preferred embodiment of the present invention, the mixture of diesters comprises:

- from 70 to 95% by weight of the dicarboxylic acid diester of formula (I'), preferably the methyl diester.
- from 5 to 30% by weight of the dicarboxylic acid diester of formula (I''), preferably the methyl diester, and
- from 0 to 10% by weight of the dicarboxylic acid diester of formula (II), preferably the methyl diester.

[0036] A mixture of diesters, wherein the group A is branched, is marketed by Solvay under the name of Rhodiasolv® IRIS. Such mixtures, as well as the suitable methods for obtaining them are notably described in documents **WO 2007/101929**, **WO 2007/141404** and **WO 2008/062058**.

[0037] It is noted that according to an embodiment, the Oil (H) is a mixture of a solvent according to the first alternative (with A being a linear group) and

of a solvent according to the second alternative (with a branched group A). This may for example be a mixture of the Rhodiasolv® IRIS and Rhodiasolv® RPDE products.

- [0038] In step (a), the mixing of the aqueous slurry and the Oil (H) is performed by any suitable means, for example using a stirrer at 50-500 revolutions per minute (rpm), preferably at 50-200 rpm. Advantageously, high-speeding stirring (e.g. larger than 500 rpm) is not necessary to form the liquid mixture in step (a).
- [0039] Preferably, the mixing in step (a) forms a liquid mixture where the hydrophobic particulate material and the oil phase are both uniformly dispersed in the aqueous phase. In particular, the oil phase is desirably mixed with the aqueous slurry to form an emulsion, to provide for an optimum bonding between the hydrophobic particles and dispersed oil phase. In this case, emulsifiers, particularly non-ionic emulsifiers, may be used in the liquid mixture formed in step (a) to ensure oil-in-water emulsion stability.
- [0040] The optimum amount of Oil (H) applied in step (a) will depend on the particular Oil (H) selected and the physical properties (e.g. size, surface morphology, density, etc.) of the hydrophobic particulate material in the slurry. Typically, the amount of Oil (H) is from about 0.01 to 15 % by weight, and preferably from about 0.1 to 10 % by weight based on the weight of said hydrophobic particulate material.
- [0041] In one embodiment of the present invention, the aqueous slurry used in step (a) further contains at least one collector. A "collector" as used herein refers to any molecule that is dissolvable in the Oil (H) and promotes bonding or association of Oil (H) with the target hydrophobic particulate material when so dissolved. Examples of collectors include, but are not limited to the following classes of molecules: aliphatic acids and corresponding salts, aliphatic or aromatic xanthates, aliphatic hydroximate acids, and aliphatic amines.
- [0042] Optionally, the aqueous slurry used in step (a) may further contain at least one activator. An "activator" as used herein is any molecule well known in the flotation art that can be dissolved in the aqueous phase and promote

attachment of an oil-coated gas bubble with the target hydrophobic particulate material when so dissolved. Examples of activators include, but are not limited to, inorganic, divalent salts (e.g., copper sulphate), various weak acids (e.g., hydrogen sulfide, sodium meta-bisulfite, and hydrofluoric acid), and complex agents (e.g., diethylene triamines).

- [0043] In another aspect, the present invention also provides an aqueous slurry comprising: water, a hydrophobic particulate material, and an Oil (H), wherein the amount of Oil (H) is from 0.01 to 15% by weight, and preferably from 0.1 to 10% by weight based on the weight of said hydrophobic particulate material. Optionally, the aqueous slurry may contain at least one collector and/or at least one activator as described above.
- [0044] A person skilled in the art would understand that the design parameters of the aqueous slurry in the step (a) for optimal flotation condition setting are not limited to the above additives and could properly set the concentration of each additive with respect to the weight of target hydrophobic particulate material.
- [0045] In step (b), by introducing a gas the liquid mixture, gas bubbles are generated therein which selectively adhere the hydrophobic particulate material (mostly in the form of dispersed particle-oil aggregates), thus producing a froth containing the hydrophobic particulate material, by flotation technique.
- [0046] Suitable gases include air, carbon dioxide, nitrogen, methane and other light hydrocarbon gases which are inert to the hydrophobic particulate material. Preferred gases include air and nitrogen.
- [0047] In step (b), the flotation may be conducted at temperatures within the range from about 0°C to 100°C, preferably within the range from about 10°C to 40°C. Moreover, the flotation may be conducted at pressures within the range from about 1 to about 200 psig, preferably from about 5 to 100 psig.
- [0048] Typically, in step (b), the flotation is carried out under mild agitation of 50-500 rpm and preferably at 50-200 rpm in the liquid mixture, e.g., using a mechanical stirrer or a rotor, to keep the hydrophobic particles in

suspension and disperse the gas bubbles. Advantageously, according to the present invention, high-speeding agitation (e.g. larger than 500 rpm) is not necessary in step (b).

[0049] Step (b) may be carried out in any suitable flotation apparatus, such as one or more of a conventional flotation cell or a flotation column. Typically, as is well known in the art, a conventional flotation cell consists simply of a vessel equipped with at least one mechanical stirrer or other suitable means for maintaining a general suspension of particulates within the cell during the flotation process. Unlimited examples of such flotation cell include the stirred tank as illustrated in **CA 2172028**, as well as Denver flotation cell of different commercial models.

[0050] As the flotation in step (b) causes the froth containing the hydrophobic particulate material to move towards the surface of the aqueous slurry, said froth can be moved and collected from the flotation apparatus.

[0051] In step (c) of the process invention, said froth is recovered to obtain the hydrophobic particulate material as desired. Specifically, the hydrophobic particles may be recovered by washing the collected froth portion with a light oil such as naphtha, drying as required, and sending to storage or to downstream use. Advantageously, as the proportion of the Oil (H) is typically small with respect to the hydrophobic particulate material, the Oil (H) can be left in association with the recovered hydrophobic particles without substantially affecting the intended downstream usage.

Brief description of drawings

[0052] Fig. 1 is a schematic diagram of a prior art flotation cell apparatus, which comprises a main body **3** connected with a feed inlet **1**, a bottom chamber **2** fitted to the main body **3**, and a first fritted disk **4** located between the main body **3** and the bottom chamber **2**. The bottom chamber **2** has an oil feed inlet **a** for introducing an oil phase, and a gas inlet on the opposite side for introducing a compressed gas of N₂. A second fritted disk **4** is located in the gas inlet passageway, so that the compressed gas can pass through the fritted disk into the oil phase in the bottom chamber **2** and generate oil-coated bubbles in the aqueous phase within the main body **3**,

driving agglomerates towards the top of the apparatus. The floated agglomerates were then collected from outlet **b**.

[0053] Fig. **2** is a schematic diagram of a flotation cell apparatus used in the Examples of the present invention. The flotation apparatus comprises a main body **4** connected with a feed inlet **1** and a froth-collecting lauder **3**, a bottom chamber **2** fitted to the main body **4**, and a gas-permeable fritted disk **6** located between the main body **4** and the bottom chamber **2**. The froth-collecting lauder **3** has an outlet **5** for removing the collected agglomerates from the flotation apparatus. The bottom chamber **2** has a gas feed inlet **2a** for introducing a compressed gas into the flotation apparatus.

Description of embodiments

[0054] **Materials:**

- (1) Rhodiasolv® IRIS: obtained from Solvay, a mixture of diesters comprising more than 80 wt % of dimethyl ethylsuccinate and dimethyl 2-methylglutarate, and having a relative density of 1.055 (relative to water)
- (2) 200# Solvent Oil: obtained from Sinopharm, having a relative density of 0.72-0.74 (relative to water)
- (3) Talc powder (D_{50} : $\sim 5\mu\text{m}$): obtained from Sinopharm

Examples

[0055] **Example 1**

[0056] Flotation test was carried out for a synthetic aqueous talc slurry made by mixing 2 gram of talc powder into 150 ml water in a glass beaker, with a mild agitation in the range of 60 - 120 rpm. Subsequently, 97.5 mg of Rhodiasolv® IRIS was added to the talc slurry and conditioned for 2 minutes. Then the slurry was transferred into a micro-scale flotation apparatus as shown in Fig. **2**, through its feed inlet **1** and into its main body **4**. The flotation apparatus further comprises a froth-collecting lauder **3** connected with the main body **4**, a bottom part **2** fitted to the main body **4** for providing a gas inlet **2a**, and a gas-permeable fritted disk **6** located between the main body **4** and the bottom part **2**. The froth-collecting lauder

3 has an outlet **5** for removing the collected agglomerates from the flotation apparatus.

[0057] With the help of a magnetic stirrer placed on the fritted disk **6** (not shown), the slurry mixture was further conditioned under mild agitation in the range of 60-120 rpm, for 2 minutes, to reach a good distribution of talc particles and oil phase **7** in the aqueous phase **8**. Next, a compressed N₂ gas was introduced through the gas inlet **2a**, at a rate of 7 liter/min. The N₂ gas passed through the holes in the fritted disk **6**, and formed a plurality of gas bubbles in the aqueous phase **8**, eventually causing the agglomerates float upwards to the top of the apparatus and overflow into the froth-collecting launder **3**. The gas supply was shut off after two minutes, and then the agglomerates were collected and separated from the apparatus through the outlet **5**. Separately, the agglomerates from outlet **5** and the mixture remaining in the main body **4** were collected, oven-dried, and respectively weighed to calculate the talc particle recovery. The talc recovery rate was calculated to be 53%.

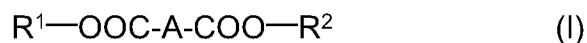
[0058] **Comparative Example 1**

[0059] Flotation test identical to Example 1 was carried out in a same micro-scale flotation apparatus as shown in Fig. **2**, except that the 97.5 mg of Rhodiasolv® IRIS was replaced by 97.5 mg of 200# Solvent Oil. The talc recovery rate was calculated to be 10%.

[0060] Clearly, by replacing the conventional mineral oil with an oil having a greater density than water in the flotation process, fine particle recovery rate has increased significantly. This indicates a stronger particle collecting ability of the high-density oil, represented by Rhodiasolv® IRIS.

Claims

1. A process for separating a hydrophobic particulate material from an aqueous slurry containing the same, the process comprising the steps of:
 - (a) mixing an aqueous slurry containing a hydrophobic particulate material with an oil having a greater density than water [Oil (H)], to form a liquid mixture;
 - (b) introducing a gas into the liquid mixture to produce a froth containing the hydrophobic particulate material, by flotation; and
 - (c) recovering said froth to obtain said hydrophobic particulate material.
2. The process of claim 1, wherein the hydrophobic particulate material is selected from a group consisting of coal, base-metal oxide type metallic minerals, platinum group metals, ferrous metals, rare earth minerals, non-metallic minerals, phosphate minerals and clays.
3. The process of claim 1 or 2, wherein the hydrophobic particulate material is talc.
4. The process of claim 1 or 2, wherein the hydrophobic particulate material is coal.
5. The process of any one of the preceding claims, wherein the hydrophobic particulate material includes a substantive portion of fine particulate materials, wherein the fine particulate materials are composed of particles having an average diameter D50 of between 0.1 and 500 μm , preferably between 0.1 and 100 μm , and more preferably between 3 and 20 μm .
6. The process of any one of the preceding claims, wherein the amount of Oil (H) used is from 0.01 to 15% by weight, and preferably from 0.1 to 10% by weight based on the weight of said hydrophobic particulate material.
7. The process of any one of the preceding claims, wherein the Oil (H) comprises a diester solvent if formula (I):



wherein

the R^1 and R^2 groups, which are identical or different, represent a linear or branched, cyclic or noncyclic, $\text{C}_1\text{—C}_{20}$ alkyl, aryl, alkylaryl or arylalkyl group, and the A group represents a linear or branched divalent alkylene group.

8. The process of claim 7, wherein the A group is a linear divalent alkylene group of formula $(CH_2)_r$, and wherein r is an average number comprised between 2 and 4 inclusive.
9. The process of claim 8, wherein the Oil (H) comprises one or more diesters selected from:
 - (i) dimethyl adipate;
 - (ii) a mixture of dimethyl adipate, dimethyl glutarate, and dimethyl succinate;
 - (iii) diisobutyl adipate; and
 - (iv) a mixture of disobutyl adipate, diisobutyl glutarate, and diisobutyl succinate.
10. The process of claim 7, wherein the group A is a branched divalent C3-C10 alkylene group.
11. The process of claim 10, wherein the Oil (H) is a mixture comprising the diesters of dicarboxylic acids of the formulae (I'), (I'') and optionally (II):

$$R^1-OOC-A_{MG}-COO-R^2 \quad (I')$$

$$R^1-OOC-A_{ES}-COO-R^2 \quad (I'')$$

$$R_1-OOC-(CH_2)_4-COO-R_2 \quad (II)$$
 wherein:

A_{MG} is a group of formula $-CH(CH_3)-CH_2-CH_2-$, and

A_{ES} is a group of formula $-CH(C_2H_5)-CH_2-$.
12. The process of any one of the preceding claims, wherein the aqueous slurry further contains at least one collector selected from a group consisting of aliphatic acids and corresponding salts, aliphatic or aromatic xanthates, aliphatic hydroximate acids, and aliphatic amines.
13. The process of any one of the preceding claims, wherein the aqueous slurry further contains at least one activator selected from a group consisting of inorganic, divalent salts, weak acids, and complex agents.
14. The process of any one of the preceding claims, wherein in step (b), the flotation is carried out under agitation of 50-500 rpm and preferably at 50-200 rpm in the liquid mixture.
15. An aqueous slurry comprising: water, a hydrophobic particulate material, and an oil having a greater density than water [Oil (H)], wherein the amount of Oil

(H) is from 0.01 to 15% by weight, and preferably from 0.1 to 10% by weight based on the weight of said hydrophobic particulate material.

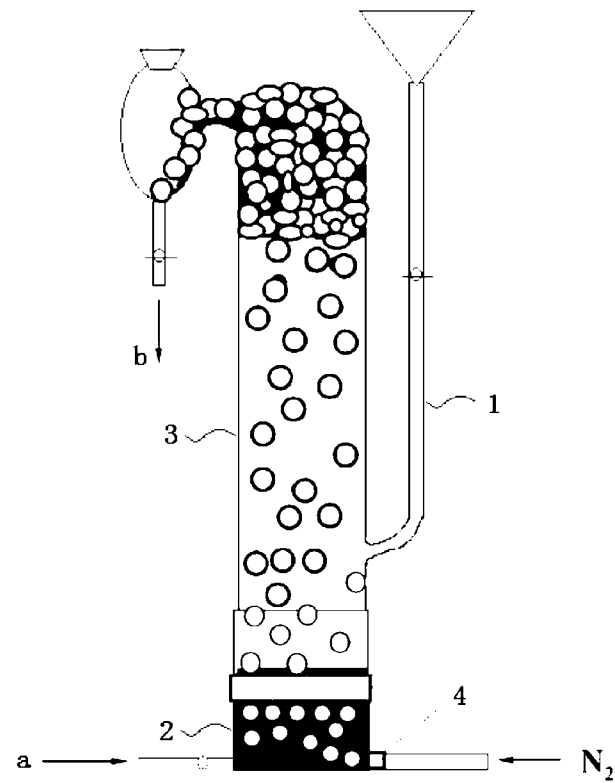


Fig. 1

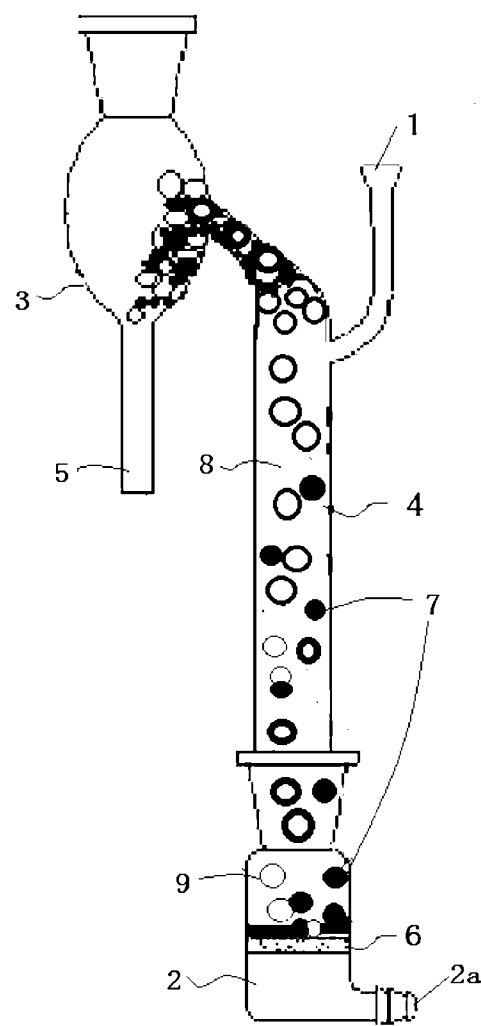


Fig. 2

INTERNATIONAL SEARCH REPORT

International application No.

PCT/CN2015/073542

A. CLASSIFICATION OF SUBJECT MATTER

B03D 1/008(2006.01)i; B03D 1/02(2006.01)i; B03D 101/00(2006.01)i; B03D 103/00(2006.01)i

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)

B03D1/-; B03D101/-; B03D103/-

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)

CNPAT, CNKI, WPI, EPODOC, STN: rhodia, coal, mineral, clay, talc, metal, flotation, floatation, adipate, glutarate, succinate, oil, ester, froth, particulate

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	GB 717927 A (DISTILLERS COMPANY LIMITED) 03 November 1954 (1954-11-03) see page 1 lines 20-31, page 2 lines 20-80	1-15
X	CN 101530830 A (BAOTOU LINFENG RARE EARTH CHEMICAL CO., LTD.) 16 September 2009 (2009-09-16) see page 1 paragraphs 1, 4	1-8, 10, 12-15
X	CN 101274993 A (ZHEJIANG UNIVERSITY OF TECHNOLOGY) 01 October 2008 (2008-10-01) see page 1 paragraph 5 to page 3 paragraph 4	1, 5-8, 10, 14-15
X	US 5234110 A (KOBLE, R. W.) 10 August 1993 (1993-08-10) see column 7 line 27 to column 8 line 52	1, 5-11, 14-15
X	CN 102553725 A (CENTRAL SOUTH UNIVERSITY) 11 July 2012 (2012-07-11) see paragraphs [0046]-[0050]	1-6, 12-15
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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

13 November 2015

Date of mailing of the international search report

04 December 2015

Name and mailing address of the ISA/CN

STATE INTELLECTUAL PROPERTY OFFICE OF THE
P.R.CHINA
6, Xitucheng Rd., Jimen Bridge, Haidian District, Beijing
100088, China

Facsimile No. (86-10)62019451

Authorized officer

LIU, Hongyan

Telephone No. (86-10)82246696

INTERNATIONAL SEARCH REPORT

International application No.

PCT/CN2015/073542

C. DOCUMENTS CONSIDERED TO BE RELEVANT

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A	US 5122290 A (FOSPUR LIMITED) 16 June 1992 (1992-06-16) see the whole document	1-15
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A	WO 97/25149 A1 (ALLIED COLLOIDS LIMITED ET AL.) 17 July 1997 (1997-07-17) see the whole document	1-15
A	WO 00/09268 A1 (VERSITECH, INC. ET AL.) 24 February 2000 (2000-02-24) see the whole document	1-15
A	US 4158623 A (AMERICAN CYANAMID COMPANY) 19 June 1979 (1979-06-19) see the whole document	1-15

INTERNATIONAL SEARCH REPORT
Information on patent family members

International application No.

PCT/CN2015/073542

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				EP	0270986	B1	01 April 1992
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Information on patent family members

International application No.

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