Claims

1. A composition comprising:

TiO_2 nanocrystals in the form of agglomerates and/or aggregates; and

an SO_4^{2-} as an anionic species associated with the TiO_2 agglomerates/aggregates, wherein:

the diameter of the TiO_2 agglomerates/aggregates is from 0.02 μm to 5.0 μm;

the diameter of the TiO_2 nanocrystals is from 4 to 70 nm;

the BET surface area of the composition is from 6 to 250 m^2/g;

the TiO_2 nanocrystals are substantially in the anatase form;

Ti is present in an amount of from 55.9 wt% to 59.0 wt%;

O is present in an amount of from 40.5 wt% to 41.5 wt%;

S is present in an amount of from 0.01 wt% to 2.6 wt%;

the ratio of the SO_4^{2-} on the surface of the TiO_2 agglomerates/aggregates compared to the SO_4^{2-} within the interior volume of the TiO_2 agglomerates/aggregates is from 2:1 to 10:1.

2. The composition according to Claim 1, wherein the direct band gap of the TiO_2 nanocrystals is from 3.00 to 3.70 eV and/or the indirect band gap of the TiO_2 nanocrystals may be from 2.90 to 3.50 eV.

3. The composition of Claim 1 or Claim 2, wherein the composition has FTIR peaks at approximately 3620-3850 cm^{-1}, 3159 cm^{-1}, 1400 cm^{-1}, 1215 cm^{-1}, 1148 cm^{-1}, 1051 cm^{-1} and 980 cm^{-1}.

4. The composition according to any one of the preceding claims, wherein:

the diameter of the agglomerates/aggregates is from 0.05 μm to 3.0 μm; and/or

the diameter of the TiO_2 nanocrystals is from 5 to 50 nm.

5. The composition according to any one of the preceding claims, wherein the BET surface area of the composition is from 6.0 to 9.0 m^2/g, or from 20.0 to 90.0 m^2/g or from 115 to 250 m^2/g.

6. The composition according to any one of the preceding claims, wherein the ratio of the anionic species on the surface of the TiO_2 agglomerates/aggregates compared to the anionic species within the interior volume of the TiO_2 agglomerates/aggregates is from 3:1 to 8:1.

7. The composition according to Claim 6, wherein the ratio of the anionic species on the surface of the TiO_2 agglomerates/aggregates compared to the anionic species within the interior volume of the TiO_2 agglomerates/aggregates is from 5:1 to 8:1.

8. The composition according to any one of the preceding claims, wherein 0.1 wt% of the composition reduces the dissolved organic carbon in 99.9 wt% of reverse osmosis concentrate by from 70% to 80% after 6 hours of photocatalytic reaction.

9. A method of preparing TiO_2 nanocrystals according to any one of Claims 1 to 8, the method comprising the steps of:

(a) hydrolysing a titanium source in a water/solvent mixture to form a hydrous TiO_2 material;

(b) filtering the hydrous TiO_2 material and washing the filtered hydrous TiO_2 material with a washing solution;

(b) drying and grinding the filtered and washed hydrous TiO_2 material into a powder;

(c) calcinating the powder to form anhydrous TiO_2 nanocrystals; and

(d) optionally further grinding the anhydrous TiO_2 nanocrystals, wherein

the titanium source is titanyl sulfate;
the solvent used in the hydrolysis reaction is ethanol; and
the water/solvent ratio is from 2:1 to 4:1, or only water is used.

10. The method of Claim 9, wherein the hydrolysis is conducted at from 25 to 190°C and/or the calcination step is conducted at a temperature of from 100°C to 1000°C using a temperature ramp of from 0.1°C to 100°C per minute for from 0.1 to 48 hours..

11. The method of Claim 9 or Claim 10, wherein the weight ratio of the titanium source to the solvent/water in the hydrolysis step is from 1:1000 to 10:1.

12. The method of any one of Claims 9 to 11, wherein the washing solution is selected from one or more of 0.01 to 5 M ammonia (aq), methanol, ethanol, isopropanol, acetone, methyl ethyl ketone, methyl isobutyl ketone, methyl formate, ethyl formate, methyl acetate, and ethyl acetate.

13. The method of any one of Claims 9 to 12, wherein step (a) further comprises adding a anionic source to the titanium source and water/solvent mixture, optionally wherein the

anionic source contains one or more (or is capable of producing one or more) anions selected from the group consisting of F^-, Br^-, I^-, PO_4^{3-}, NO_3^-, BO_3^{3-}, and SiO_3^{2-}.

14. Use of the composition or any one of Claims 1 to 8 as a photocatalyst.

15. The use of Claim 14, wherein the photocatalyst is used for:

the treatment of any one of wastewater, drinking water and ROC;

air purification; or

surface self-cleaning.