

Claims

1. A method for tuning a time-domain emissive profile of an upconversion nanoparticle, the method comprising the step of manipulating a rising, decay and/or peak moment of an excited state population.
2. The method of claim 1, wherein manipulation of the rising, decay and/or peak moment of the excited state population is achieved by altering interfacial energy migration (IEM) in the nanoparticles.
3. The method of claim 2, wherein IEM is altered by exposing the nanoparticle to different excitation wavelengths.
4. The method of any one of claims 1 to 3, wherein the nanoparticles are UCNPs.
5. The method of claim 4, wherein the UCNPs comprise one or more of: neodymium, ytterbium, thulium, erbium, lanthanum, cerium, praseodymium, neodymium, promethium, samarium, europium, gadolinium, terbium, dysprosium, holmium, lutetium, scandium and yttrium.
6. The method of claim 5, wherein the UCNPs comprise neodymium, ytterbium, thulium and/or erbium.
7. The method of any one of claims 4 to 6, wherein the UCNPs contain a host material selected from an alkali fluoride, an oxide or an oxysulfide.
8. The method of claim 7, wherein the alkali fluoride is NaGdF₄, Ca₂F, NaYF₄, LiYF₄, NaLuF₄, LiLuF₄ or KMnF₃, and the oxide is Y₂O₃.
9. The method of any one of claims 4 to 8, wherein the UCNPs are core-multi-shell UCNPs.
10. The method of claim 9, wherein the core-multi-shell UCNPs comprise a core, a migration layer and a sensitisation layer.
11. The method of claim 10, wherein the migration layer comprises Yb³⁺.
12. The method of claim 10 or claim 11, wherein the sensitization layer comprises Yb³⁺ and Nd³⁺.
13. The method of any one of claims 10 to 12, wherein the core comprises Yb³⁺, Er³⁺ and/or Tm³⁺.

14. The method of any one of claims 10 to 12, wherein the core comprises Yb³⁺ and Er³⁺ or Yb³⁺ and Tm³⁺.
15. The method of any one of claims 4 to 14, wherein the UCNPs are selected from: core-multi-shell β -NaYF₄: Nd³⁺, Yb³⁺, Tm³⁺ UCNPs and core-multi-shell β -NaYF₄: Nd³⁺, Yb³⁺, Er³⁺ UCNPs.
16. The method of any one of claims 4 to 15, wherein the UCNPs have a coefficient of variation (CV) value less than about 15%, or less than about 10%, or less than about 5%.
17. A multiplex assay method for identifying a luminescent probe in a multiplex assay, the method comprising: stimulating the luminescent probe to produce luminescence, and measuring the rising time, peak moment and/or decay time of the luminescence.
18. The method of claim 17, wherein the multiplex assay is a suspension array.
19. The method of claim 17 or claim 18, further comprising: stimulating a plurality of luminescent probes to produce luminescence; measuring the rising times, peak moments and/or decay times of the luminescence, and identifying one or more probes based on differences in the rising times, peak moments and/or decay times.
20. The method of any one of claims 17 to 19, wherein the rising time, peak moment and/or decay time of the luminescence provide one or more codes.
21. The method of any one of claims 17 to 20, wherein the luminescent probe is a nano-tag, sphere, particle or carrier.
22. The method of any one of claims 17 to 21, wherein the luminescent probe includes one or more nanoparticles.
23. The method of any one of claims 17 to 22, wherein the luminescent probe includes one or more nanoparticles as described above in connection with the first aspect.
24. A method for performing a multiplex assay, the multiplex assay including using, as probes, a plurality of nanoparticles having luminescence profiles possessing different rising times, peak moments and/or decay times, wherein the probes are distinguished from one another based on their differing rising times, peak moments and/or decay times.
25. The method of claim 24, wherein the luminescent probe includes one or more nanoparticles as described above in connection with the first aspect.

26. A method for preparing a library of spectrally distinct nanoparticles comprising:
- (a) providing a plurality of different classes of nanoparticles, wherein each different class of nanoparticle has a luminescence profile possessing distinct rising times, peak moments and/or decay times;
 - (b) varying one or more of the following parameters of the nanoparticles within each class, so as to provide the library of spectrally distinct nanoparticles:
 - core size of the nanoparticles;
 - concentrations of emitter ions and sensitizer ions in the core;
 - thickness of a sensitisation layer;
 - concentration of sensitizer ions in the sensitisation layer; and
 - presence or absence of a passivation layer.
27. The method of claim 26, wherein at least three different classes of nanoparticles are prepared, and each class comprises at least 10 different types of nanoparticles.
28. The method of claim 26 or claim 27, wherein the nanoparticles are UCNPs.
29. The method of any one of claims 26 to 28, wherein the different classes of UCNPs are classes of UCNPs having different combinations of activators and/or sensitizers.
30. The method of claim 28 or claim 29, wherein the UCNPs comprise one or more of: neodymium, ytterbium, thulium, erbium, lanthanum, cerium, praseodymium, neodymium, promethium, samarium, europium, gadolinium, terbium, dysprosium, holmium, lutetium, scandium and yttrium.
31. The method of any one of claims 28 to 30, wherein the UCNPs comprise neodymium, ytterbium, thulium and/or erbium.
32. The method of any one of claims 28 to 31, wherein the UCNPs contain a host material selected from an alkali fluoride, an oxide or an oxysulfide.
33. The method of claim 32, wherein the alkali fluoride is NaGdF_4 , Ca_2F , NaYF_4 , LiYF_4 , NaLuF_4 or LiLuF_4 , KMnF_3 , and the oxide is Y_2O_3 .

34. The method of any one of claims 26 to 33, wherein the plurality of different classes of UCNPs includes at least one class having core-multi-shell UCNPs.
35. The method of claim 34, wherein the core-multi-shell UCNPs comprise a core, a migration layer and a sensitisation layer.
36. The method of claim 35, wherein the migration layer comprises Yb^{3+} .
37. The method of claim 34 or claim 35, wherein the sensitization layer comprises Yb^{3+} and Nd^{3+} .
38. The method of any one of claims 35 to 37, wherein the core comprises Yb^{3+} , Er^{3+} and/or Tm^{3+} .
39. The method of any one of claims 35 to 37, wherein the core comprises Yb^{3+} and Er^{3+} or Yb^{3+} and Tm^{3+} .
40. The method of any one of claims 26 to 39, wherein the plurality of different classes of UCNPs includes the following: core-multi-shell $\beta\text{-NaYF}_4$: Nd^{3+} , Yb^{3+} , Tm^{3+} UCNPs, core-multi-shell $\beta\text{-NaYF}_4$: Nd^{3+} , Yb^{3+} , Er^{3+} UCNPs and $\beta\text{-NaYF}_4$: Yb^{3+} , Tm^{3+} UCNPs.
41. The method of any one of claims 26 to 40, wherein the UCNPs have a coefficient of variation (CV) value less than about 15%, or less than about 10%, or less than about 5%.
42. The method of any one of claims 26 to 41, wherein all of the parameters are varied.
43. A library of spectrally distinct nanoparticles when obtained by the method of any one of claims 26 to 42.
44. Use of the library of spectrally distinct nanoparticles of claim 43 in a multiplex assay, wherein the nanoparticles are used as probes.
45. The use of claim 44, wherein the probes are distinguished from one another based on at least differing rising times, peak moments and/or decay times of their luminescence profiles.
46. The use of claim 44 or claim 45, wherein the probes are decoded using wide-field time-resolved microscopy or deep learning.