Claims

1. A method for performing a multiplex assay, the multiplex assay including using, as probes, a plurality of upconverting nanoparticles (UCNPs) having luminescence profiles,

wherein the UCNPs are core-multi-shell UCNPs, wherein the core-multi-shell UCNPs comprise a core, a migration layer and a sensitisation layer,

wherein the luminescence profiles possess different rising times, peak moments and/or decay times manipulated through an interfacial energy migration (IEM) process, and

wherein the probes are distinguished from one another based on their differing rising times, peak moments and/or decay times.

2. The method of claim 1, 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.

3. The method of claim 1 or claim 2, wherein the UCNPs comprise neodymium, ytterbium, thulium and/or erbium.

4. The method of any one of claims 1 to 3, wherein the UCNPs contain a host material selected from an alkali fluoride selected from $NaGdF_4$, Ca_2F, $NaYF_4$, $LiYF_4$, $NaLuF_4$, $LiLuF_4$, and $KMnF_3$, an oxide which is Y_2O_3, or an oxysulfide.

5. The method of any one of claims 1 to 4, wherein the migration layer comprises Yb^{3+}, and/or

the sensitization layer comprises Yb^{3+} and Nd^{3+}, and/or

the core comprises:

Yb^{3+}, Er^{3+} and/or Tm^{3+}, or

Yb^{3+} and Er^{3+} or Yb^{3+} and Tm^{3+}.

6. The method of any one of claims 1 to 5, wherein the UCNPs are selected from core-multi-shell β-$NaYF_4$: Nd^{3+}, Yb^{3+}, Tm^{3+} UCNPs, core-multi-shell β-$NaYF_4$: Nd^{3+}, Yb^{3+}, Er^{3+} UCNPs and β-$NaYF_4$: Yb^{3+}, Tm^{3+} UCNPs.

7. The method of any one of claims 1 to 6, wherein the UCNPs have a coefficient of variation (CV) value less than about 15%, or less than about 10%, or less than about 5%.

8. A method for preparing a library of spectrally distinct upconverting nanoparticles (UCNPs) comprising:

(a) providing a plurality of different classes of UCNPs, wherein each different class of UCNPs has a luminescence profile possessing distinct rising times, peak moments and/or decay times manipulated through a interfacial energy migration (IEM) process, wherein the UCNPs are core-multi-shell UCNPs, wherein the core-multi-shell UCNPs comprise a core, a migration layer and a sensitisation layer;

(b) varying one or more of the following parameters of the UCNPs within each class, so as to provide the library of spectrally distinct UCNPs:

core size of the UCNPs;

concentrations of emitter ions and sensitiser ions in the core;

thickness of the sensitisation layer;

concentration of sensitiser ions in the sensitisation layer; and

presence or absence of a passivation layer.

9. The method of claim 8, wherein the different classes of UCNPs are classes of UCNPs having different combinations of activators and/or sensitisers.

10. The method of claim 8 or claim 9, 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.

11. The method of any one of claims 8 to 10, wherein the UCNPs comprise neodymium, ytterbium, thulium and/or erbium.

12. The method of any one of claims 8 to 11, wherein the UCNPs contain a host material selected from an alkali fluoride selected from $NaGdF_4$, Ca_2F, $NaYF_4$, $LiYF_4$, $NaLuF_4$, $LiLuF_4$, and $KMnF_3$, an oxide which is Y_2O_3, or an oxysulfide.

13. The method of any one of claims 8 to 12, wherein the migration layer comprises Yb^{3+}, and/or

the sensitization layer comprises Yb^{3+} and Nd^{3+}, and/or

the core comprises:

Yb^{3+}, Er^{3+} and/or Tm^{3+}, or

Yb^{3+} and Er^{3+} or Yb^{3+} and Tm^{3+}.

14. The method of any one of claims 8 to 13, wherein the plurality of different classes of UCNPs includes the following: core-multi-shell β-$NaYF_4$: Nd^{3+}, Yb^{3+}, Tm^{3+} UCNPs, core-multi-shell β-$NaYF_4$: Nd^{3+}, Yb^{3+}, Er^{3+} UCNPs and β-$NaYF_4$: Yb^{3+}, Tm^{3+} UCNPs.

15. The method of any one of claims 8 to 14, wherein the UCNPs have a coefficient of variation (CV) value less than about 15%, or less than about 10%, or less than about 5%.