

Claims

1. A computerized method for processing scattered images obtained by imaging through scattering media, comprising:
 - providing a trained neural network model trained with a training dataset of scattered images comprising associated pairs of low-resolution images and high-resolution images, each image comprising a series of separated bands;
 - receiving an input scattered image by the trained neural network model;
 - processing the input scattered image using the trained neural network model;
 - and
 - generating an output image by the trained neural network model in response to said processing of the input scattered image,
 - wherein the output image has a higher resolution than the input scattered image.
2. The computerized method according to claim 1, further comprising training the neural network model, said training comprising:
 - (a) extracting, from the training dataset, an associated pair of low-resolution and high-resolution images;
 - (b) identifying an input pixel from the low-resolution image and a corresponding true output pixel from the high-resolution image;
 - (c) selecting a cluster of pixels from the low-resolution image, the cluster of pixels surrounding the input pixel;
 - (d) weighting each pixel in a cluster of pixels using a set of weight and bias parameters;
 - (e) generating a processed output pixel from said processing of the cluster of pixels;
 - (f) determining an error between the processed output pixel and the true output pixel;
 - (g) backpropagating the error to adjust the parameters in step (d);
 - (h) iteratively performing steps (d) to (g) to minimize the error,
 - wherein the minimized error is associated with an optimized set of parameters for the neural network model.
3. The computerized method according to claim 2, said training further comprising repeating steps (a) to (h) for each associated pair of images in the training dataset.

4. The computerized method according to claim 2 or 3, wherein step (d) comprises successively weighting each pixel at least twice.
5. The computerized method according to any one of claims 2 to 4, wherein step (e) comprises:
- generating a raw output pixel from said processing of the cluster of pixels;
 - processing the raw output pixel using a logistic function; and
 - generating the processed output pixel from said processing of the raw output pixel.
6. The computerized method according to any one of claims 2 to 5, wherein step (g) is performed using a gradient descent function.
7. The computerized method according to any one of claims 2 to 6, wherein the error comprises a mean squared error.
8. The computerized method according to any one of claims 2 to 7, wherein the scattered images are fluorescence images.
9. A method of imaging a part or the whole of a human or animal body, using an imaging device, comprising:
- a near-infrared light source;
 - a light directing means or apparatus;
 - an array comprising nanocrystals capable of fluorescing upon excitation from light from the near-infrared light source; and
 - a detecting means or apparatus configured to detect light emitted by the nanocrystals,
- where the method comprises the steps of:
- (a) positioning a first side of the part or whole of the human or animal body to be imaged to face the near-infrared light source, light directing means or apparatus and a detecting means or apparatus and a second side of the part or whole of the human or animal body to be imaged to face an array comprising nanocrystals;
 - (b) directing near-infrared light from the near-infrared light source through the first and second surfaces of the part or whole of the human or animal body to be imaged via the light directing means or apparatus and into the array comprising nanocrystals; and
 - (c) detecting fluorescent light released from the nanocrystals using the detecting means or apparatus.

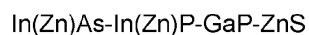
10. The method according to Claim 9, further comprising the step of capturing an image of the part or whole of the human or animal body to be imaged based on the detected fluorescent light, the image being a scattered image.

11. The method according to Claim 10, further comprising the step of processing the scattered image using the computerized method described in any one of Claims 1 to 8 to enhance the scattered image.

12. The method according to any one of Claims 9 to 11, wherein, in the imaging device:

- (a) the near-infrared light source is a laser capable of emitting light at near-infrared wavelengths; and/or
- (b) the light directing means or apparatus comprises a mirror; and/or
- (c) the array comprising giant shell quantum dots is positioned on a moveable platform such that the array is movable relative to the near-infrared light source and/or a light beam from the near-infrared light source is moveable relative to the array; and/or
- (d) the detecting means or apparatus further comprises an imaging apparatus, optionally wherein the detecting means or apparatus further comprises an imaging processing unit.

13. The method according to any one of Claims 9 to 11, wherein, in the imaging device the nanocrystals capable of fluorescing upon excitation from light from the near-infrared light source are giant shell quantum dots having the formula:



wherein:

In(Zn)As is the core of the quantum dot;

In(Zn)P is the giant shell;

GaP represents an interlayer shell between In(Zn)P and ZnS; and

ZnS represents an outer layer shell of the quantum dot.

14. The method according to Claim 13, wherein the quantum dot is one in which one or more of the following apply:

- (a) the ZnS outer layer comprises ZnS and a hydrophobic or a hydrophilic organic compound, optionally wherein the hydrophobic organic compound is oleic acid, optionally wherein the hydrophilic organic compound is mercaptosuccinic acid, further optionally wherein the hydrophilic organic compound is functionalised with a biological targeting agent (e.g. the

biological targeting agent may be selected from one or more of the group consisting of folic acid and a cancer-specific antibody);

(b) the quantum dot displays an emission peak at from 820 to 850 nm, such as from 828 to 837 nm, such as 828 nm or 837 nm; and/or

the quantum dot displays a photoluminescence lifetime of from 20 to 100 ns, such as from 30 to 70 ns, such as from 40 to 60 ns, such as 59 ns; and/or

the quantum dot absorbs light at a wavelength of from 400 to 800 nm; and/or

the quantum dot displays a photoluminescence quantum efficiency of from 60 to 75%;

(c) the quantum dot has an average size according to transmission electron microscopy of from 6 to 7 nm, such as 6.6 nm; and/or

the quantum dot has an average hydrodynamic size of from 8 to 9 nm, such as 8.6 nm;

and

(d) the atomic percentages in the quantum dot are as follows: In from 35 to 45%; As from 1 to 5%; P from 25 to 35%; Zn from 5 to 10%; Ga from 5 to 9%; and S from 8 to 15%, optionally wherein the atomic percentages in the quantum dot are as follows: In from 39.7 to 39.8%; As from 2.2 to 2.3%; P from 31.3 to 31.4%; Zn from 8.5 to 8.6%; Ga from 7.5 to 7.6%; and S from 10.3 to 10.4%.

15. An imaging device comprising:

a near-infrared light source;

a light directing means or apparatus;

an array comprising nanocrystals that are capable of fluorescing upon excitation from light from the near-infrared light source; and

a detecting means or apparatus configured to detect light emitted by the nanocrystals.

16. The imaging device according to Claim 15, wherein:

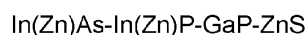
(a) the near-infrared light source is a laser capable of emitting light at near-infrared wavelengths; and/or

(b) the light directing means of apparatus comprises a mirror; and/or

(c) the array comprising nanocrystals is positioned on a moveable platform such that the array is movable relative to the near-infrared light source and/or a light beam from the near-infrared light source is moveable relative to the array.

17. The imaging device according to Claim 15 or Claim 16, wherein the detecting means or apparatus further comprises an imaging apparatus, optionally wherein the detecting means or apparatus further comprises an imaging processing unit.

18. The imaging device according to any one of Claims 15 to 17, wherein, in the imaging device the nanocrystals capable of fluorescing upon excitation from light from the near-infrared light source are giant shell quantum dots having the formula:



wherein:

In(Zn)As is the core of the quantum dot;

In(Zn)P is the giant shell;

GaP represents an interlayer shell between In(Zn)P and ZnS; and
ZnS represents an outer layer shell of the quantum dot.

19. The imaging device according to Claim 18, wherein the quantum dot is one in which one or more of the following apply:

(a) the ZnS outer layer comprises ZnS and a hydrophobic or a hydrophilic organic compound, optionally wherein the hydrophobic organic compound is oleic acid, optionally wherein the hydrophilic organic compound is mercaptosuccinic acid, further optionally wherein the hydrophilic organic compound is functionalised with a biological targeting agent (e.g. the biological targeting agent may be selected from one or more of the group consisting of folic acid and a cancer-specific antibody);

(b) the quantum dot displays an emission peak at from 820 to 850 nm, such as from 828 to 837 nm, such as 828 nm or 837 nm; and/or

the quantum dot displays a photoluminescence lifetime of from 20 to 100 ns, such as from 30 to 70 ns, such as from 40 to 60 ns, such as 59 ns; and/or

the quantum dot absorbs light at a wavelength of from 400 to 800 nm; and/or

the quantum dot displays a photoluminescence quantum efficiency of from 60 to 75%;

(c) the quantum dot has an average size according to transmission electron microscopy of from 6 to 7 nm, such as 6.6 nm; and/or

the quantum dot has an average hydrodynamic size of from 8 to 9 nm, such as 8.6 nm;

and

(d) the atomic percentages in the quantum dot are as follows: In from 35 to 45%; As from 1 to 5%; P from 25 to 35%; Zn from 5 to 10%; Ga from 5 to 9%; and S from 8 to 15%, optionally wherein the atomic percentages in the quantum dot are as follows: In from 39.7 to 39.8%; As from 2.2 to 2.3%; P from 31.3 to 31.4%; Zn from 8.5 to 8.6%; Ga from 7.5 to 7.6%; and S from 10.3 to 10.4%.

20. A method of diagnosis comprising the steps of:

- (a) supplying a plurality of nanocrystals capable of fluorescing upon excitation from light from the near-infrared light source to a subject;
- (b) subjecting a target site on the subject to light irradiation; and
- (c) detecting a signal, or lack thereof, generated by the nanocrystals to provide a diagnosis.

21. The method according to Claim 20, further comprising the step of capturing an image of the target site based on the detected signal, the image being a scattered image.

22. The method according to Claim 20 or Claim 21, further comprising the step of processing the scattered image using the computerized method described in any one of Claims 1 to 8 to enhance the scattered image for the diagnosis.

23. The method according to any one of Claims 20 to 22, wherein, in the imaging device the nanocrystals capable of fluorescing upon excitation from light from the near-infrared light source are giant shell quantum dots having the formula:



wherein:

In(Zn)As is the core of the quantum dot;

In(Zn)P is the giant shell;

GaP represents an interlayer shell between In(Zn)P and ZnS; and

ZnS represents an outer layer shell of the quantum dot.

24. The method according to Claim 23, wherein the quantum dot is one in which one or more of the following apply:

(a) the ZnS outer layer comprises ZnS and a hydrophobic or a hydrophilic organic compound, optionally wherein the hydrophobic organic compound is oleic acid, optionally wherein the hydrophilic organic compound is mercaptosuccinic acid, further optionally wherein the hydrophilic organic compound is functionalised with a biological targeting agent (e.g. the biological targeting agent may be selected from one or more of the group consisting of folic acid and a cancer-specific antibody);

(b) the quantum dot displays an emission peak at from 820 to 850 nm, such as from 828 to 837 nm, such as 828 nm or 837 nm; and/or

the quantum dot displays a photoluminescence lifetime of from 20 to 100 ns, such as from 30 to 70 ns, such as from 40 to 60 ns, such as 59 ns; and/or

the quantum dot absorbs light at a wavelength of from 400 to 800 nm; and/or

the quantum dot displays a photoluminescence quantum efficiency of from 60 to 75%;

(c) the quantum dot has an average size according to transmission electron microscopy of from 6 to 7 nm, such as 6.6 nm; and/or

the quantum dot has an average hydrodynamic size of from 8 to 9 nm, such as 8.6 nm; and

(d) the atomic percentages in the quantum dot are as follows: In from 35 to 45%; As from 1 to 5%; P from 25 to 35%; Zn from 5 to 10%; Ga from 5 to 9%; and S from 8 to 15%, optionally wherein the atomic percentages in the quantum dot are as follows: In from 39.7 to 39.8%; As from 2.2 to 2.3%; P from 31.3 to 31.4%; Zn from 8.5 to 8.6%; Ga from 7.5 to 7.6%; and S from 10.3 to 10.4%.