SHAPE ANALYSIS DEVICE

FIELD OF THE INVENTION

The present invention relates to a device for the characterisation of one or more particles in a fluid sample.

BACKGROUND TO THE INVENTION

The discovery and deployment of new materials requires their detailed characterisation. In the case of emerging materials for environmental (energy, agricultural), healthcare (nanomedicines, therapeutics) or food industry (food, packaging) details such as size, shape, charge, and concentration are essential. There is increasing evidence that properties of materials such as nanomaterials and their applications are not only dependent on the chemical properties of the materials but also the physical and mechanical characteristics of the materials. Rapid, onsite or inline analysis within the manufacturing industry is limited. Current state of the art uses microscopy (electron or optical) which is costly, low throughput and provides limited information of the materials in their natural environment. Solution based techniques include light scattering which can be complicated by flow. Furthermore, it can be difficult to work with multimodal sample sets and turbid solutions. There is also lack of technologies available to quantify shape properties of nano-objects in a high-throughput manner.

An emerging technology over the last two decades, which has become more common place for biological samples such as DNA, are Resistive Pulse Sensors (RPS). Most of the research and commercial activity within RPS has focused on DNA sequencing/analysis. The theory and applications of RPS for nanomaterials is emerging and growing rapidly and is ready to be exploited and applied to the manufacturing of emerging nanomaterials.

The traditional route for analysis of materials is to run the reaction/synthesis, extract and then analyse the products. These workflows are often referred to as batch reactors. The translation of batch synthesis onto continuous flow platforms represent an area of increased research over the last decade. They offer lower production costs, as well as reducing the variation in products from batch-to-batch. However, infrequent sampling/monitoring of the reaction within fluidic reactors limits the benefit of the flow process. Thus, improvements within micro-reactor systems lie in the manufacturing of complete laboratories on a chip. These “lab-on-a-chip” devices guarantee uniform mixing, and fluidic behaviour with integrated continuous inline monitoring of chemical products for high-throughput processing.

It is desirable for a sample mixture to have individual particle sorting and analysis so that the size, charge and concentration of various particles can be determined. Current techniques have a fixed range such that they only measure one type of material. There is a need for high-throughput inline sensors for nanomaterials with single particle resolution, capable of dealing with nano to micro particles.

An emerging fabrication process for microfluidic systems is additive manufacturing (AM) or 3D printing. It is a favourable alternative mainly due to its ability to build a 3D design from an STL (standard tessellation language) file with no intermediate steps, thus minimising labour, time and costs. AM allows bespoke flow channels to be designed and interfaced into for the analytical platform.

SUMMARY

According to an aspect of the present disclosure, there is provided a device for characterisation of one or more particles in a fluid sample, the device comprising:

an inlet;

an outlet;

a microfluidic channel extending between the inlet and the outlet and providing an axial flow path for fluid flowing therealong; and

a first particle sensor for detecting the passage of particles moving along the axial flow path, wherein the first particle sensor comprises: first and second electrodes positioned along the microfluidic channel; and a detection region location at a point along the axial flow path between the first and second electrodes,

wherein, in use, one or more particles flowing along the microfluidic channel are detected by the first particle sensor and passage of said one or more particles is recorded as a pulse,

wherein the device further comprises at least one second particle sensor comprising a nanopore,

wherein the second particle sensor is located downstream of the detection region of the first particle sensor,

wherein the nanopore of the second particle sensor is located in a second channel which extends from the microfluidic channel, and

wherein the nanopore of the second particle sensor does not extend across the full width of the second channel.

In an example, there is provided a device for characterisation of one or more particles in a fluid sample, the device comprising: an inlet; an outlet; a microfluidic channel extending between the inlet and the outlet and providing an axial flow path for fluid flowing therealong; a particle sensor for detecting the passage of particles moving along the axial flow path first and second electrodes positioned along the microfluidic channel; and wherein, in use, one or more particles flowing along the microfluidic channel are detected by the first particle sensor and passage of said one or more particles is recorded as a pulse (e.g. a resistive pulse).

According to an example, there is provided a device for characterisation of one or more particles in a fluid sample, the device comprising: a first particle sensor comprising a base comprising a microfluidic channel, wherein the microfluidic channel comprises a first electrode and a second electrode positioned along the microfluidic channel, and a detection region between the first and second electrodes; an inlet; and an outlet, wherein in use, a fluid sample comprising at least one particle flows in through the inlet, along the microfluidic channel of the first particle sensor, over the first and second electrodes, and exits through the fluid outlet, and wherein the passage of said at least one particle through the detection region is recorded as a pulse (e.g. a resistive pulse).

According to an example, there is provided a computer implemented method, comprising: receiving, as an input from a particle sensor having first and second electrodes, pulse data representing a current pulse corresponding to a particle, and comparing the received data to

prestored characterising shape data representing particles of known shape; determining, based on the comparison, a shape of the at least one particle; and outputting an indication of the determined shape of the particle.

According to an example, there is provided a computer implemented method, comprising: receiving, as an input from a particle sensor having first and second electrodes, pulse data representing a current pulse corresponding to a particle of known shape; and determining a model in dependence on the received data indicative of the particle of known shape.

According to an example, there is provided a computer-implemented method of characterising a nanoparticle, comprising: receiving pulse data indicative of current flow between first and second electrodes associated with a microfluidic channel whilst the nanoparticle passes though the microfluidic channel; classifying the pulse data as corresponding to one of a plurality of predetermined types of nanoparticle using a pulse-shape model.

FIGURES

The present invention will now be described by way of example only and with reference to the accompanying drawings in which:

CLAIMS

1. A device for characterisation of one or more particles in a fluid sample, the device comprising:
an inlet;
an outlet;
a microfluidic channel extending between the inlet and the outlet and providing an axial flow path for fluid flowing therealong; and
a first particle sensor for detecting the passage of particles moving along the axial flow path, wherein the first particle sensor comprises: first and second electrodes positioned along the microfluidic channel; and a detection region location at a point along the axial flow path between the first and second electrodes,
wherein, in use, one or more particles flowing along the microfluidic channel are detected by the first particle sensor and passage of said one or more particles is recorded as a pulse,
wherein the device further comprises at least one second particle sensor comprising a nanopore,
wherein the second particle sensor is located downstream of the detection region of the first particle sensor,
wherein the nanopore of the second particle sensor is located in a second channel which extends from the microfluidic channel, and
wherein the nanopore of the second particle sensor does not extend across the full width of the second channel.

2. The device according to claim 1, wherein the first particle sensor is configured to detect particles of from 1 μm to 100 μm in size.

3. The device according to claim 1 or claim 2, wherein the second particle sensor provides a flow path for particles.

4. The device according to Claim 3, wherein the flow path of the second channel extends obtusely, acutely or orthogonal to the axial flow path.

5. The device according to any of claims 1 to 4, wherein the second particle sensor is configured to detect particles within a different size range to the first particle sensor.

6. The device according to claim 5, wherein the second particle sensor is configured to detect particles of from 1 nm to 1 μm in size.

7. The device according to any one of claims 1 to 6, wherein the second channel extends perpendicularly from the microfluidic channel.

8. The device according to any one of claims 1 to 7, wherein the nanopore of the second particle sensor is a solid state nanopore comprising a hole formed in a membrane.

9. The device according to claim 8, wherein the membrane is formed from a material selected from the group consisting of silicon nitride, silicon dioxide, polyurethane and polyester.

10. The device according to any one of claims 1 to 9, wherein the nanopore is provided in a nanopipette.

11. The device according to any of claims 1 to 10 wherein the second particle sensor comprises an electrode.

12. The device according to any one of claims 1 to 11, wherein the second particle sensor comprises a holder which houses the nanopore and an electrode, wherein the holder has the second channel therein in which the nanopore is located.

13. The device according to claim 12, wherein the holder is in the form of a plug or screw which is releasably inserted into a port of the first particle sensor, such that a fluid connection is formed between the microfluidic channel and the second channel.

14. The device according to any one of claims 1 to 13, wherein the second particle sensor comprises a tube in fluid communication with the second channel, wherein the tube provides a further fluid outlet.

15. The device according to any one of claims 1 to 14, comprising two or more second particle sensors.

16. The device according to claim 15, wherein each of the second particle sensors is configured to detect a different particle size range.

17. The device according to any one of claims 1 to 16, wherein the device comprises a flow regulator adapted to control the fluid flow through the second particle sensor.

18. The device according to any preceding claim, wherein the device comprises a third sensor configured for measuring a parameter of the fluid.

19. The device according to claim 18, wherein the parameter is selected from temperature, pH, oxygen content, ionic strength and viscosity.

20. The device according to any preceding claim, wherein the first particle sensor comprises a base comprising the microfluidic channel, wherein the device further comprises a lid which is configured to be located on the base and to seal the microfluidic channel.

21. The device according to claim 20, wherein the lid comprises a primary ridge which is configured to be received within the microfluidic channel, thereby reducing the volume of the channel.

22. The device according to claim 21, wherein the primary ridge further comprises a secondary ridge extending from the primary ridge, thereby creating a constriction within the channel.

23. The device according to claim 22, wherein the primary ridge and the secondary ridge together span the height and width of the microfluidic channel, and wherein the secondary ridge comprises a conduit which allows fluid to flow through the secondary ridge when the lid seals the microfluidic channel.

24. The device according to any one of claims 20 to 23, wherein the lid comprises a polymer layer on a surface of the lid which mates with the base so as to seal the microfluidic channel.

25. The device according to claim 24, wherein the polymer layer is a polydimethyl siloxane (PDMS).

26. The device according to any one of claims 20 to 25, wherein the lid is attached to the or a base with one or more screws.

27. The device according to claim 26 when dependent on claim 24, wherein upon tightening the screws the polymer layer can be forced into the microfluidic channel, thereby reducing the volume of the channel.

28. The device according to any one of claims 20 to 27, wherein the base further comprises a groove which comprises an O-ring which surrounds the microfluidic channel and is configured to prevent leaks from the microfluidic channel.

29. The device according to any preceding claim, wherein the device is configured on a chip.