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(72) Inventor(s):	Benjamin Hardy Wunsch Joshua Thomas Smith Sung-Cheol Kim Stacey Gifford
(73) Proprietor(s):	International Business Machines Corporation (Incorporated in USA - New York) New Orchard Road, Armonk, New York 10504, United States of America
(74) Agent and/or Address for Service:	IBM United Kingdom Limited Intellectual Property Department, Hursley Park, Winchester, Hampshire, SO21 2JN, United Kingdom

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Additional Fields

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Other: **WPI, EPODOC**

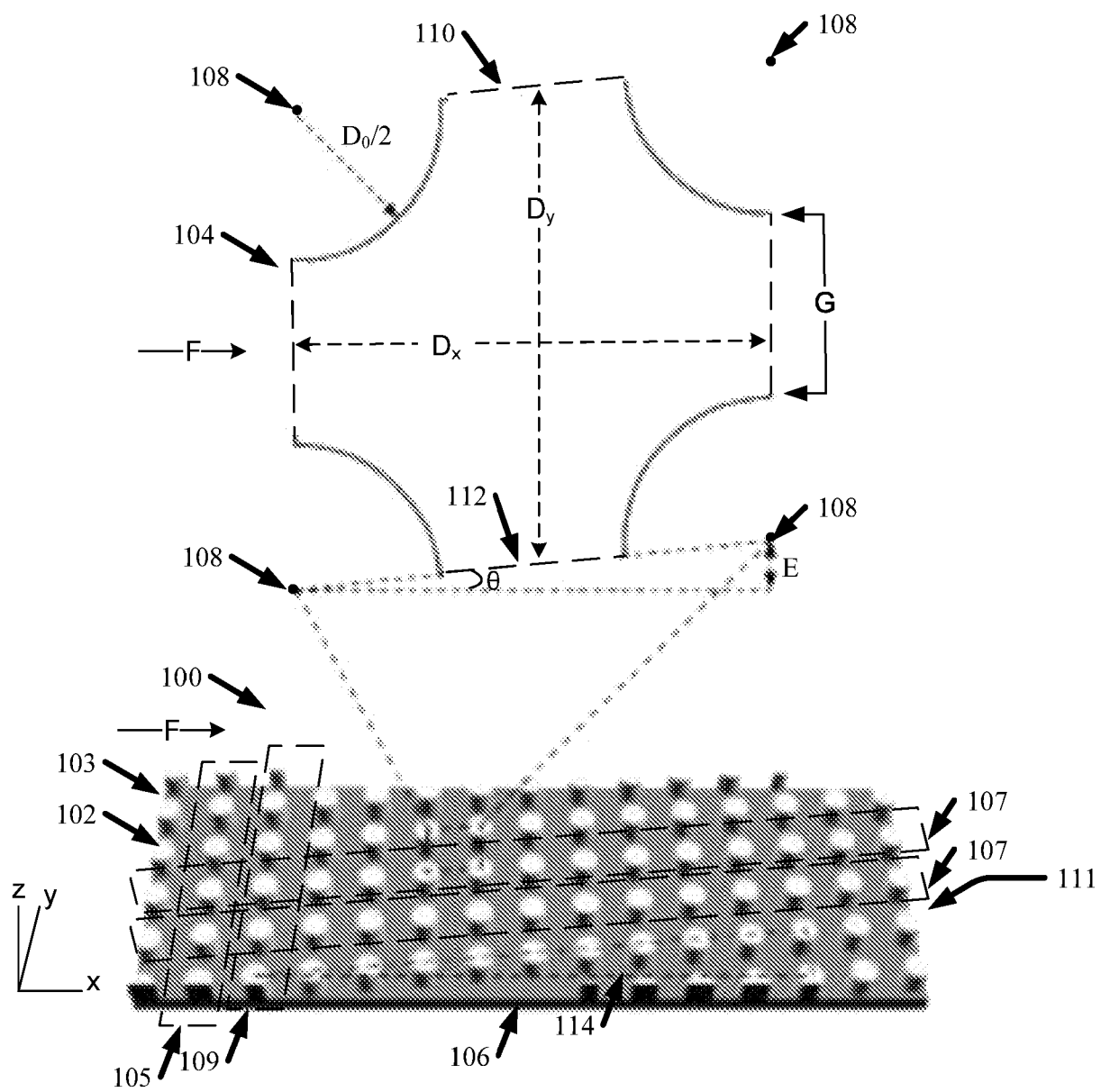


FIG. 1

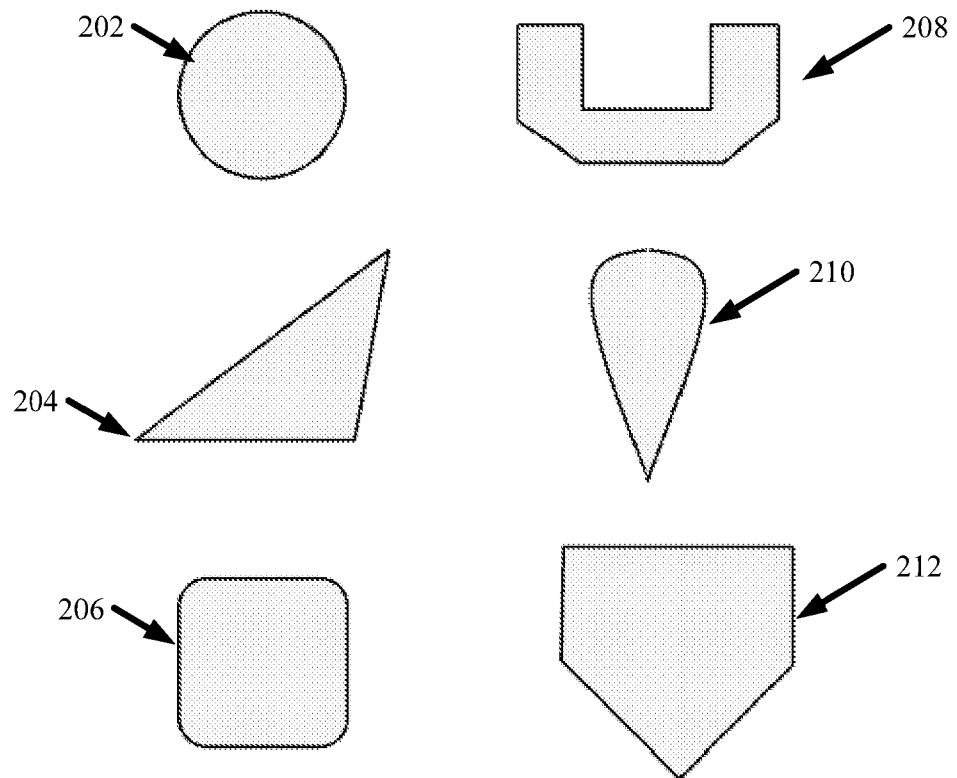
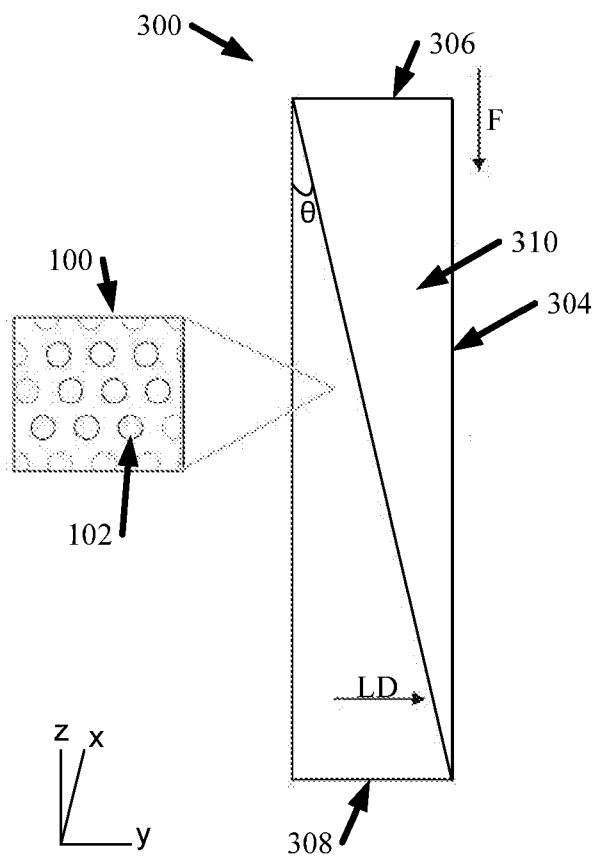
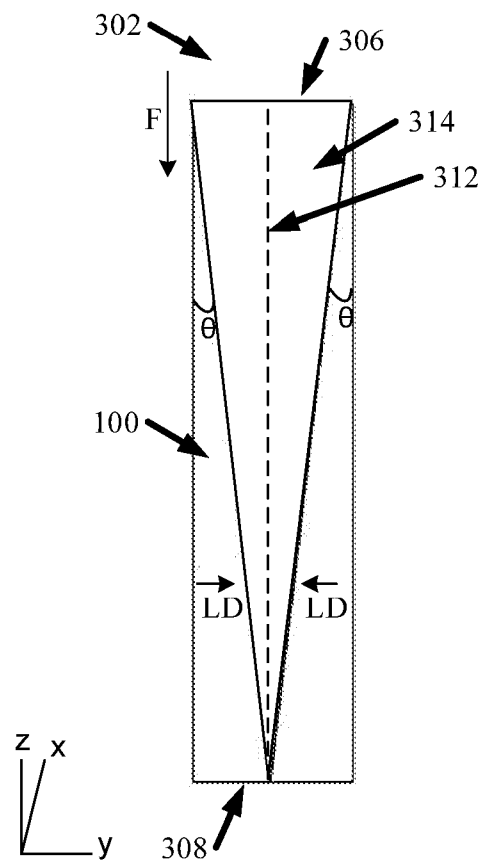


FIG. 2

**FIG. 3A****FIG. 3B**

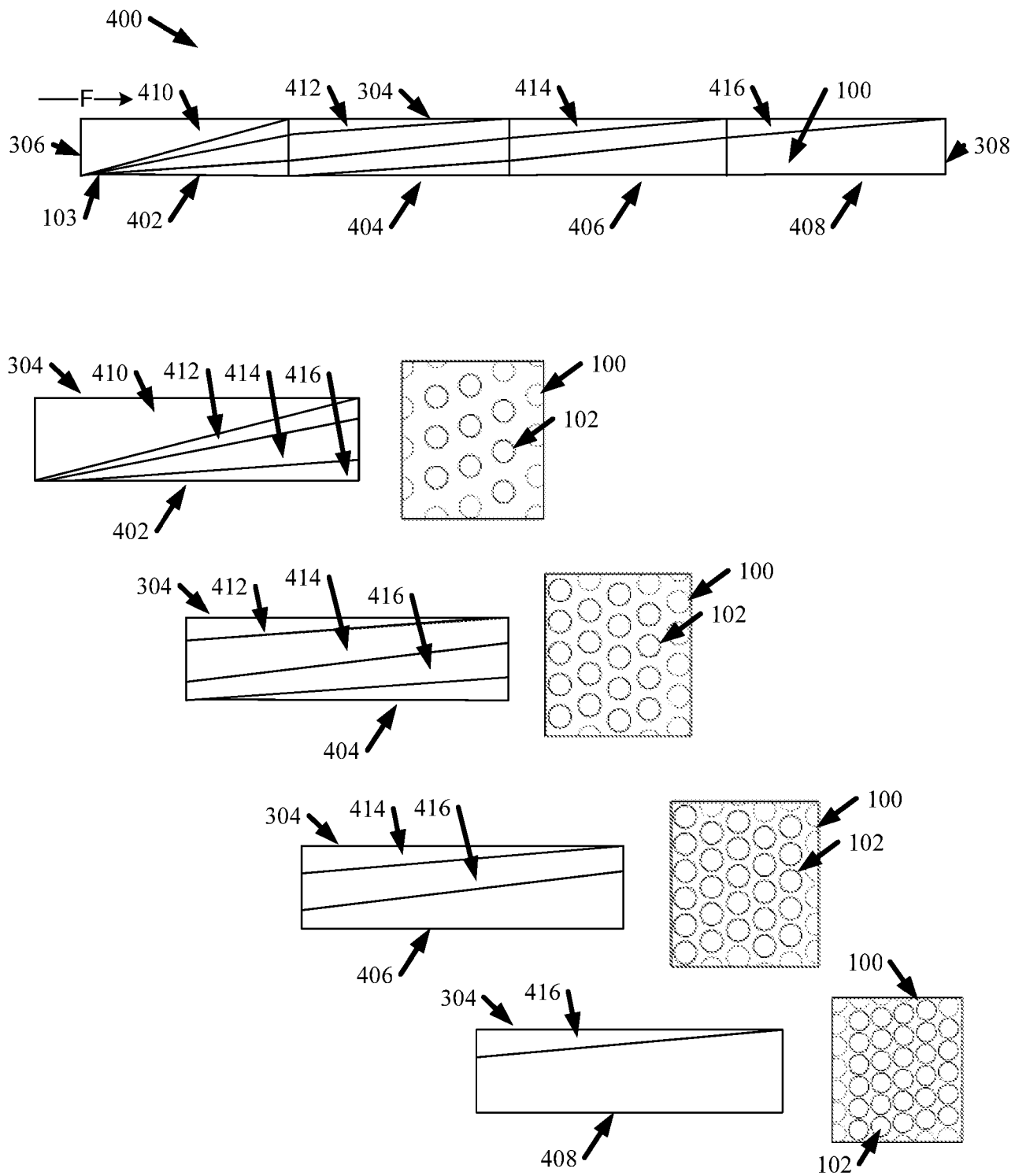


FIG. 4

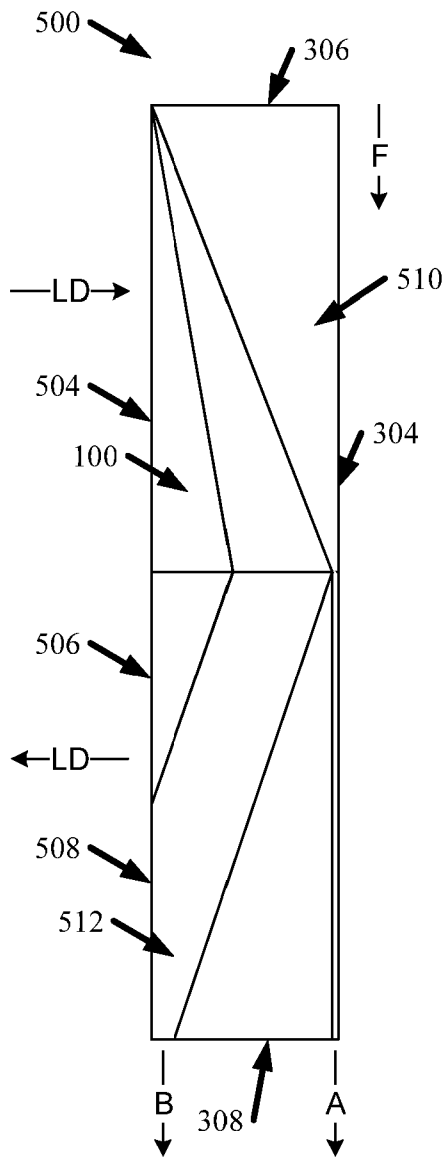


FIG. 5A

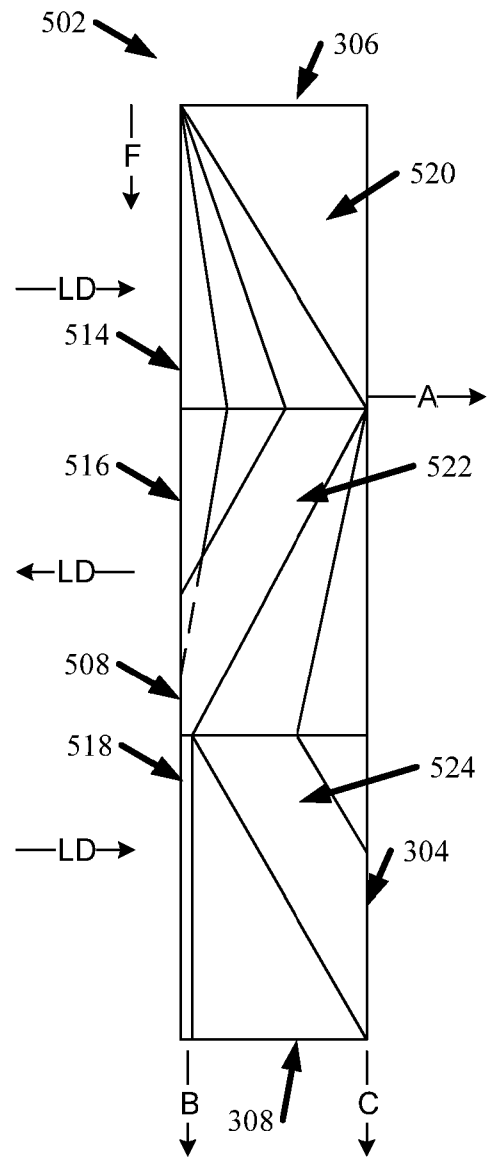
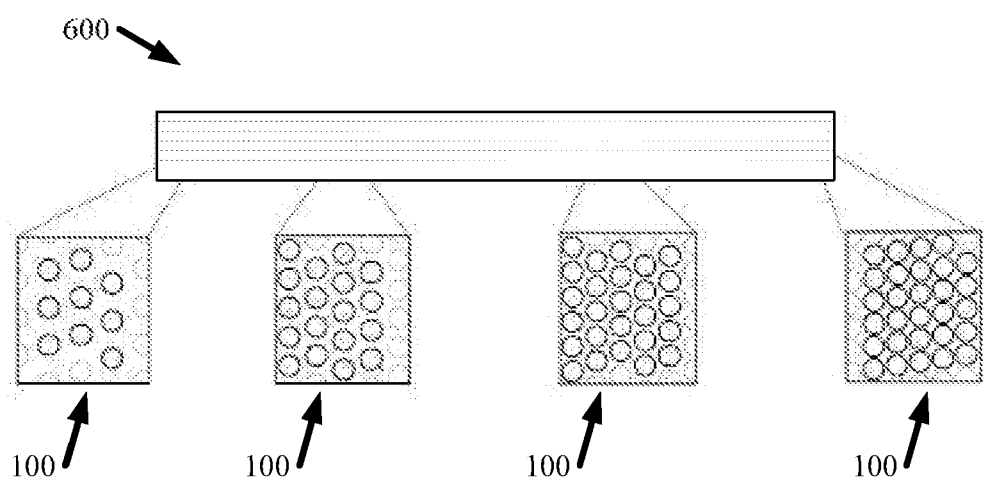


FIG. 5B

**FIG. 6**

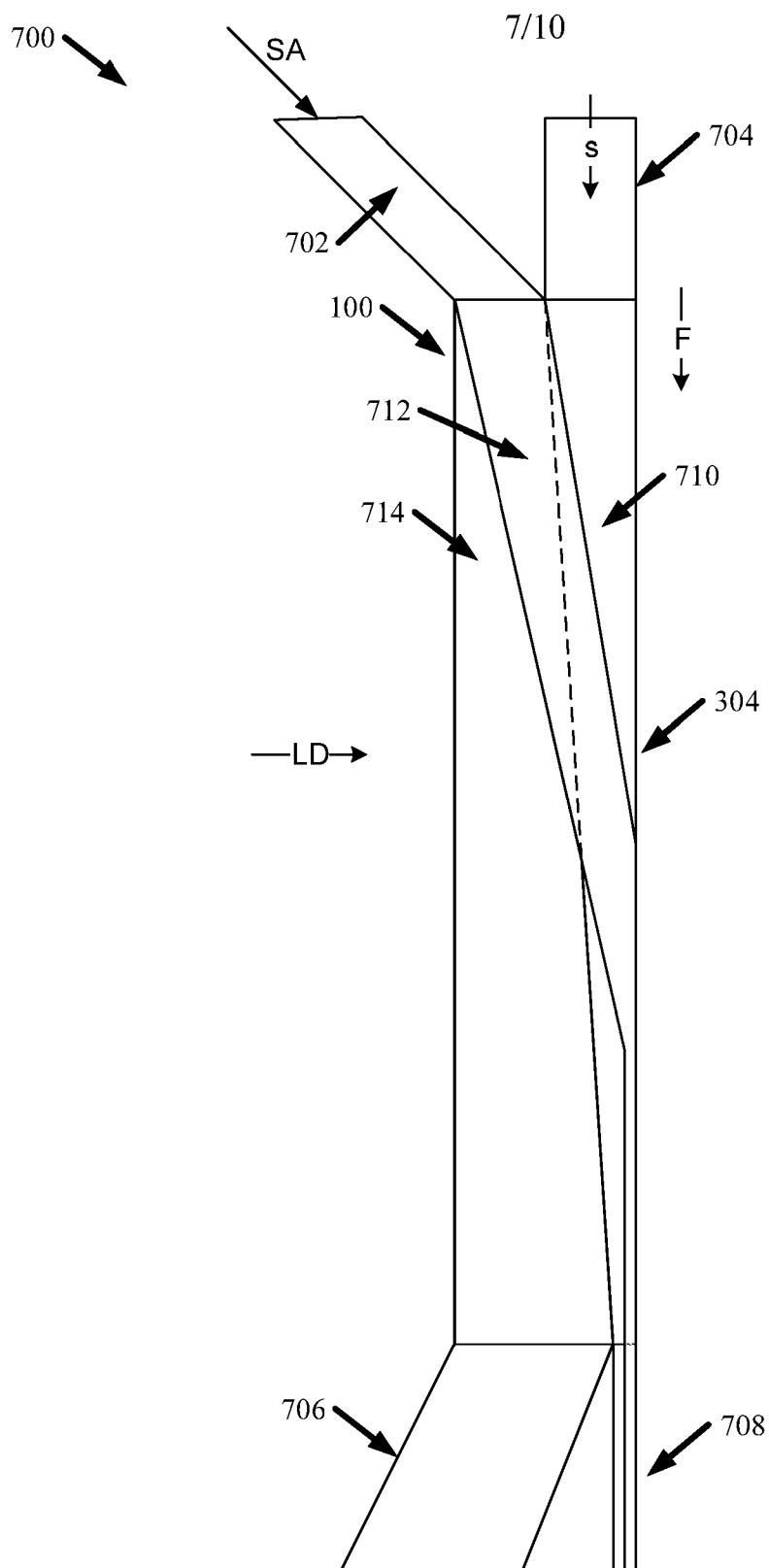
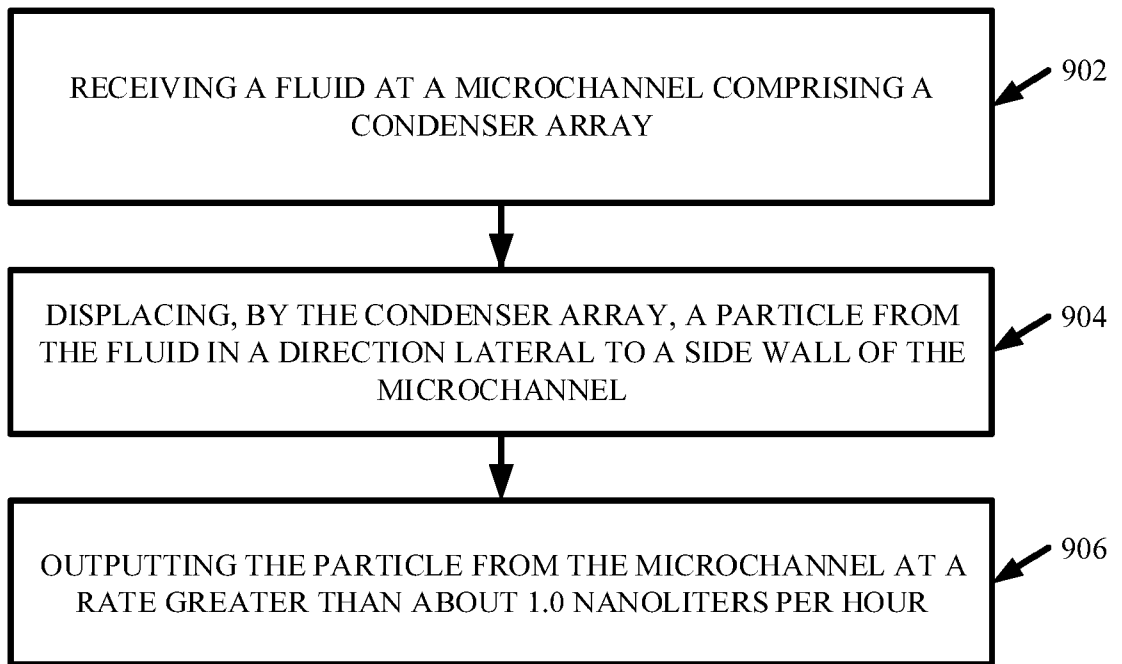
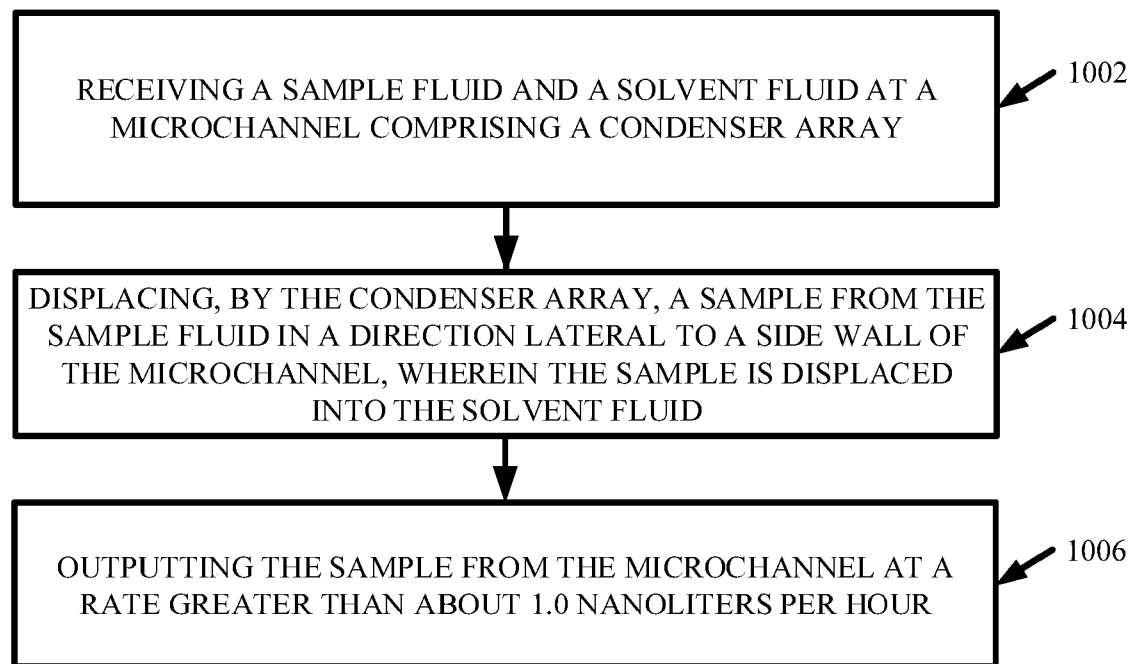


FIG. 7

900 →

FIG. 9



1000 **FIG. 10**

MICROSCALE AND MESOSCALE CONDENSER DEVICES

BACKGROUND

[0001] The present invention relates to microscale and/or mesoscale condenser devices, and more specifically to microscale and/or mesoscale condenser arrays for microfluidic separation and/or purification of mesoscale and/or nanoscale particles.

[0002] The ability to purify particles (e.g., colloids) is important for practical applications and analysis of nanomaterials. Nowhere is this more vital than in biology and medicine, where bio-colloids ranging from proteins, vesicles and organelles, constitute the molecular building blocks of all living things. Purification typically makes a spatial requirement: desired colloids can be transferred to a specific space, thereby removing them from other contaminants and undesired species. Much of nanotechnology and biotechnology has been concerned with purification techniques, including gel electrophoresis, chromatography, centrifugation, affinity binding and molecular sieving. In all of these techniques, energy is expended to physically transfer a colloidal species from a mixture into a non-contaminated solvent, effecting purification.

[0003] Despite the successes of established purification techniques, the emerging field of lab-on-a-chip and/or microfluidic technologies has posed a challenge to these classical methods. The need to purify small quantities of sample rapidly and precisely on chip, particularly for rare samples or remote locations, has negated many of the previous advantages of colloidal purification technologies, such as centrifugation and/or affinity methods, which can require large machinery or fragile chemistries to operate. New technologies, based on periodic nanostructures or “metamaterials” have proven effective for on-chip purification systems, one example being microscale and nanoscale deterministic lateral displacement (“nanoDLD”), which uses asymmetric mesoscale pillar arrays to laterally displace jets of colloid mixtures into size-sorted streams. A variation on this method, termed nanoscale condenser arrays (“nCA”), produces lateral splitting of colloid mixtures in a flowing stream using manipulation of the fluid flow itself, producing a nearly size-agnostic method of displacing particles.

[0004] Despite the advantage of on-chip metamaterial approaches such as nanoDLD and nCA, there remains an issue of throughput. Techniques such as nanoDLD and nCA have extremely low flow rates (e.g. < 1 nanoliter per hour (nL/hr)) owing to nanoscale dimensional confinement effects on fluid flow, and on-chip electrophoresis methods produce no appreciable mass flow, making the preparation of samples from on-chip technologies highly impractical. This leaves an unsatisfied space in lab-on-a-chip technology, in which chips can process samples but cannot render enough of the product for further analysis (e.g., either on-chip or off-chip).

SUMMARY

[0005] The following presents a summary to provide a basic understanding of one or more embodiments of the invention. This summary is not intended to identify key or critical elements, or delineate scope of the invention or any scope of the claims. Its sole purpose is to present concepts in a simplified form as a prelude to the more detailed description that is presented later. In embodiments of the invention described herein, apparatuses and/or methods regarding to microscale and/or mesoscale condenser arrays for microfluidic separation and/or purification of mesoscale and/or nanoscale particles are described.

[0006] According to the present invention there are provided an apparatus according to the independent claims.

[0007] Reserved.

[0008] Reserved.

[0009] Reserved.

BRIEF DESCRIPTION OF THE DRAWINGS

[0010] FIG. 1 is a diagram of condenser array embodying the invention;

[0011] FIG. 2 is a diagram of pillar shapes of a condenser array embodying the invention;

[0012] FIG. 3A is a diagram of a condenser array embodying the invention for displacing one or more particles towards a collection wall;

[0013] FIG. 3B is a diagram of a condenser array embodying the invention for displacing one or more particles towards a sub-channel;

[0014] FIG. 4 is a diagram of a condenser array embodying the invention comprising a plurality of stages with varying pillar gaps;

[0015] FIG. 5A is a diagram of a condenser array embodying the invention comprising a plurality of states with varying displacement directions;

[0016] FIG. 5B is a diagram of a condenser array embodying the invention comprising a plurality of states with varying displacement directions;

[0017] FIG. 6 illustrates a diagram of an example, non-limiting condenser array that can comprise a pillar gap gradient in accordance with one or more embodiments described herein.

[0018] FIG. 7 is a diagram of a condenser array embodying the invention for displacing one or more particles towards a collection wall to facilitate microfluidic purification;

[0019] FIG. 8 is a diagram of a condenser array embodying the invention for displacing one or more particles towards a collection channel to facilitate microfluidic purification;

[0020] FIG. 9 is a flow diagram of a method embodying the invention for facilitating microfluidic separation via one or more condenser arrays; and,

[0021] FIG. 10 is a flow diagram of a method embodying the invention for facilitating microfluidic purification via one or more condenser arrays.

DETAILED DESCRIPTION

[0022] The following detailed description is merely illustrative and is not intended to limit the invention and/or application or uses of the invention. Furthermore, there is no intention to be bound by any expressed or implied information presented in the preceding Background or Summary sections, or in the Detailed Description section.

[0023] One or more embodiments of the invention are now described with reference to the drawings, wherein like referenced numerals are used to refer to like elements throughout. In the following description, for purposes of explanation, numerous specific details are set forth in order to provide a more thorough understanding of the invention. It is evident, however, in various cases, that embodiments of the invention can be practiced without these specific details.

[0024] FIG. 1 is a diagram of a condenser array 100 embodying the invention. The array 100 is located within a microchannel 103 and comprises a plurality of pillars 102. The array 100 operates on a principle of hydrodynamic chaos facilitated by one or more lattice structures 104 defined by the pillars 102. The array 100 may be a microscale condenser array and/or a mesoscale condenser array. For example, the array 100 may have one or more geometries on the microscale and/or the mesoscale. As used herein, the term “microscale” refers to devices, apparatuses, and/or features having one or more characteristic dimensions greater than or equal to 1 micrometer and less than or equal to 999 micrometers. As used herein, the term “mesoscale” refers to devices, apparatuses, and/or features having one or more characteristic dimensions greater than or equal to 0.1 millimeters and less than or equal to 100 millimeters.

[0025] A fluid flows through the microchannel 103, and thereby the array 100, in a direction indicated by the arrow “F” in FIG. 1. When a fluid flow F is directed through the array 100, the pillars 102 deflect the fluid itself, causing a minor lateral component to the fluid flow which does not average out over the length of the microchannel 103. A net lateral displacement of the fluid laterally moves particles of the fluid; and thereby effects a spatial displacement or “condensation” within the array 100. The array 100 concentrates particles into a concentrated stream. Further, the concentrated stream may comprise particles of a particular size or particles of various sizes.

[0026] Condensing particles (e.g., colloids) of the fluid into a concentrated stream is useful for concentrating a sample and/or preparing a sample for further separation into streams based on size/chemistry for purification. Since the array 100 manipulates the fluid flow itself, particles within the fluid, regardless of size, experience the same lateral displacement. The condensing (e.g., the lateral fluid displacement) achieved by the array 100

depends on the geometry of the lattice structures 104 and/or the pillars 102. Previous art has specified the geometry only on the nanoscale (e.g., less than 500 nanometers (nm) for all dimensions). The condenser array 100 may comprise a microscale structure that manipulates nano-size particles.

[0027] As shown in FIG. 1, the pillars 102 are arranged in columns (e.g., column 105 traversing the microchannel 103 along the “y” axis) and rows (e.g., row 107 traversing the microchannel 103 along the “x” axis). Additionally, adjacent columns 105, 109 comprising the pillars 102 can be arranged offset each other (e.g., along the y axis), thereby positioning the rows at an angle to walls 106 of the microchannel 103. FIG. 1 shows an expanded view of a lattice structure 104 defined by four pillars (e.g., pillar 102 can be an example of one of the four pillars).

[0028] The lattice structure 104 is defined by four pillars of the pillars (e.g., where one or more pillars can be as shown at pillar 102). The lattice structure 104 may be located throughout the array 100 or at a portion of the array 100. Further, the four pillars 102 can be adjacent to each other. For example, two adjacent pillars 102 of a column 105 and two adjacent pillars 102 of a row 107 can define a lattice structure 104, wherein the column 105 and the row 107 can be adjacent to each other. FIG. 1 shows an example of four exemplary pillars 102, which defines a lattice structure 104, with dashed lines. Further, as shown in FIG. 1, dashed lines delineate an expanded view of a lattice structure 104 defined by the four pillars 102. One of ordinary skill in the art will recognize, that the array 100 may comprise one or more lattice structures 104 in one or more locations within the microchannel 100 other than the location of the expanded lattice structure 104 shown in FIG. 1.

[0029] As shown in FIG. 1, “E” represents a lateral shift between centers 108 of pillars 102 of sequential columns. The lateral shift (e.g., represented by E) between sequential columns of pillars 102 is characterized by formula 1: D_y/N . The lateral shift (e.g., represented by E) of the array 100 may be greater than or equal 0.01 and/or less than or equal to 0.3.

[0030] As shown in FIG. 1, “ D_y ” represents a first distance across the lattice structure 104 along the y axis of the array 100. D_y extends from a first boundary 110 of the lattice structure 104 to a second boundary 112 of the lattice structure 104. Further, the first boundary 110 can be defined by a first center line of a first row 107 of pillars 102, and the second boundary 112 is defined by a second center line of a second row 107 of pillars 102; wherein the first row 107 and the second row 107 may be adjacent to each other. D_y may be greater than or equal to 1 μm and/or less than or equal to 100 μm .

[0031] As shown in FIG. 1, "N" represents a number of sequential columns to overcome the lateral shift and place two columns in alignment. For example, for the array 100 shown in FIG. 1, N is equal 10 as indicated by the dashed triangle 114, which exemplifies the lateral shift.

[0032] Further, as shown in FIG. 1, " D_x " represents a second distance across the lattice structure 104 along the x axis of the array 100. D_x can extend from a third boundary 116 of the lattice structure 104 to a fourth boundary 118 of the lattice structure 104. Further, the third boundary 116 can be defined by a third center line of a first column 105 of pillars 102, and the fourth boundary 118 can be defined by a fourth center line of a second column 105 of pillars 102; wherein the first column 105 and the second column 105 may be adjacent to each other. Additionally, D_y is measured along a first direction (e.g., along the y axis of the array 100) orthogonal to a second direction (e.g., along the x axis of the array 100), along which the D_x is measured. D_x may be greater than or equal to 1 μm and less than or equal to 100 μm .

[0033] Moreover, as shown in FIG. 1 " D_0 " represents a diameter of the pillars 102 defining a subject lattice structure 104. D_0 may be greater than or equal to 0.5 μm and/or less than or equal to 99.5 μm . Further, the pillars 102 may have a height greater than or equal to 1 μm and/or less than or equal to 100 μm . As shown in FIG. 1, "G" represents a pillar gap between adjacent pillars 102 of the same column 105. The array 100 may have a G of greater than or equal to 0.5 micrometers (μm) and/or less than or equal to 100 μm . Further, as shown in FIG. 1, " θ " represents an angle respective of a wall 106 of the microchannel 103. θ may be greater than 0 degrees and less than 90 degrees.

[0034] A lattice ratio of the lattice structure 104 is characterized by formula 2: D_x/D_y . The lattice ratio may be greater than 0.1 and/or less than or equal to 1.0 to facilitate operation of the array 100. Additionally, a geometry ratio of the array 100 is characterized by formula 3: D_0/D_y . The geometry ratio may be greater than 0.1 and less than or equal to 1.0 to facilitate operation of the array 100. Additionally, the array 100 may comprise greater than or equal 100 columns of pillars 102 to facilitate operation. For example, the array 100 may have an overall length (e.g., along the x axis) greater than or equal to 0.1 millimeters (mm) and less than or equal to 10 mm. An array 100 comprising one or more of the geometries described herein may facilitate microscale and/or mesoscale array 100 structures and/or facilitate high throughput rates.

[0035] FIG. 2 is a diagram of shapes of the pillars (e.g., pillar 102). FIG. 2 shows cross sections of example pillars 102. While FIG. 2 depicts six exemplary shapes, the architecture of the pillars 102 is not so limited. One of ordinary skill in the art will recognize that the pillars (e.g., pillar 102) may be formed as alternative shapes from the ones depicted in FIG. 2 and other geometric dimensions (e.g., regarding the array 100 and/or the lattice structure

104) may be facilitated based on the information described herein. FIG. 2 shows a circular shape 202, a triangular shape 204, a square shape 206, a U-shape 208, a napiform shape 210, a pentagonal shape 212 (e.g., an irregular pentagon).

[0036] FIGs. 3A and 3B are diagrams of microchannels 300, 302. In FIGs. 3A and 3B the array 100 traverses the entirety of the microchannel 300, 302; however, the array 100 can traverse a portion of the microchannel 300, 302. One or more of the microchannels 300, 302 may have the structure and/or functionality of microchannel 103.

[0037] The lateral shift (e.g., represented by E in FIG. 1) defines the angle (e.g., represented by θ) of the rows of pillars 102 along the axial length (e.g., along the x axis) of the microchannel 300, 302. In turn, the angle (e.g., represented by θ) defines a lateral displacement direction (e.g., represented by arrow "LD") for the condenser array 100. The lateral displacement direction (e.g., represented by arrow LD) indicates a direction in which particles are displaced. A fluid may flow (e.g., in a fluid direction indicated by arrow F) through the array 100 at a steady state, effected by an external driving force such as electro-osmotic flow, pressure driven flow, capillary flow, a combination thereof, and/or the like.

[0038] The microchannel 300 shown in FIG. 3A may be a wall-focused microchannel, wherein particles are displaced in a lateral displacement direction (e.g., indicated by arrow LD) towards a collection wall 304. Further, particles collect along the collection wall 304, thereby forming a concentrated stream of particles. A fluid is provided to the array 100 via an inlet side 306 of the microchannel 300. The fluid flows (e.g., in a direction indicated by arrow F) through the array 100 to an outlet side 308 of the microchannel 300, wherein the fluid and particles exit the array 100 and microchannel 300. As the fluid flows through the array 100, particles within the fluid are displaced (e.g., in a direction indicated by arrow LD) towards the collection wall 304. As particles collect along the collection wall 304, the particles form a concentrated stream that exits the array 100 through a portion of the outlet side 308 of the microchannel 300. In FIG. 3A, the flow of particles through the array 100 is exemplified by a region 310. Thus, the microchannel 300 (e.g., a wall-focused microchannel) comprises a single lateral displacement direction (e.g., indicated by arrow LD), which pushes particles against the collection wall 304, effecting condensation of the inlet stream into a concentrated stream.

[0039] The microchannel 302 shown in FIG. 3B is a channel-focused microchannel, wherein the fluid is displaced in a plurality of lateral directions (e.g., indicated by arrows LD) towards a collection channel 312 (e.g., a sub-channel). Further, particles collect along the collection channel 312 forming a concentrated stream of particles. Fluid is provided to the array 100 via an inlet side 306 of the microchannel 302. The fluid flows (e.g., in a direction indicated by arrow F) through the array 100 to an outlet side 308 of the microchannel 302, wherein the fluid and particles exit the array 100 and the microchannel 302. As the fluid flows through the array 100, particles are

displaced in a first lateral displacement direction towards the collection channel 312 and other particles are displaced in a second lateral displacement direction towards the collection channel 312. In other words, lattice structures 104 of the array 100 can be configured to displace particles in the first lateral displacement direction, while other lattice structures 104 of the array 100 can be configured to displace particles in the second lateral displacement direction.

[0040] As particles collect along the collection channel 312 the particles form a concentrated stream that exits a portion of the outlet side 308 of the microchannel 302. In FIG. 3B, the flow of particles through the array 100 is exemplified by a region 314. Thus, microchannel 302 (e.g., a channel-focused microchannel) comprises a mirror plane with two opposing lateral flows, which pushes particles into a single stream within the array 100, termed the collection channel 312.

[0041] The collection channel 312 may be located at any coordinate along the lateral width of the microchannel (e.g., along the y axis) by scaling two sections of the pillars 102 (e.g., two portions of the condenser array 100). While FIG. 3B shows the collection channel 312 located along the middle of the array 100, the collection channel 312 may be located further to the left or right of the location shown in FIG. 3B. Furthermore, the lateral directions (e.g., indicated by arrows LD) may be reflected outward to displace particles against both walls of the microchannel 302.

[0042] The array 100 may comprise uniform geometries or varying geometries. For example, FIG. 4 is a diagram of a microchannel 400 comprising varying geometries. Microchannel 400 comprises a array 100 with a plurality of stages having respective geometries or a plurality of adjacent arrays 100 with respective geometries. For sake of simplicity, microchannel 400 is described herein as comprising a array 100 with a plurality of stages, each of which can have different geometries. The microchannel 400 may have the structure and/or functionality of microchannels 103, 300, 302.

[0043] Fluid flows through the microchannel 400 from the inlet side 306 to the outlet side 308 (e.g., in a direction indicated by arrow F). As fluid flows through the microchannel 400, the fluid is manipulated by an array 100. The array 100 comprises a plurality of stages, such as a first stage 402, a second stage 404, a third stage 406, and a fourth stage 408. While FIG. 4 shows four stages, additional or fewer stages are also envisaged. The array 100 may comprise any number of required stages such that the hydrodynamic resistance does not impede required throughput. Each stage of the array 100 can be characterized by different geometries, which include, but are not limited to: different pillar 102 widths (e.g., represented by D_0), different pillar 102 heights, different pillar 102 shapes, different pillar 102 gaps (e.g., represented by G), different lateral shifts (e.g., represented by E), different pillar 102 row angles (e.g., represented by θ), different first distances (e.g., represented by D_y), different second distances (e.g., represented by D_x), different lattice ratios, different geometry ratios, a combination thereof, and/or

the like. FIG. 4 shows that the pillar 102 gap (e.g., represented by G) may narrow with each sequential stage of the array 100 of the microchannel 400.

[0044] As fluid flows through the array 100, it is manipulated differently by each stage. Each stage of the array 100 may have a different pillar gap size (e.g., represented by G), thereby causing a different angle of deflection for four different colloid species, A through D. The size of the colloid species may vary and may be characterized as $A > B > C > D$. The first stage 402 displaces the largest colloid species, A, against the collection wall 304, where it is isolated by a side channel or outlet. Each additional stage has a modified geometry ratio (e.g., characterized by D_0/D_y), which increases the angle of deflection for the next largest colloid, allowing a systematic condensation and isolation of all colloidal species. In other words: the second stage 404 displaces the second largest colloid species, B, against the collection wall 304, where it can be isolated by another side channel or outlet; the third stage 406 displaces the third largest colloid species, C, against the collection wall 304, where it can be isolated by another side channel or outlet; and the fourth stage 408 displaces the fourth largest colloid species, D, against the collection wall 304, where it can be isolated by another side channel or outlet. As shown in FIG. 4, the third region 410 depicts a flow path of the largest colloid species A, the fourth region 412 depicts flow path of the second largest colloid species B, the fifth region 414 depicts a flow path of the third largest colloid species C, and the sixth region 416 depicts a flow path of the fourth largest colloid species D. This allows multiple colloid species to be purified from a single fluid stream based on size.

[0045] FIGs. 5A and 5B are diagrams of microchannels 500, 502 comprising arrays 100 that facilitate displacement of particles in multiple lateral displacement directions. The arrays 100 of microchannel 500 and microchannel 502 comprise a plurality of stages, which exhibit multiple lateral displacement directions.

[0046] Regarding FIG. 5A, fluid can flow through microchannel 500 (e.g., in a fluid direction indicated by arrow F) from an inlet side 306 to an outlet side 308. As the fluid flows through microchannel 500 the array 100 displaces respective particle species within the fluid in varying lateral displacement directions (e.g., as indicated by arrows LD). For example, a fifth stage 504 of the array 100 displaces the fluid in a first lateral displacement direction (e.g., to the right in FIG. 5A as indicated by arrow LD). Thereby a first colloid species (e.g., A) is displaced along the collection wall 304 and form a concentrated stream that exits the array 100 by the outlet side 308 (e.g., as depicted by arrow A). Also, a sixth stage 506 of the array 100 displaces the fluid in a second lateral displacement direction (e.g., to the left in FIG. 5A as indicated by arrow LD). Thereby a second colloid species (e.g., B) is displaced along a second collection wall 508 and form another concentrated stream that exits the array 100 by the outlet side 308 (e.g., as depicted by arrow B). The seventh region 510 depicts a flow path of the first colloid species (e.g., A) through the array 100. The eighth region 512 depicts a flow path of the second colloid species (e.g., B) through the array 100.

[0047] Regarding FIG. 5B, fluid can flow through microchannel 502 (e.g., in a fluid direction indicated by arrow F) from an inlet side 306 to an outlet side 308. As the fluid flows through microchannel 502 the array 100 displaces respective particle species within the fluid in varying lateral displacement directions (e.g., as indicated by arrows LD). For example, a seventh stage 514 of the array 100 displaces the fluid in a first lateral displacement direction (e.g., to the right in FIG. 5B as indicated by arrow LD). Thereby a first colloid species (e.g., A) is displaced along the collection wall 304 and form a concentrated stream that exits the array 100 by a side outlet (e.g., as depicted by arrow A). Also, an eighth stage 516 of the array 100 displaces the fluid in a second lateral displacement direction (e.g., to the left in FIG. 5A as indicated by arrow LD). Thereby a second colloid species (e.g., B) can be displaced along a second collection wall 508 and form another concentrated stream that exits the array 100 by the outlet side 308 (e.g., as depicted by arrow B). Further, a ninth stage 518 of the condenser array 100 displaces the fluid in the first lateral displacement direction again. Thereby a third colloid species (e.g., C) is displaced along the collection wall 304 and form another concentrated stream that exits the array 100 by the outlet side 308 (e.g., as depicted by arrow C). The ninth region 520 depicts a flow path of the first colloid species (e.g., A) through the array 100. The tenth region 522 depicts a flow path of the second colloid species (e.g., B) through the array 100. The eleventh region 524 depicts a flow path of the second colloid species (e.g., C) through the array 100.

[0048] Thus, FIGs. 5A and 5B show arrays 100 in which the lateral direction of each sequential stage can be varied to manipulate particle population(s) by size. In the two-stage embodiment shown in FIG. 5A, a two species jet of colloids is manipulated such that the larger species (e.g., A) is condensed and isolated on one side of the channel (e.g., collection wall 304), and the second species (e.g., B) is deflected and condensed on the opposite side (e.g., second collection wall 508). This spatial separation allows the two jets of particles to then be isolated at the outlet (e.g., outlet side 308) of the array 100, to effect high resolution separation. The three-stage design shown in FIG. 5B effects the same separation on a 3 species particle (e.g., colloidal) jet. One of ordinary skill in the art will appreciate that any number of stages, each of varying geometry and length, can be sequentially run to effect different deflections and isolations of particles. Embodiments of the invention in which the array 100 facilitates multiple lateral displacement directions have the advantage of separating and/or purifying various particles (e.g., colloids) based on size.

[0049] FIG. 6 is a diagram of a microchannel 600 comprising a multi-stage condenser array 100. As shown in FIG. 6, various shades of an array 100 comprising the microchannel 600 represent respective array 100 geometries. FIG. 6 depicts expanded views of four exemplary stages of the array 100, having respective geometries (e.g., varying pillar 102 gaps G). FIG. 6 shows a staged array 100, in which the transition between different geometries is a gradual change between each pillar 102 row 107. An array 100 comprising the shown gradient change in the particle deflection, as opposed to an abrupt transition in the staged design, can be used for

mixtures of particles in which the size difference is a continuous distribution (dispersion) and therefore requires a continuous fractionation to effect separation.

[0050] FIG. 7 is a diagram of a microchannel 700 comprising a wall-focused array 100 and facilitate purification of a sample fluid.

[0051] The microchannel 700 comprises an array 100 in fluid communication with a sample inlet 702 and a solvent inlet 704. A sample fluid flows through the sample inlet 702 (e.g., in a direction indicated by arrow "SA") and into the array 100. A solvent fluid flows through the solvent inlet 704 (e.g., in a direction indicated by arrow "S") and into the array 100. The sample and solvent fluids flow through the array 100 (e.g., in a direction indicated by arrow F) and exit via contaminant outlets 706 and sample outlets 708. As the fluids flow through the array 100, the fluids are displaced in a lateral displacement direction (e.g., in a general direction indicated by arrow LD). Further, samples within the sample fluid are displaced towards a collection wall 304. Also, the solvent fluid is displaced towards the collection wall 304. The sample and solvent fluids collect along the collection wall 304 and form a concentrated stream, which exits the array 100 via the sample outlet 708. Contaminants within the sample fluid remain free of the collection wall 304 and exit the array 100 via the contaminant outlet 706. A twelfth region 710 depicts a flow path of the solvent fluid through the array 100. A thirteenth region 712 depicts a flow path of the samples through the array 100. Also, a fourteenth region 714 depicts a flow path of the contaminants through the array 100.

[0052] Microchannel 700 purifies colloidal samples with high band pass, such as extracellular vesicles. In this case, purification isolates colloid species of interest from other colloids outside of a certain size range, larger and smaller particles, including salts, small molecules, contaminants, etc., present in the original injected sample stream. This purification is effected by the simultaneous injection of a pure solvent stream co-axial with the sample stream. The pure solvent stream, its composition selected by the user depending the application requirements, generates a clean solution space into which particles can be deflected, effecting the purification.

[0053] FIG. 8 is a diagram of a microchannel 800 comprising a channel-focused array 100 to facilitate purification of a sample fluid.

[0054] The microchannel 800 comprises an array 100 in fluid communication with sample inlets 702 and solvent inlets 704. A sample fluid flows through the sample inlet 702 (e.g., in a direction indicated by arrows SA) and into the array 100. Also, a solvent fluid flows through the solvent inlet 704 (e.g., in a direction indicated by arrow S) and into the array 100. The sample and solvent fluid flow through the condenser array 100 (e.g., in a direction indicated by arrow F) and exit via contaminant outlets 706 and sample outlets 708. As the fluids flow through the array 100, the fluids are displaced towards in multiple lateral displacement directions (e.g., in directions

indicated by arrows LD). Further, one or more samples within the sample fluid are displaced towards a collection channel 312. Also, the solvent fluid is displaced towards the collection channel 312. The sample and solvent fluid can collect along the collection channel 312 and form a concentrated stream, which exits the array 100 via the sample outlet 708. In contrast, contaminants within the sample fluid remain free of the collection channel 312 and exit the array 100 via the contaminant outlets 706. A fifteenth region 802 depicts a flow path of the solvent fluid through the array 100. A sixteenth region 804 depicts a flow path of the samples through the array 100. Also, a seventeenth region 806 depicts a flow path of the contaminants through the array 100.

[0055] Various embodiments of the invention can be utilized to design microchannels that facilitate sample purification. While FIGs. 7 and 8 show a single solvent inlet 704, microchannels comprising a plurality of solvent inlets 704 in fluid communication with the array 100 are also envisaged. Additionally, microchannels 700 and 800 may be modified to comprise multi-stage arrangements (e.g., in accordance with embodiments of the invention shown in FIGs. 4-6) to purify and/or collect multiple particle size ranges. For example, the array 100 described herein (e.g., the array 100 of FIG. 7 and/or 8) may comprise a multi-wall-focus (e.g., a double wall-focus) configuration and/or a multi-channel-focus (e.g., a double channel-focus) configuration.

[0056] FIG. 9 is a flow diagram of a method 900 for separating one or more particles from a fluid using a condenser array 100.

[0057] At 902, the method 900 comprises receiving a fluid at a microchannel 103, 300, 302, 400, 500, 502, 600, 700, 800 comprising one or more arrays 100. The fluid is received at the microchannel 103, 300, 302, 400, 500, 502, 600, 700, 800 via inlets (e.g., an inlet side 306). The fluid is supplied to the microchannel 103, 300, 302, 400, 500, 502, 600, 700, 800 at a steady rate (e.g., via a pressure system).

[0058] At 904, the method 900 comprises displacing, by the array 100, particles from the fluid in a direction lateral (e.g., a lateral displacement direction) to a side wall of the microchannel 103, 300, 302, 400, 500, 502, 600, 700, 800. Further, at 906 the method 900 comprises outputting (e.g., via an outlet such as side outlet 308) the particles from the microchannel 103, 300, 302, 400, 500, 502, 600, 700, 800 at a rate greater than about 1.0 nL/hr. The one or more particles may be outputted at 906 at a rate greater than or equal to 1.0 nL/hr and less than or equal to 60 mL/hr.

[0059] FIG. 10 is a flow diagram of a method 1000 for purifying a sample fluid using a condenser array 100.

[0060] At 1002, the method 1000 comprises receiving a sample fluid and a solvent fluid at a microchannel 103, 300, 302, 400, 500, 502, 600, 700, 800 comprising one or more arrays 100. The sample and solvent fluid are received at the microchannel 103, 300, 302, 400, 500, 502, 600, 700, 800 via inlets (e.g., an inlet side 306, sample

inlet 702, and/or solvent inlet 704). The sample and solvent fluid are supplied to the microchannel 103, 300, 302, 400, 500, 502, 600, 700, 800 at a steady rate (e.g., via a pressure system).

[0061] At 1004, the method 1000 comprises displacing, by the array 100, a sample from the sample fluid in a direction (e.g., a lateral displacement direction) lateral to a side wall of the microchannel 103, 300, 302, 400, 500, 502, 600, 700, 800. Further, the sample is displaced into the solvent fluid by the array 100. Moreover, at 906 the method 900 comprises outputting (e.g., via an outlet such as side outlet 308, a contaminant outlet 706, and/or a sample outlet 708) the particles from the microchannel 103, 300, 302, 400, 500, 502, 600, 700, 800 at a rate greater than about 1.0 nL/hr. The particles may be outputted at 906 at a rate greater than or equal to 1.0 nL/hr and less than or equal to 60 mL/hr.

[0062] The term “or” is intended to mean an inclusive “or” rather than an exclusive “or.” That is, unless specified otherwise, or clear from context, “X employs A or B” is intended to mean any of the natural inclusive permutations. That is, if X employs A; X employs B; or X employs both A and B, then “X employs A or B” is satisfied under any of the foregoing instances. Moreover, articles “a” and “an” as used in the subject specification and annexed drawings should generally be construed to mean “one or more” unless specified otherwise or clear from context to be directed to a singular form. As used herein, the terms “example” and/or “exemplary” are utilized to mean serving as an example, instance, or illustration. For the avoidance of doubt, the subject matter disclosed herein is not limited by such examples. In addition, any aspect or design described herein as an “example” and/or “exemplary” is not necessarily to be construed as preferred or advantageous over other aspects or designs, nor is it meant to preclude equivalent exemplary structures and techniques known to those of ordinary skill in the art.

[0063] What has been described above include mere examples of systems and methods. It is, of course, not possible to describe every conceivable combination of components, and methods for purposes of describing the invention, but one of ordinary skill in the art can recognize that many further combinations and permutations of the invention are possible. Furthermore, to the extent that the terms “includes,” “has,” “possesses,” and the like are used in the detailed description, claims, appendices and drawings such terms are intended to be inclusive in a manner similar to the term “comprising” as “comprising” is interpreted when employed as a transitional word in a claim. The descriptions of the various embodiments of the invention have been presented for purposes of illustration, but are not intended to be exhaustive or limited to the invention. Many modifications and variations will be apparent to those of ordinary skill in the art without departing from the scope of the invention. The terminology used herein was chosen to best explain the principles of the invention, the practical application or technical improvement over technologies found in the marketplace, or to enable others of ordinary skill in the art to understand the invention.

CLAIMS

1. A microfluid apparatus for concentrating colloids, the apparatus comprising:
 - a lateral displacement array comprising pillars forming a microchannel,
 - the pillars arranged in a plurality of columns and rows, wherein a pillar gap greater than or equal to 0.5 micrometers is located between a first pillar of the pillars in a first column of the columns and a second pillar of the pillars in the first column, and wherein the first pillar is adjacent to the second pillar,
 - and wherein a first set of the pillars in a first portion of the microchannel are configured to laterally displace a fluid flowing through the condenser array towards a first side wall of the microchannel, the first set of pillars comprising a first plurality of columns, wherein adjacent columns re arranged offset each other to position a first plurality of rows at a first angle to side walls of the microchannel, the first angle greater than 0 degrees and less than 90 degrees in a first direction;
 - a second set of the pillars in a second portion of the microchannel are configured to laterally displace the fluid flowing through the condenser array towards a second side wall of the microchannel, the second set of pillars comprising a second plurality of columns, adjacent columns arranged offset each other to position a second plurality of rows at a second angle to the side walls of the microchannel, the second angle greater than 0 degrees and less than 90 degrees in a second direction opposite to the first direction,
 - wherein the second side wall is opposite to the first side wall, and the second portion is after the first portion in a direction of flow of the microchannel; and
 - means for collecting a set of first colloids on the first side wall , and means for collecting a set of second colloids on the second side wall, the first colloids different from the second colloids.
2. The apparatus of claim 1, wherein the array comprises a set of lattices, each lattice comprising two adjacent pillars in a first column and two adjacent pillars in a second column, the first column adjacent to the second column, wherein a first ratio is less than or equal to 1.0, the first ratio characterized by D_x/D_y , wherein D_x represents a first distance across the lattice in a first direction, wherein D_y represents a second distance across the lattice in a second direction, and wherein the first direction is orthogonal to the second direction.
3. The apparatus of claim 2, wherein a second ratio is greater than 0.5, the second ratio characterized by D_0/D_y , wherein D_0 represents a diameter of the pillars.
4. The apparatus of claim 3, wherein the pillars are further arranged in a plurality of rows, and wherein a boundary of the lattice is defined by a shape of the pillars, respective center lines of the columns, and respective center lines of the rows.