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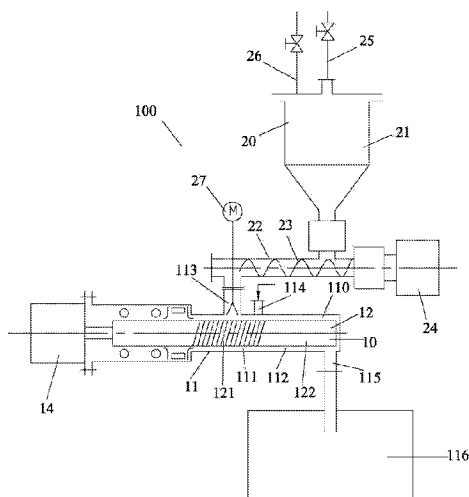
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(54) Title: MATERIAL PROCESSING APPARATUS WITH A PRE-PROCESSING ZONE AND A PROCESSING ZONE



(57) Abstract: A material processing apparatus (10) includes a first member (11) and a second member (12) rotatable relative to the first member (11) and at least partially received within the first member (11). The first and second members (11, 12) form a substantially annular processing passage (110) therebetween. The processing passage (110) includes a pre-processing zone (111) and a processing zone (112). A circumferential surface of the first member (11) or the second member (12) facing the pre-processing zone (111) has protruding and/or concave portions, while circumferential surfaces of the first and second members (11, 12) facing the processing zone (112) are relatively smooth. The processing zone (112) is configured such that materials in the processing zone (112) can form Couette flow when a relative rotation speed between the first and second members (11, 12) reaches a certain value.

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MATERIAL PROCESSING APPARATUS WITH A PRE-PROCESSING ZONE AND A PROCESSING ZONE

The present application claims the benefit of and priority to Chinese Patent Application Serial Number 200610173371.5, entitled “Device for Mixing and Reacting,” filed on Dec. 30, 2006, Chinese Patent Application Serial Number 200610172191.5, entitled “Device for Mixing and Reacting,” filed on Dec. 30, 2006, Chinese Patent Application Serial Number 200610172190.0, entitled “Device for Mixing and Reacting with Pretreatment Chamber and Treatment Chamber,” filed on Dec. 30, 2006, Chinese patent application (serial number to be provided) entitled “Mixer,” filed on Dec. 29, 2007, and Chinese patent application (serial number to be provided) entitled “Device and Method for Mixing Materials,” filed on Dec. 29, 2007, each of which is incorporated herein by reference.

FIELD OF INVENTION

The present invention is related to a material processing apparatus comprising a pre-processing zone and a processing zone.

BACKGROUND OF THE INVENTION

A conventional rotor-stator mixer typically includes a stator provided with a cylindrical chamber and a cylindrical rotor coaxially received in the cylindrical chamber of the stator. Opposite cylindrical surfaces of the stator and the rotor define a narrow annular chamber therebetween. Fluids fed in the narrow annular chamber are urged to move relative to each other by a large shear force produced by high speed rotation, and thereby are mixed with each other.

However, known rotor-stator may not be suitably used to process solid materials because of the difficulty to feed solid materials into the narrow annular chamber and distribute solid materials in liquid materials uniformly. It happens often that liquid materials flow into a solid material feeding port, which results in agglomeration and then jam of the solid material feeding port.

SUMMARY OF THE INVENTION

Embodiments of the present invention provide a material processing apparatus. The material processing apparatus includes a first member and a second member received or partially received within the first member and rotatable relative to the first member. An annular processing passage is formed between the first and second members. The processing passage includes a pre-processing zone and a processing zone. A circumferential surface of the first member or the second member facing the pre-processing zone has protruding or/and concave portions, while circumferential surfaces of the first and second members facing the processing zone are relatively smooth. In one embodiment, circumferential surfaces of the first and second members facing the processing zone have no protruding or concave portions, or the area taken by the protruding and concave portion(s) on the circumferential surfaces of the first

and second members facing the processing zone is proportionally much smaller than the area taken by the protruding and concave portion(s) on the circumferential surface of the first or second member facing the pre-processing zone. The processing zone of the processing passage is configured such that materials in the processing passage can form Couette flow when a relative rotation speed between the first and second members reaches a predetermined value.

Embodiments of the present invention further provides a material processing apparatus including a first member and a second member rotatable relative to the first member and at least partially received within the first member. A substantially annular processing passage is provided between the first and second member. The processing passage includes a pre-processing zone and a processing zone, and the pre-processing zone is configured such that a force is provided by the pre-processing zone to push materials in the pre-processing zone into the processing zone when the first member and the second member rotate relative to each other, and the processing zone is configured such that materials in the processing zone forms Couette flow when relative rotation speed between the first and second members reaches a predetermined value.

The pre-processing zone is used for pre-processing materials, and in the pre-processing zone, for example, materials may be preliminarily mixed, smashed, caused to preliminary react with each other, fed into the processing zone by an axial force provided by the pre-processing zone, or combinations thereof. The processing zone is used for processing the pre-processed materials, and in the processing zone, the materials may be homogeneously mixed by high shear forces provided by relative rotation between the first and second members, or caused to react with each other, alternatively or additionally, the reaction between the materials may be accelerated or thoroughly completed.

The material processing apparatus is capable of processing fluid materials, which may include one or more from liquid materials, gaseous materials, colloidal materials and powder materials. Therefore materials that can be processed by the material processing apparatus include, but are not limited to, mixture of liquid and powder materials, mixture of liquid and gaseous materials, mixture of liquid, gaseous and powder materials, and mixture of liquid and colloidal materials, etc.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1A-1E schematically illustrate different embodiments of a second member of a material processing apparatus.

FIG. 2A-2K schematically illustrate different assembly embodiments of first and second members of the material processing apparatus.

FIG. 3 schematically illustrates an embodiment of sealing member of the material processing apparatus.

FIG. 4 schematically illustrates another embodiment of sealing member.

FIG. 5A-5C illustrate another three embodiments of sealing member.

FIG. 6A-6B respectively illustrate a material processing system including the material processing apparatus.

FIG. 7A-7C illustrate three embodiments of drive device for the material processing apparatus.

FIG. 8-9 illustrate a fluid feeding apparatus for the material processing apparatus.

FIG. 10-12 illustrate a temperature control device for the material processing apparatus.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

Detailed description of the material processing apparatus will be given hereafter by illustrating some specific embodiments in conjunction with the accompanying drawings.

For ease of discussion, a part of the first member or the second member corresponding to the pre-processing zone will be referred to below as the pre-processing section of the first member or the second member, respectively. Similarly, a part of the first member or the second member corresponding to the processing zone will be referred to below as the processing section of the first member or the second member, respectively.

FIG. 6A illustrates a material processing system 100 including a material processing apparatus 10 and some apparatus or devices coupled to the material processing apparatus 10, such as a drive device 14 and a material feeding apparatus 20. The material processing apparatus 10 includes a first member 11 functioning as a stator and a second member 12 functioning as a rotor. An annular processing passage 110 is formed between an inner surface of the first member 11 and an outer surface of the second member 12. The processing passage 110 includes a pre-processing zone 111 and a processing zone 112. The inner surface of the first member 11 is relative smooth, and the outer surface of the second member 12 includes a relative smooth section corresponding to the processing zone 111 and a section having screw patterns corresponding to the pre-processing zone 112. Correspondingly, the second member 12 includes a pre-processing section 121 and a processing section 122.

Alternatively, in another embodiment, the first member serves as a rotor and the second member serves as a stator.

The first or second member may rotate relative to one another at a rate ranged between 1000rpm to 12000rpm, or preferably between 3000rpm to 8000rpm, which depends on actually needs.

The pre-processing zone may constitute 10~90%, or preferably 20~50% of a

total length of the pre-processing and processing zones.

A radial size of the processing zone, i.e. a radial distance between the inner surface of processing section of the first member and the outer surface processing section of the second member, may be in micron scale, and it can be tens to thousands microns. For example, the radial size of the processing zone may be 50~80 microns, 80~120 microns (e.g. 100 microns), 120~130 microns, 130~200 microns (e.g. 200 microns), 200~350 microns, about 350 microns, 750 microns, 1000 microns, 2000 microns, 3000 microns or 5000 microns, etc. Even though the first and second processing surfaces may be very closely spaced, but they do not contact with each other during rotation.

Fig. 2A illustrates an embodiment of a part of the material processing apparatus 10. Referring to FIG. 2A, surfaces s111 of the first and second members facing the pre-processing zone 1011 have protruding or concave portion 1211. Surfaces s121 of the first and second members facing the processing zone have no protruding or concave portion (projections or recesses), or the area taken by the protruding and concave portion(s) on the surfaces s121 is proportionally much smaller than area taken by the protruding and concave portion(s) on the surfaces s111.

The projections or recesses may be created by mechanical methods, electrical erosion, lithography, electroplate, strong stick techniques.

For material processing apparatuses for lab scale applications, the projections or recesses may have radial sizes, for example, ranged between 1~5000 microns, along a radial direction of the first or second member. For those for industrial applications, the projections or recesses may have relatively larger sizes.

The projections and recesses may be in shapes of dots, stripes or any other regular or irregular shapes.

During relative rotation between the first and second members, an axial component force may be provided to the materials in the pre-processing zone to urge them into the processing zone, especially those materials with a high viscosity or those solid materials in powder form.

In one embodiment, protruding or concave portion(s) can be continuous stripes, discontinuous stripes, combinations of continuous and discontinuous stripes, or dots arranged in stripe-like tracks. In one embodiment, the stripes or/and the stripe-like dot tracks extend at an angle larger than 0 degree and smaller than 90 degrees from the axial direction of the rotor, so as to provide an axial force to feed materials from the pre-processing zone into the processing zone. The stripes or/and dot tracks may be spaced equidistant or at varying distances from each other.

The stripes may have cross-sections in shapes such as triangles, trapezia, rectangles, polygons, semicircles, circles, semi-ellipses, or etc.

In one embodiment, the material processing apparatus may be aslant mounted

such that the pre-processing zone is located higher than the processing zone in vertical direction and therefore materials in the pre-processing zone can be fed into the processing zone more easily.

Referring to FIG. 1A, in one embodiment, the surface of the pre-processing section 121 of the second member 12 has continuous stripes, the surface of the processing section 122 of the second member 12 is relative smooth. When the second member 12 rotates relative to the first member 11, the stripes can provide an axial force to materials in the pre-processing zone to make them move towards the processing zone. The stripes may be spaced at 0.5~20mm, preferably about 5mm, from each other. The stripes may have radial sizes (distance between the top and bottom of the stripes along a radial direction of the second member) of 0.2~5mm. For example, the stripes may have radial sizes of 1.5mm.

Referring to FIG. 1B, in another embodiment, the surface of the pre-processing section 121 has discontinuous stripes, the surface of the processing section 122 is relative smooth. When the second member 12 rotates relative to the first member 11, the stripes can provide an axial force to materials in the pre-processing zone to make them move towards the processing zone. Alternatively, the discontinuous stripes may be not uniformly distributed.

Referring to FIG. 1C, in yet another embodiment, the surface of the pre-processing section 121 has dots arranged in stripe-like tracks, the surface of the processing section 122 is relative smooth. When the second member 12 rotates relative to the first member 11, the dots arranged in stripe-like tracks can provide an axial force to materials in the pre-processing zone to make them move towards the processing zone.

Referring to FIG. 1D, in yet another embodiment, the surface of the pre-processing section 121 has continuous stripes and recesses 1231 breaking in the stripes, the surface of the processing section 122 is relative smooth. When the second member 12 rotates relative to the first member 11, the stripes can provide an axial force to materials in the pre-processing zone to make them move towards the processing zone. The recess may have a length that corresponds to 20~50% of the length of the surface of the pre-processing section 121.

Alternatively, the recess 1231 may be provided at other positions, such as positions remote from the processing section 122, or positions in the middle of the pre-processing section 121. There is no limit as to the number of recess 1231, and there may be more than one (e.g. two, three, or four) recesses. If there are two or more recesses, these recesses may be symmetrically or unsymmetrically distributed.

Referring to FIG. 1E, in yet another embodiment, the surface of the pre-processing section 121 has continuous stripes and dots 1232 between the stripes and the processing section 122, the surface of the processing section 122 is relative smooth. When the second member 12 rotates relative to the first member 11, the

stripes can provide an axial force to materials in the pre-processing zone to make them move towards the processing zone, and the dots 1232 can provide a function of mixing the materials.

Sizes of the pre-processing zone and the processing zone will be described hereafter by taking material processing apparatuses with continuous stripes on their unsmooth pre-processing surfaces as examples.

FIG. 2A-2D illustrate examples in which the first member defines a receiving chamber which includes a pre-processing section with a first diameter and a processing section with a second diameter smaller than the first diameter, and in which the second member includes a processing section having a third diameter and a pre-processing section having an inner diameter and an outer diameter respectively equal to and larger than the third diameter.

Referring to FIG. 2A, a second member 12 includes a pre-processing section 121 with an unsmooth pre-processing surface defined by helically extending rectangular stripes 1211, and a processing section 122 with a smooth processing surface. The pre-processing section 121 has an inner diameter d_1 and an outer diameter d_2 respectively equal to and larger than a diameter d_3 of the processing section 122. A first member 11 defines a receiving chamber 101 including a pre-processing section 1011 and a processing section 1012 for respectively accommodating the pre-processing section 121 and processing section 121 of the second member 12. The pre-processing section 1011 has a diameter larger than a diameter of the processing section 1012.

FIG. 2B illustrates trapeziform stripes 1211 helically extending on a pre-processing section 121 of the second member 12.

FIG. 2C illustrates triangular stripes 1211 helically extending on a pre-processing section 121 of the second member 12.

FIG. 2D illustrates stripes 1211 in such shapes that gaps between adjacent stripes are arc-shaped.

Alternatively, FIG. 2E~2H illustrate examples in which the first member defines a receiving chamber which includes a pre-processing section and a processing section having a same diameter, and in which the second member includes a processing section having a diameter and a pre-processing section having an inner diameter and an outer diameter respectively smaller than and equal to the diameter of the processing section. Stripes in FIG. 2E~2H are respectively similar to those in FIG. 2A~2D.

Alternatively, in FIG. 2I, the second member 12 includes a processing section 122 and a pre-processing section 121 which has an outer diameter larger than a diameter of the processing section 122 and an inner diameter smaller than the diameter of the processing section 122. The first member 11 defines a receiving

chamber 101 which includes a pre-processing section 1011 and a processing section 1012 having a same diameter.

In FIG. 2J, the second member 12 includes a processing section 122 and a pre-processing section 121 which has an outer diameter larger than a diameter of the processing section 122 and an inner diameter smaller than the diameter of the processing section 122. The first member 11 defines a receiving chamber 101 which includes a pre-processing section 1011 and a processing section 1012 having a diameter smaller than a diameter of the pre-processing section 1011.

In FIG. 1K, the second member 12 includes a processing section 122 and a pre-processing section 121 which has both an outer diameter and an inner diameter smaller than a diameter of the processing section 122. The first member 11 defines a receiving chamber 101 which includes a pre-processing section 1011 and a processing section 1012 having a diameter larger than a diameter of the pre-processing section 1011.

Sealing member

The material processing apparatus may further include a sealing member from sealing the processing passage from the outside environment.

In one embodiment, the sealing member comprises a sealing chamber, which is provided with a first port allowing a first fluid introduced into the sealing chamber, and a second port allowing fluids outputted from the sealing chamber. The first port may be connected with a first fluid source, and the second port may communicate with environment, or alternatively be connected with a first fluid collecting device. The sealing member may further comprises a first seal element sealing the processing passage from the sealing chamber, and a second seal element sealing the sealing chamber from the outside environment.

The first fluid may be gaseous or liquid materials, and preferably is gaseous material such as air, nitrogen, inert gas, and more preferably is gas that does not react with the material in the processing chamber. If the first fluid is air, air from the second port can be discharged to the environment directly or after simple treatment such as filtration. If the first fluid is relatively expensive gas such as inert gas, the gas discharged from the second port may be purified and recycled.

The first fluid may be fed into the sealing chamber at a high rate, and may have a function for cooling the first and second sealing elements and maybe a further function for preventing the sealing member such as seal rings from softening. Otherwise, as the first fluid fed at a high rate and discharged from the second port forms a stream flowing through the sealing chamber, by such a stream of the first fluid, material leaked from the processing chamber can be driven out of the sealing chamber from the second port. That is to say, the sealing chamber can be cleaned up by the stream of the first fluid. The first fluid in the sealing chamber can be controlled at a stable pressure, such that a gas seal can be provided for additionally sealing the

materials in the processing chamber. For example, the second port may be connected with a pressure flow controller (PFC) so as to control the pressure of in the sealing chamber, which pressure is preferably smaller than the pressure in the processing passage. Moreover, since a space might be formed between the second sealing element (the sealing element disposed between the sealing chamber and the processing passage herein) and the second member once if attrition occurs to the second sealing element, the first fluid in the sealing chamber further has a function for preventing air entering the processing chamber through that space. Therefore, if the first fluid is a gas inert with respect to the material in the processing chamber, the material in the processing chamber can be protected from being contaminated.

The first and second sealing elements may be in varied forms, by means of a screw thread, seal rings made from various kinds of materials, or graphite seal, etc.

Some examples of the sealing member will be provided as follows.

Referring to FIG. 3, in one embodiment, a screw thread 1311 formed on the second member 12 serves as a first sealing element, and a seal ring 132 serves as a second sealing element. The screw thread 1311 and the seal ring 132 are spaced from each other along a longitudinal direction of the first or second member, and define an annular sealing chamber 130 therebetween. The sealing chamber 130 is provided with a first port 133 and a second port 134.

Referring to FIG. 4, in another embodiment, seal rings 1312 and 132 serve as first and second sealing elements respectively. The seal rings 1312 and 132 are spaced from each other along a longitudinal direction of the first or second member, and define a sealing chamber 130 therebetween. The sealing chamber 130 is provided with a first port 133 and a second port 134.

More variations of the sealing member as illustrated in FIG. 4 will be provided hereafter.

Referring to FIG. 5A, seal rings 131 and 132 respectively serve as the first and second sealing elements. After the material processing apparatus has been running for a period of time, attrition will occur to the seal rings 131 and 132, and gaps 1310 and 1320 may be caused between the seal rings and the second member 12. However, as the gaps 1310 and 1320 are very narrow, the material in the material processing chamber 110 may not leak to the sealing chamber 130 if only the first fluid in the sealing chamber is maintained at a certain pressure. Additionally, after the seal rings are abraded, lubricant is no longer needed and no abrasive dust is produced, therefore pollution to the material in the processing chamber 110 will be greatly reduced, relative to the time before the seal rings are abraded, if only the first fluid in the sealing chamber 130 is inert with respect to the material in the processing chamber 110.

In one embodiment, grooves 135 and 136 may be respectively provided on a cylindrical outer surface of the second member 12 and a cylindrical inner surface of

the first member 11u, such that materials leaking from the processing chamber 110 can be collected in the grooves 135 and 136 and prevented from moving towards the second sealing element 132 and out from the gap 1320. The groove 136 is provided at a position corresponding to both the first port 133 and the second port 134 such that the materials collected in the groove 136 can be taken out of the sealing chamber 130 from the second port 134 by the high speed stream of the first fluid. The groove 135 is configured and positioned to allow the materials collected therein to be blew into the groove 136 and then taken out from the second port 134. For example, the groove 135 may be located in alignment with the groove 136 along a flow direction of the stream of the first fluid, and configured narrower than the groove 136 along a direction perpendicular to the flow direction of the stream of the first fluid.

In one embodiment, the first port 135 and the second port 136 is respectively located in a top and a bottom portion of the sealing chamber 130. Alternatively, the first and second port may be located in any other positions if only materials leaking from the processing chamber 110 can be easily taken out from the second port 136 by the stream of the first fluid.

Referring to FIG. 5B, in one embodiment, the first and second sealing elements 131 and 132 are single-lip seals respectively having lips 1311 and 1321 both protruding inwards the sealing chamber 130. Due to attrition of the sealing elements 131 and 132, narrow gaps 1310 and 1320 may be respectively formed between the sealing element 131 and the second member 12, and between the sealing element 132 and the second member 12. If a pressure in the sealing chamber 130 is higher than the pressure in the processing passage 110, the lip 1311 of the first sealing element 131 can be pressed towards the second member 12 to achieve a seal between the processing passage 110 and the sealing chamber 130. If a pressure in the sealing chamber 130 is higher than a pressure outside the material processing apparatus, as generally it is, the lip 1321 of the second sealing element 132 can be pressed towards the second member 12 to achieve a seal between the sealing chamber 130 and the outside environment. Otherwise, the first fluid flowing through the sealing chamber 130, if being a gas with a certain pressure, may function as a gas curtain capable of further sealing the processing passage 110 from the outside environment.

Referring to FIG. 5C, in one embodiment, the first and second sealing elements 131 and 132 are single-lip seals mounted on the first member 11. The first sealing element 131 has a lip 1311 protruding inwards the processing passage 110, and the second sealing element 132 has a lip 1321 protruding inwards the sealing chamber 130. Due to attrition of the sealing elements 131 and 132, narrow gaps 1310 and 1320 may be respectively formed between the sealing element 131 and the second member 12, and between the sealing element 132 and the second member 12. If a pressure in the sealing chamber 130 is lower than the pressure in the processing passage 110, the lip 1311 of the first sealing element 131 can be pressed towards the second member 12 to achieve a seal between the processing passage 110 and the sealing chamber 130. If a pressure in the sealing chamber 130 is higher than a pressure outside the material

processing apparatus, as generally it is, the lip 1321 of the second sealing element 132 can be pressed towards the second member 12 to achieve a seal between the sealing chamber 130 and the outside environment. Otherwise, the first fluid flowing through the sealing chamber 130, if being gaseous, may function as a gas curtain capable of further sealing the processing passage 110 from the outside environment.

As mentioned above, the described sealing members have many important advantages. For example, a more reliable seal effect can be achieved because, in addition to a seal effect established by the sealing elements, a further gas curtain seal can be provided by a gas flowing through the sealing chamber. Another advantage is that the reliable seal effect can be maintained even when attrition occurs to the sealing elements and therefore there is no need to replace attrited sealing elements. Moreover, as to the attrited sealing elements, lubricant is no longer needed because they would not rub the second member any more, therefore pollution which may be caused by the lubricant is avoided. Further, due to existence of the gas curtain seal, not the total seal effect only depends on the first sealing element, therefore the first sealing element can be simplified to facilitate cleaning of the processing passage. Furthermore, as leaks that escape from the processing passage can be taken out by the first fluid flowing through the sealing chamber and then collected, pollution which may be caused by the leaks also can be avoided.

Above embodiments of the material processing apparatus are illustrated as examples and has no limitation to the invention. There are many variations can be made by those skilled in the art. For example, it is possible that the first member serves as a rotor and has a smooth pre-processing surface, yet the second member serves as a stator and has an unsmooth pre-processing surface. Also it is possible that both pre-processing surfaces provided by the first and second members are unsmooth.

The first and second members of the material processing apparatus may be made from the same material or respectively made from different materials. Materials suitable for making the material processing apparatus include, but are not limited to cast iron, stainless steel, alloy, metals (such as aluminium), macromolecule materials (such as plastic), inorganic materials (such as ceramic, glass or quartz glass), and composite material, which can be chosen depending on characters of the materials to be processed, characters of products, reaction or mixing condition, and manufacture cost, etc.

If protruding stripes are provided on the pre-processing sections of the first or second member by electroplate or strong stick techniques, the stripes can be made from a material the same as or different from that of the first or second member, also depending on characters of the materials to be processed, characters of products, reaction or mixing condition, and manufacture cost, etc.

In many cases, some other apparatus may be coupled to the material processing apparatus as above disclosed to form a material processing system to complete material feeding, processing, collecting, and etc. For example, aside from the material

processing apparatus, the material processing system may further include a drive device for driving a rotor of the material processing apparatus to rotate, a feeding apparatus for feeding solid or fluid material into the processing passage, a collecting device for collecting products from the processing passage, a temperature control device for controlling a temperature in the processing passage, or etc.

Drive device

Returning to FIG.6A, the drive device 14 is adapted to drive the second member 12 to rotate, and it may be electric motor, magnetic actuator or the like. Some examples of magnetic actuators are provided hereafter.

FIG. 7A illustrates a material processing system 100x including a material processing apparatus 10x, in which a rotor is driven by a magnetic actuator. The material processing apparatus 10x has a first member 11x functioning as a stator and defining therein a cylindrical receiving chamber 101x, and a second member 12x received in the receiving chamber 101x and functioning as a rotor. The second member 12x is made from magnetic material and provided with two rotary shafts 125x respectively at two longitudinal ends thereof. The two rotary shafts 125x engages with two bearings 127x mounted in the receiving chamber 101x, respectively. An annular space between the first member 11x and the second member 12x serves as the processing chamber for processing materials. The material processing system 100x further includes a third member 14x mounted around periphery outer of the first member 11x and functioning as a magnetic actuator capable of actuating the second member 12x to rotate. In one embodiment, the magnetic actuator 14x includes a pair of symmetrically disposed coil windings. Once activated by alternating electric current, the coil windings establish a desired electromagnetic field in the receiving chamber 101x, such that the second member 12x can be actuated to rotate. There may be a cover 13x covering an end opening of the receiving chamber 101x and no other seal member is needed.

FIG. 7B illustrates another material processing system 100y, in which a rotor is magnetically driven, similar to the material processing system 100x. A main difference from the material processing system 100y is that, in the material processing system 100y, the magnetic actuator 14y is disposed adjacent to one longitudinal end of the material processing apparatus 10y and longitudinally covers only a section of the material processing apparatus 10y other than the whole material processing apparatus 10y. The second member 12y may be totally made from magnetic material, or have a part 121y thereof that is longitudinally covered by the magnetic actuator 14y made from magnetic material, but the other part 122y that is not longitudinally covered by the magnetic actuator 14y made from non-magnetic material. Such a structure may facilitate to connect other peripheral apparatus, such as feeding apparatus or temperature control device to the section of the material processing apparatus 10y that is not covered by the magnetic actuator 14y.

Alternatively, the magnetic actuator may be other device capable of establishing

a desired magnetic field for actuating a member to rotate.

For example, FIG. 7C illustrates yet another material processing system 100z, in which a rotatable barrel-like magnet 14z is used as a magnetic actuator for actuating a magnetic second member 12z received in the barrel-like magnet 14z to rotate. The barrel-like magnet 14z rotates and thereby establishes a varying magnetic field for actuating the second member 12z to rotate.

Feeding apparatus

Returning to FIG. 6A, the solid material feeding apparatus 20 is used to feed solid material into the material processing apparatus 10. In one embodiment, the material feeding apparatus 20 is a screw feeder coupled to a first material inlet 113 of the pre-processing zone 111. The screw feeder 20 includes a storage room 21 for storing solid material, a feeding channel 22, a screw 23 accommodated in the feeding channel 22, and an actuator 24 for actuating the screw 23 to rotate. The screw feeder 20 may further include a purification conduit 25, which is connected with the storage room 21 and allows air in the storage room 21 to be expelled before material feeding is started, in order to prevent the solid material from being polluted by the air, and a blowing conduit 26, which is connected with the storage room 21 and allows gas of a certain pressure to be blown into the storage room 21 and then flow through the whole screw feeder 20, in order to prevent from material jam.

The gas from the conduit 26 is preferably inert to the solid material in the storage room 21, or at least inert to the solid material in the storage room 21 under a certain condition. In many cases, the gas can be nitrogen, helium, neon, argon, or their mixtures.

In addition, there may be a vibration device to vibrate the first material inlet 113, in order to prevent the material from plugged at the first material inlet 113. The vibration device may be actuated by pulse gas or mechanical collision.

In FIG. 6A, the screw feeder 20 is set in a manner that the screw 23 is longitudinally parallel to the material processing apparatus 10. However, there is no limit to the setting manner of the screw feeder. For example, in FIG. 6B, the screw feeder 20 is set in a manner that the screw 23 is longitudinally perpendicular to the material processing apparatus 10.

More details about screw feeders can be referred to products of Jilin Jida Powder Engineering Equipment Co. Ltd, Changzhou Pingzhitongfang Drying Equipment Co. Ltd, and Taicang Xingongtang Glass Co. Ltd.

As known by those skilled in the art, the solid material feeding apparatus alternatively may be powder conveyor pumps, pipe or chain feeders, or the likes.

Returning to FIG. 6A, the material processing system 100 may further include a fluid feeding apparatus (not shown in FIG. 6A) coupled to a second material inlet 114 beside the first material inlet 113 and adjacent to the processing zone 112 of the

processing chamber 110. Details about the fluid material feeding apparatus will be described in conjunction with FIG. 8-9 hereafter.

Referring to FIG. 8, a fluid feeding apparatus 30 includes a feeding unit 31 and a drive unit 32. The feeding unit 31 includes a container 311 for storing a fluid to be processed, an outlet 313, and a compressing member 312 for compressing a space in the container 311.

In one embodiment, the compressing member 312 is a syringe plunger, one end of which is movably received in the container 311, and the other end of which is connected to the drive unit 32. When actuated by a force provided by the drive unit 32, the plunger 312 moves towards the outlet 313 to press the fluid in the container 311 to the processing chamber 110. A seal member (not shown) may be provided between the plunger 312 and the container 311 to prevent fluid leakage.

Alternatively, the compressing member 312 may be elements capable of compressing a space in the container 311 other than a syringe plunger.

The feeding unit 31 may have any capacity, preferably 1~1000ml, for example, 5ml, 7ml, 20ml, or 100ml. Additionally, the feeding unit 31 may be temperature controlled, such that the fluid in the feeding unit 31 can be heated or cooled to a certain temperature before entering the processing chamber 110, so as to save processing time, or sometimes reduce a viscosity of the fluid.

The drive unit 32 is used to provide a power to drive the compressing member 312, and it can be any device capable of driving the compressing member 312 to move at a uniform or variable speed.

In one embodiment, the drive unit 32 includes an executing element 323 for driving the compressing member 312 to move and a power providing element 321 for providing a power to actuate the executing element 323. The power providing element 321 may be electronic motors or the likes, and the executing element 323 may be movable slides, flexible arms or the likes. The drive unit 32 may further include a retainer 322 for retaining the feeding unit 31.

The power providing element 321 may actuate the executing element 323 directly or via other elements. In one embodiment, the drive unit 32 further includes an actuator 324 linking executing element 323 and the power providing element 321. Via the actuator 324, the power providing element 321 actuates the executing element 323 to move the compressing member 312. For example, the actuator 324 may be a thread spindle and the executing element 323 is assembled to the actuator 324 through thread engagement, thus the power providing element 321 can drive the actuator 324 to rotate to thereby actuate the executing element 323 to move linearly.

Alternatively, the power providing element 321 may be directly coupled to the compressing member 312 to drive the compressing member 312 to move.

The drive unit 32 may further includes a movement controller or the like adapted

to control the executing element 323 to move for a pre-determined distance, in a pre-determined path, along a pre-determined direction and etc. In one embodiment, the drive unit 32 includes a first control element 325 and two second control elements 326a and 326b. The first control element 325 includes two parallel guide shafts, which define movement track and direction of the executing element 323. The second control elements 326a and 326b are disposed on the first control element 325 in order to limit the executing element 323 to move within a pre-determined distance, and therefore to prevent the executing element 323 from exerting too much force to the compressing member 312. Alternatively, the first and second control elements may be in other forms. For example, the first control element can be rails, guide grooves or the likes.

Referring to FIG. 9, there is a three-way connector 33 between the feeding unit 31 and the material processing apparatus 10 (schematically drawn and details thereof is not illustrated in FIG. 9). The three-way connector 33 has a first port connected with the outlet 313 of the feeding unit 31, a second port connected with the material processing apparatus 10 via a valve 331, and a third port connected with a fluid reservoir 34 via a valve 332. In a fluid feeding state, the valve 331 is opened and the valve 332 is closed, the compressing member 312 compresses the space in the container 311 to force the fluid in the container 311 into the material processing apparatus 10. In a fluid refilling state, the valve 332 is opened and the valve 331 is closed, the compressing member 312 returns to release the compressed space in the container 311, such that the container 311 is refilled with fluid from the fluid reservoir 34.

Alternatively, the fluid feeding apparatus may be other device, such as injection device, pump and the like.

Again returning to FIG. 6A, alternatively, maybe the first material inlet 133 is adapted to allow fluid feeding and connected with a fluid material feeding apparatus, yet the second inlet 114 is adapted to allow solid material feeding and connected with a solid material feeding apparatus.

Collecting device

Referring to FIG. 6A, the material processing system 100 may further include a collecting device 116 coupled to a collecting outlet 115 of the processing zone 112.

By the material processing system 100 as illustrated in FIG. 6A, for example, solid and fluid materials can be respectively fed into the pre-processing zone 111, preliminarily mixed in the pre-processing zone 111 and fed into the processing zone 112 through strips or the likes on the pre-processing section of the second member 12, and then processed in the processing zone 112. The solid material also can be smashed in the pre-processing zone 111. Products from the processing zone 112 can be collected by the collecting device 116, and the collected products may be analyzed.

Temperature control device

In addition, the material processing system may further include a temperature control device. Referring to FIG. 10-12, a temperature control device 51 is set to surround the first member 11t in order to control the temperature in the processing chamber 110t.

As can be seen from FIG. 11, the temperature control device 51 includes a cylindrical barrel 511 and a temperature control member 512 in the cylindrical barrel 511. The cylindrical barrel 511 is formed with openings 513 and 514. The temperature control member 512 includes a plurality of heat exchange elements 5121. In one embodiment, as shown in FIG. 12, the heat exchange elements 5121 are ring-shaped plates defining therein a hole or the like 5122 corresponding to a periphery shape of the first member 11t. Alternatively, the heat exchange element 5121 may be in any other shape only if an inner periphery thereof mates with the periphery shape of the first member 11t. For example, the heat exchange element 5121 may be square or polygonal plate with a hole in.

Additionally, the heat exchange element 5121 may be provided with one or more notches 5123, may be uniformly or asymmetrically distributed in the heat exchange element 5121. The different heat exchange element 5121 may have a same number of notches 5123 or may have different numbers of notches 5123.

Referring to FIG. 10, in assembly, the heat exchange elements 5121 are soldered on a periphery surface of the first member 11t such that the first member 11t is accommodated in the holes of the heat exchange elements 5121. Corresponding notches 5123 in different heat exchange element 5121 may be aligned with each other, or alternatively, offset from each other, to form a straight or curving passage that allows fluids for heating or cooling to flow through. The passage 5123 communicates with spaces 5125 between the heat exchange elements 5121. Referring to FIG. 11, in one embodiment, each of the heat exchange elements 5121 is provided with two symmetrically distributed notches 5123 as shown in FIG. 12. In assembly, the corresponding notches 5123 of the heat exchange elements 5121 are aligned with each other to form two straight passages 5122.

In one embodiment, the passage 5122 is designed to have a flow resistance much smaller than that of the spaces 5125 between the heat exchange elements 5121, such that fluids introduced from the opening 513 partially flows in the passage 5122 adjacent to the opening 513 along an axial direction, and partially flows in the spaces 5125 along a circumferential direction to reach the passage 5122 far from the opening 513. The fluid flowing in each passage 5122 partially continues to flow along the passage 5122, and partially flows into the next space 5125. Due to the flow resistance difference, the fluid is apt to flow along the passages 5122, and therefore the fluid can rapidly flow into each space 5125. Thus, flows in the different spaces 5125 have a substantially same flow rate and good temperature uniformity is achieved.

In one embodiment, the temperature control device 51 has a fluid outlet (the opening 514 here) located adjacent the other side relative to the opening 513, such

that fluids in different spaces 5125 have a substantially same flow rate.

The openings 513 and 514 may directly communicate with the passages 5122 respectively, or alternatively, communicate with the spaces 5125.

Returning to FIG. 10, the fluid introduced from the opening 513 or 514 can rapidly change the temperature in the material processing apparatus 10t. As reactions in the material processing apparatus 10t may be either exothermic or endothermic reactions, the introduced fluid can be used to circularly bring heat to or taking heat away from the material processing apparatus 10t. When a rotor of the material processing apparatus 10t is rapidly rotating, huge heat may be produced due to the shear friction. In many cases, cool fluid is introduced from the opening 513 or 514 and cycled in the temperature control device 51, such that the huge heat produced by the shear friction can be taken away. However, in some other cases, the reaction in the material processing apparatus 10t is endothermic one and the heat produced by the shear friction is less than that consumed by the endothermic reaction, so high temperature fluid may be introduced into the temperature control device to provide heat for the material processing apparatus 10t.

In one embodiment, the first member 11t is a thin-walled barrel, and there is only a thin wall between the processing chamber 110t and the temperature control device 51, therefore the fluids cycling in the temperature control device 51 can rapidly exchange heat with the fluids being processed in the processing chamber 110t, such that the temperature in the processing chamber 110t can be easily controlled by the temperature control device 51. Further, as the processing chamber 110t is very narrow in the radial direction thereof, fluids in the processing chamber 110t come into a uniform temperature in a short time.

Additionally, there may be a second temperature control device 52 mounted near a bearing (not shown in FIG. 10) of the material processing apparatus 30t, for example, on a bearing seat of the bearing. When the second member 12t is rapidly rotating, a temperature of the bearing may rapidly increase. Therefore, if without a temperature control device, such as a cooling device, for cooling the bearing, lubricant failure may occur, abrasion of the bearing may be accelerated, and then the service life of the bearing may be shortened.

The second temperature control device 52 may include openings 521 and 522, which may be ports of valves or pipes. Fluids such as coolant, lubricant or bearing oil may be provided from the second temperature control device 52 to the bearing seat through the openings 521 and 522. In one embodiment, the fluid is introduced from the opening 521 and outputted from the opening 522, takes heat away, and also lubricates the bearing. The second temperature control device 52 also has a function of controlling the temperature of the second member 12t that has one end thereof protruding into the bearing seat. The end of the second member 12t that protrudes into the bearing seat can be controlled to have a temperature substantially equal to that of the other end of the second member 12t received in the first member 11t, such that

heat exchange along the second member 12t can be decreased or avoided. Therefore, undesired effect to the temperature in the processing chamber 110t can be decreased.

There may be a third temperature control device 53 mounted near a drive device (not shown in FIG. 10) of the material processing apparatus 10t. The third temperature control device 53 may include openings 531 and 532, through which fluids can be provided to bring heat to or take heat away from the drive device, so as to control the temperature of the drive device. For example, if the drive device gives out huge heat during running, the third temperature control device 53 may provide water for cooling the drive device. Again for example, if the drive device is an electronic motor, which may be burnt out in over-temperature conditions, the third temperature control device 53 may be used to reduce the temperature of the electronic motor and prevent it from being burnt out.

Automatic control

It can be understood that, automatic control of the material processing apparatus or system, and processing of data achieved by the material processing apparatus or system, can be performed by computer systems.

The computer system (e.g., a server system) refers to a computer or a computer readable medium designed and configured to perform some or all of the processes as described in the present invention. A computer (e.g., a server) used herein may be any of a variety of types of general-purpose computers such as a personal computer, network server, workstation, or other computer platform to be developed. As well known in the art, the computer typically includes some or all the following parts, for example, a processor, an operating system, a computer storage device, an input device, an output device and a combination thereof. The computer may further include other parts such as a cache memory, a data backup unit, and many other devices. It will be understood by those skilled in the art that there are many possible configurations for the parts of a computer.

The processor used herein may include at least one microprocessor, field programmable logic array, or at least one specific integrated circuit corresponding to a certain application. For example, the processor includes, but not limited to, Pentium series processor of Intel Corp., microprocessor of Sun Microsystems Corp., SPARC processor of Sun Microsystems Corp., PowerPC processor of Motorola Corp., MIPS processor MIPS Technologies Inc., Vertex series of field programmable logic array of Xilinx Inc. and other processors.

The operating system used herein comprises machine code which, when executed by a processor, coordinates and executes functions of other parts in the computer and facilitates the processor to execute the function of computer program that may be written in a variety of programming languages. In addition to managing data flow among other parts in the computer, the operating system also provides scheduling, input-output control, file and data management, memory management,

communication control and related services, which are all known in the prior art. Exemplary operating system includes, for example, Windows operating system from the Microsoft Corporation, Unix or Linux-type operating system available from many vendors, other operating system to be developed and a combination thereof.

The computer storage device used herein may be any storage means, for example, random access memory (RAM), magnetic medium such as a resident hard disk or tape, optical medium such as read and write compact disc, or the like. The storage means may be any known or future device, including a compact disk drive, a tape drive, a removable hard disk drive, or a diskette drive. Such storage devices may typically read/write the computer program, from/to the storage medium such as a compact disk, magnetic tape, removable hard disk, or floppy diskette. All of the computer program storage media may be considered as a computer program product. The computer program product typically stores computer software program or/and data. The computer program typically is stored in a system memory or/and a storage device.

It is well known to those skilled in the art that, a computer software program of the present invention may be executed by being loaded into a system memory or/and a storage device through an input device. On the other hand, all or part of the software program may also reside in a read-only memory or the like, which don not require the software program to be loaded through input device firstly. It will be understood by those skilled in the art that the software program or part of the software program may be loaded by the processor into the system memory or the cache memory or both in a known manner, so as to execute and perform a random sampling.

In an embodiment of the invention, the software is stored in a computer server which connects to an end user terminal, an input device or an output device through a data cable, a wireless connection, or a network system.

As well known in the art, the network system comprises hardware and software electrically connected in the computer or device. For example, the network system may include Internet, Ethernet 10/1000, IEEE (Institute for Electrical and Electronic Engineers) 802.11x, IEEE 1394, xDSL (Digital Subscriber Line), Bluetooth, LAN (local area network), WLAN (wireless LAN), GPS (global position system), CDMA (Code Division Multiple Access), 3G (3rd Generation), PACS (Picture Archiving and Communication System), or any other system based on ANSI approved standard.

Additionally, a system and method disclosed in a pending PCT patent application Serial No. PCT/CN2007/070386 by the same applicant, filed July 30 2007, titled "Computer-aided graphical system, method and program product for designing experiment flow" can be applied to design and control experiment processes for the material processing apparatus or system as described here.

Applications

Material processing may be material mixing, emulsification, polymerization, extraction, reaction, preparation, or their combination. Therefore the material

processing apparatus or system as above described has a wide application. Some application examples are provided as follows.

1. Rapidly mixing two or more materials to achieve a uniformly mixed and well dispersed fluid mixture

The material processing apparatus or system can be used to rapidly and uniformly mixing two or more materials, which may be polymer, dope, pigment, dye, printing ink, oil paint, adhesive, lubricant, additive, surfactant, emulsifier, glycerin, benzene, crude oil, diesel, heavy oil, water, organic solvent, ionic liquid, olefin, food, or feed. The fluid mixture may be solutions, emulsion, micro-emulsion, colloid, and etc.

Products by the mixing process may be analyzed by optical microscope (OM), scanning electric microscope (SEM), atomic force microscope (AFM), transmission electron microscopy (TEM) or the likes, which usually are used to determine uniformity, dispersion degree, drop size or particle size of the mixtures. Uniformity and dispersion degree are important factors to evaluate the quality of a mixture. In some cases, uniformly mixed and well dispersed two or more materials may have greatly improved physical properties, for example, density, molecular weight, viscosity, pH value and the like.

2. Liquid emulsification

The material processing apparatus or system can be used to carry out emulsification, including two-phase emulsification (i.e. O/W and W/O), three-phase emulsification (e.g. oil solvent/emulsifier/water), or four-phase emulsification (e.g. oil solvent/emulsifier/coemulsifier/water).

Typical oil solvents include C₆₋₈ straight chain hydrocarbon and cycloalkane containing 6~8 carbon atoms, and typical emulsifiers include ionic and nonionic surfactants. Typical cationic surfactants include Cetyl Trimethyl Ammonium Bromide (CTAB), Dodecyl Trimethyl Ammonium Chloride (DTAC), Dioctadecyl Dimethyl Ammonium Chloride (DODMAC), Cetyl Pyridinium Bromide (CPB) and etc., typical anionic surfactants include Sodium Dodecyl Sulfate (SDS), Aerosol-Ot (AOT), Sodium Dodecyl Benzene Sulfonate (SDBS), Alcohol Ether Sulfate (AES) and etc., and typical nonionic surfactants include Polyvinyl Alcohol, Dodecanoyl Diethanolamine, Fatty Alcohol-polyoxyethylene ether, Alkylphenol Ethoxylates and etc. For example, the nonionic surfactant may be TX-6、 AEO5、 AEO7、 AEO9、 AEO12、 Triton X-100, Span series or Tween series. These surfactants may be used alone or in combination. Typical coemulsifiers include fatty alcohol, such as n-Butanol, n-Pentanol, n-Hexanol, n-Heptanol, n-Octanol, n-Decanol, n-Dodecanol and etc.

Therefore the material processing apparatus or system is applicable to prepare or produce foods such as milk, butter and ice cream, cosmetics such as vanishing cream and facial wash, emulsion paints, metal cutting fluids, textile auxiliaries, emulsions used in fields of heavy oil, diesel, benzene, inorganic or organic compounds including

catalysts, adhesive, printing ink, dope, dye, pigment, ceramic pigment, magnetic materials, liquid crystal materials, polymers, and etc.

Obtained emulsions may be analyzed by optical microscope (OM), scanning electric microscope (SEM), atomic force microscope (AFM), transmission electron microscopy (TEM) or the likes, which usually are used to determine uniformity, dispersion degree, drop size or particle size of the emulsions.

The emulsions prepared by the material processing apparatus or system of the present invention have ultra-uniform and dispersed particles with a size less than 1 μ m, and are able to keep their stability for several weeks without separating into layers and without color changing.

3. Micro-emulsification

The material processing apparatus or system is applicable for both micro-dispersed systems and micro-reaction systems. As to a micro-dispersed system, two or more liquids or emulsions that can not dissolve in each other are fed into the processing passage which includes a pre-processing zone and a processing zone, then caused to form millions of drops of liquid-in-emulsifier that are uniformly and dispersedly distributed in the liquid to form micro-emulsion. As these drops have high lipophilic surfaces with high surface tension, they are not apt to combine with each other. After solvents in the system is evaporated, nano solid particles in the drops can uniformly disperse into aqueous phase and keep invariable without agglomeration or deposition.

Formation process of said microreaction system comprises: after one kind of liquid or microemulsion and another kind of liquid or microemulsion are separately injected into a high shear mixer, liquid materials, under high speed shear forces and high speed centrifugal forces, become countless tiny droplets. These droplets, resemble to "micro-reactor", can rapidly carry out chemical reaction (e.g. polymerisation, redox reaction, hydrolytic reaction, complexation reaction or the like) under certain conditions (e.g. lightening, temperature, etc.). Various nanometer materials can be produced by restricting the growth of the reaction products using the droplets of microemulsion as micro-reactors.

Said microemulsion preparation can be carried out by normal phase microemulsification process, namely O/W microemulsification process; and also can be prepared by reverse phase microemulsification process, namely W/O microemulsification process; and also can be prepared by triphasic microemulsification process, such as oil solvent / emulsifying agent/water microemulsification process; and also can be prepared by quadriphasic microemulsification process, such as oil solvent / emulsifying agent/coemulsifier/water microemulsification process.

As to the microemulsification system, it is characterized in that the oil solvent usually used is a C6-C8 alkane or cycloalkane and the conventional emulsifying

agents comprise ionic and non-ionic surfactants. The typical cationic surfactant comprises cetyltrimethylammonium bromide (CTAB), dodecyltrimethylammonium chloride (DTAC), dioctodecylammonium chloride (DODMAC), cetylpyridinium bromide (CPB), and the like. Anionic surfactant mainly comprises sodium dodecyl sulphate (SDS), sodium di-2-ethyl-1-hexyl sulfosuccinate (AOT), sodium dodecylbenzenesulfonate (SDBS), sodium dodecyl polyoxyethylene ether sulfate (AES), and the like. Non-ionic surfactant mainly comprises polyvinyl alcohol, dodecanoyl diethanolamine, polyoxyethylene fatty alcohol ethers and alkyl phenol polyoxyethylene ethers etc., such as TX-6, AEO5, AEO7, AEO9, AEO12, Triton X-100 and Span series and Tween series, etc. The above mentioned surfactants can be used separately or in combination of two or more kinds. The common coemulsifier comprises n-butanol, n-pentanol, n-hexanol, n-heptanol, n-octanol, n-decanol, n-dodecanol, and other fatty alcohols.

Said microemulsion preparation in the apparatus of the present invention can be widely used to produce various catalysts, organic silicon materials, adhesives, ink, coatings, dye, pigment, ceramic dye, semiconductor, superconductor, magnetic material, liquid crystal material, polymer, and other nanometer particles such as those of pure metal, alloy, oxide, sulfide and other nanometer inorganic compound and nanometer organic polymer; and further can be used to self-assembled nanometer particles and produce nanometer powder crystal, nanometer non-crystal power. These nanometer powers have a narrow range of particle diameter and their particle diameter is very small and can be easily controlled below 100nm.

Said microemulsion preparation can be widely used to produce various inorganic or organic nanometer materials.

Furthermore, analysis of microemulsions obtained from said microemulsification process in the apparatus of the present invention may be carried out by the following methods: optically microscopical image analysis (OM), scanning electron microscopical image analysis (SEM), atomic force microscopical image analysis (AFM), transmission electron microscopical image analysis (TEM) and X-ray diffraction analysis (XRD). These analysis methods are commonly used to analyze formation of microemulsion, and the uniformity and dispersity of the droplets or particles, as well as the particle size.

Technical effect of said microemulsification process in the apparatus of the present invention consists in good transparency of microemulsion, high uniformity and dispersion of particles, particle size below 100 nm, and high solid content, high stabilization of the microemulsion without separation or color change for a long period.

4. Substance extraction application

Extraction of the present invention can be used not only to solvent extraction method, but also to complexation extraction method, and also to extraction with ionic

liquids as extracting agent or extracting phase.

Said solvent extraction achieves extraction and separation based on the dissolving performance difference of extractants in the extracting phase. Conventional extracting phase mainly comprise organic solvents or water. Said solvent extraction and separation technique of the present invention can be widely used in inorganic chemistry, analytical chemistry, radiological chemistry, abstraction and recycle of nuclide, and other aspects.

Said complexation extraction means the following steps: contacting extractants with an extracting agent containing a complexing agent; reacting the complexing agent with the extractants to form a complex; transferring the complex to the extracting phase; with the solute being recycled during converse reaction, and the extracting agent being reused. Compared with said solvent extraction method, the complexation extraction method has two obvious advantages as follows.

(a) Said complexation extraction can provide very high distribution coefficient value under low solute concentration; therefore it can achieve a complete separation of polar organic substance under the condition of low concentration.

(b) Since solute separation depends on complex reaction, another outstanding peculiarity of said complexation extraction is its high selectivity.

Said complexation extraction of the present invention is capable of extracting and separating polar organic substances (e.g. organic carboxylic acid compounds, organic sulfonic acid compounds, organic amine compounds, organic sulfur compounds, and organic compounds with amphiprotic functional groups. The key point in these applications consists in selecting proper complexing agent, cosolvent, diluter and their composition for different system.

Said complexing agent shall meet at least one requirement listed below:

(a) The complexing agent shall have corresponding functional group, and the associated bonding energy thereof with the solute to be separated shall be at a required amount so as to easily form complex compound and achieve phase transfer;

(b) Association bond energy can not be too high, so that the complex compound easily fulfills converse reaction in the second step and the complexing agent easily regenerates;

(c) In the process of complexing reaction and solute separation, the amount of water extraction by complexing agent shall be as little as possible or water is easily wiped off from solvent with the help of complexing agent;

(d) In order to avoid irreversible loss, there shall be no other secondary reaction in the process of complexation extraction, and complexing agent shall be thermally stable and not easy to decompose and degrade.

Said cosolvent and diluter shall meet the following requirements:

(a) As good solvents for the complexing agent, they shall promote the formation of the complex compound and achievement of phase transfer;

(b) They can adjust viscosity, density and interfacial tension of mixed extracting agent so as to easily implement liquid to liquid extraction;

(c) Diluter added can decrease extracting amount of water.

Said extraction method with ionic liquids as extracting phase or extracting agent, compared with the extraction method with organic solvent, has unique advantages such as low volatility, non-flammability, thermal stability and reusability. These advantages ensure that it will not pollute the environment as is inevitable for organic solvents. Said extraction method with ionic liquids as extracting phase or extracting agent is suitable for extracting organic substances from crude oil and extracting organic substances or metallic ions from waste water. The key point in the application of extracting organic substances from crude oil or water by ionic liquid consists in selecting proper ionic liquid and its composition. The key point in the application of extracting metallic ions from water by ionic liquid consists in selecting proper extracting agent and its composition.

Said organic substances to be extracted mainly comprise aromatic hydrocarbon and their derivatives, organic carboxylic acid compounds, organic sulfonic acid compounds, organic sulfur compounds, and organic amine compounds present in oil or waste water. Involved metallic ions are mainly heavy metallic ions, such as Ni^{2+} , Cu^{2+} , Ag^+ , Au^{2+} , Hg^{2+} , Pt^{2+} , Pb^{2+} , Cr^{3+} , Cd^{2+} , Mn^{2+} and the like.

Said ionic liquids of the present invention should meet at least one of the following requirements: (a) in liquid state at normal temperature and stable in the air; (b) as slight solubility as possible in crude oil or water to decrease cross contaminants. The melting point, stability, solubility and extraction efficiency of the ionic liquids can be adjusted by selecting proper anions and cations, as well as by selecting different mixed ionic liquids.

Extractants analysis method of the present invention comprises one or more of OM, SEM, AFM, TEM, FTIR, NMR, CE. These analysis methods are commonly used to analyze uniformity, dispersion, droplet size and extraction efficiency and other properties of an extraction liquid.

Advantages of said materials extraction in the apparatus of the present invention comprise high uniformity and dispersion of the droplets, droplet size on the order of micrometers, and the natural separation of the extraction liquid after a period of time, good extraction efficiency.

5. Substance reaction application

Substance reaction application of the apparatus of the present invention involves gas phase reaction system, liquid phase reaction system or gas-liquid phase reaction system, particularly heterogeneous phase reaction system. Further, the reaction

comprises liquid-liquid reaction, polymerisation, oxidization-desulfurization reaction and the like, but not limited to these reactions.

5.1 liquid-liquid reaction application

In said liquid-liquid reaction application, said liquid can be a pure liquid or a mixture of several liquids which can be mixed or prepared in advance; said gas-liquid phase reaction system is characterized in that at least one substance is gas which can be fed from pressure vessel through pressure controlling valve and discharged out of mixer through its outlet.

Said liquid-liquid reaction method involves hydrolytic reaction, double decomposition reaction, neutralization reaction, ion exchange reaction, redox reaction, complexation reaction, complex reaction, chelation reaction, halogenating reaction, nitration reaction, cyanation reaction, epoxidation reaction, diazo reaction, alkylation reaction, esterification, condensation reaction, Fridel-Craft reaction, polymerization, and the like; said gas-liquid reaction method means that gas can be rapidly dissolved in liquid, so that two or more substances of the gas and liquid can react at very high speed, sometimes even without catalyst or/and surfactant used in the conventional methods; therefore, economically feasible reaction speed is attained.

5.2 Polymerization application

Further, the apparatus of the present invention is suitable for mixing active fluid for anion polymerization, wherein at least one active fluid comprises at least one (meth)acrylic acid monomer.

Said (meth)acrylic acid monomer preferably means acrylic anhydride, methacrylic anhydride, methyl, ethyl, propyl, n-butyl, tert-butyl, ethylhexyl, nonyl, 2-dimethyl amino ethyl acrylate.

Said polymerization can be performed outside the apparatus of the present invention, or start inside the mixer and continue outside the mixer.

One application of liquid-liquid reaction process or gas-liquid reaction process involved in the present invention is suitable for grafting reaction of alkene polymer and organic monomer containing initiator, wherein at least one organic monomer comprises at least one vinylated unsaturated heterocycle monomer containing nitrogen, sulphur or oxygen.

Said alkene polymer is particularly polyethylene, ethylene-propylene copolymer, styrene-butadiene rubber, polyisoprene, ethylene-propylene-diene ternary copolymer, polymethacrylate, polystyrene, butadiene-styrene copolymer and the like.

Said vinylated unsaturated heterocycle monomer containing nitrogen or oxygen, is particularly N-vinylimidazole, 1-vinylpyrrolidine, C-vinylimidazole, N-alkylimidazole, 1-vinylpyrrolidine, 2-vinylpyridine, 4-vinylpyridine, N-methyl-N-vinyl acetamide, diallylformamide, N-methyl-N-allyl formamide,

N-ethyl-N-allyl formamide, N-cyclohexyl-N-allyl formamide, 4-methyl-5-ethylthiazole, N-allyl-2-isooctylbenzothiazine, 2-methyl-1-vinylimidazole, 3-methyl-1-vinylimidazole, N-vinylpurine, N-vinylpiperazine, N-vinylsuccinimide, vinylpyridine, vinylmorpholine, maleic acid, acrylic acid, maleic anhydride, etc.

Said initiator is preferably ditert-butyl peroxide, dicumyl peroxide, tert-butyl cumyl peroxide, tert-butyl peroxy benzoate, tert-amyl peroxy benzoate, tert-butyl peroxybenzoate, tert-butyl peroxy benzoate, benzoyl peroxide, tert-butyl monoperoxy phthalate, hydrogen peroxide, cumene hydroperoxide, tert-amyl peroxide, etc.

In said grafting polymerization process, mixing ratio, flow rate, mixing temperature and rotation speed and other experimental parameters can be adjusted through system software to achieve rapid reaction and best products properties.

Said grafting polymerization can be performed outside the mixer of the present invention, or start inside the mixer and continue outside the mixer.

5.3 Application of gas-liquid phase desulfurization reaction

Gas-liquid reaction involved in the present invention is suitable for a gas desulfurization technique, particularly for mixing reaction of acid gas and alkaline liquid, thereof, with at least one alkaline liquid containing at least one alcohol amine compound or hydroxid.

Said alcohol amine compounds are preferably monoethanolamine, diethanolamine, diisopropanolamine, N-methyl diethanolamine, N-ethyl diethanolamine, N-propyl diethanolamine, N-butyl diethanolamine and other alkaline solution. Said alcohol amine compounds can further be mixed with other co-desulfurization solvent (e.g. sulfolane) in different volume ratios to achieve better desulfurization efficiency.

Said hydroxide is preferably sodium hydroxide (NaOH), potassium hydroxide (KOH), calcium hydroxide (CaOH), ammonium hydroxide and other alkaline solutions.

Said acid gas is preferably natural gas, refinery gas, tail gas, syngas and the like containing impurities such as hydrogen sulfide, organic sulphur (thiols), carbon dioxide.

In said gas desulfurization reaction process, mixing ratio, flow rate, mixing temperature and rotation speed and other experimental parameters can be adjusted by system software to achieve rapid desulfurization reaction and optimum desulfurization efficiency.

Said gas desulfurization reaction can be performed outside the mixer of the present invention, or starts inside the mixer and continues outside the mixer.

Said gas desulfurization technique of the present invention is also suitable for any gas and liquid reaction.

Further, the application of liquid-liquid reaction of the present invention is suitable for gas desulfurization technique, particularly for mixing reaction of acid gas and alkaline liquid, wherein at least one alkaline liquid contains at least one alcohol amine compound or hydroxide.

5.4 Application of liquid phase desulfurization

Further, said liquid phase desulfurization is suitable for redox reaction of active fluids containing an oxidant in acidic medium, wherein at least one active fluid contains at least one sulphur-containing compound.

Said sulphur-containing is particularly dialkyl substituted sulfides, dialkyl substituted thiophene and its derivatives, alkyl substituted benzothiophene and its derivatives, and alkyl substituted dibenzothiophene and its derivatives. Said alkyl comprises methyl, ethyl, propyl, n-butyl, tert-butyl, ethylhexyl, nonyl, and the like.

Said oxidant comprises peroxides and other oxides, particularly H_2O_2 , O_3 , N_2O , ClO_2 , ClO^- , $(\text{CH}_3)_2\text{CO}_2$, t-BuOOH, $\text{C}_5\text{H}_{11}\text{NO}_2$, ClO_3^- , HSO_3^- , IO_4^- , and the like.

Said acid medium comprises inorganic acids and organic acids, particularly hydrochloric acid, hydrobromic acid, hydroiodic acid, sulphuric acid, nitric acid, phosphoric acid, boracic acid, carbonic acid, methanoic acid, acetic acid, trifluoroacetic acid, and the like.

Said oxidation-desulfurization reaction can be performed outside the mixer of the present invention, or starts inside the mixer and continues outside the mixer.

Said substance reaction in the apparatus of the present invention is not limited to the above-mentioned, and it can also involve various organic chemical reactions, such as hydrogenation reaction, hydroformylation reactions, carbonylation reactions, dimerization and oligomerization of olefins, Diels-Alder reactions, acylation reactions, Heck reactions, Suzuki reactions, Stille coupling reaction, Trost-Tsuji coupling reaction, allylation reaction, nucleophilic displacement reaction, Baylis-Hillman reaction, Wittig reaction, free radicals cycloaddition reactions, asymmetric ring opening reaction of epoxides, continuous multistep reactions, and enzyme catalyzed organic reaction and asymmetric synthesis reaction, and the like. Reactants of said respective reaction can react rapidly, even sometimes without catalyst needed in the traditional reactions.

The above-mentioned oxidation-desulfurization reaction can be performed within the the apparatus of the present invention, and also can be performed within the containing chamber with two smooth surfaces.

Another aspect of the present invention relates to a method for desulfurizing sulfur-containing material, comprising the steps of providing a desulfurizer(s) and sulphur-containing material; providing a containing chamber, which is formed by a first element and a second element arranged within the first element wherein the second element can rotate relatively to the first element under the action of external

force; feeding the desulfurizer and sulphur-containing material into the containing chamber to be processed.

In another embodiment, the surface of the first or second element toward said containing chamber, can be smooth, and also can be non-smooth.

In another embodiment, the surface of the first or second element toward said containing chamber can be arranged with a disturbing part, and also can be without a disturbing part.

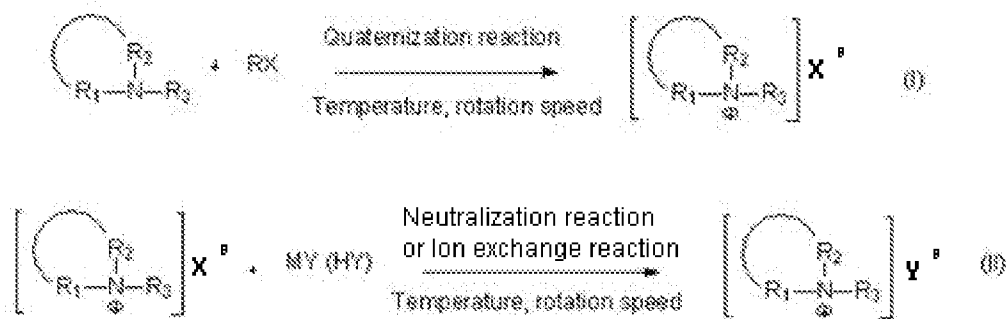
Said sulphur-containing material comprises sulfur-containing gas or/and sulfur-containing liquid. Sulfur-containing gas comprises natural gas and liquid comprises sulfur-containing crude oil. Desulfurizer can be any kind of desulfurizers in the art.

In another embodiment, the thickness of said containing chamber is on the order of micrometers.

6. Application in materials preparation

Application in ionic liquids preparation

In one embodiment for ionic liquids preparation, general reaction formula is as follows:



wherein,

R denotes methyl (CH₃), ethyl (C₂H₅), propyl (C₃H₇), butyl (C₄H₉) or other linear or branched alkyls with 1-20 carbons, and also can denote methoxy group, ethoxy group, propoxy group, butoxy group or other linear or branched alkoxy with 1-20 carbons;

R₁, R₂ each denotes methyl (CH₃), ethyl (C₂H₅), propyl (C₃H₇), butyl (C₄H₉) or other linear or branched alkyls with 1-20 carbons;

R₃ denotes H (hydrogen), methyl (CH₃), ethyl (C₂H₅), propyl (C₃H₇), butyl (C₄H₉) or other linear or branched alkyls with 1-20 carbons;

X denotes chlorine atom (Cl), bromine atom (Br), iodine atom (I) or the like;

Y denotes PF_6^- , BF_4^- , CH_3SO_3^- , CH_3CO_3^- , $\text{N}(\text{SO}_2\text{CF}_3)_2^-$ or the like;

M denotes sodium (Na), potassium (K), silver (Ag), ammonium ion (NH_4^+) or the like;

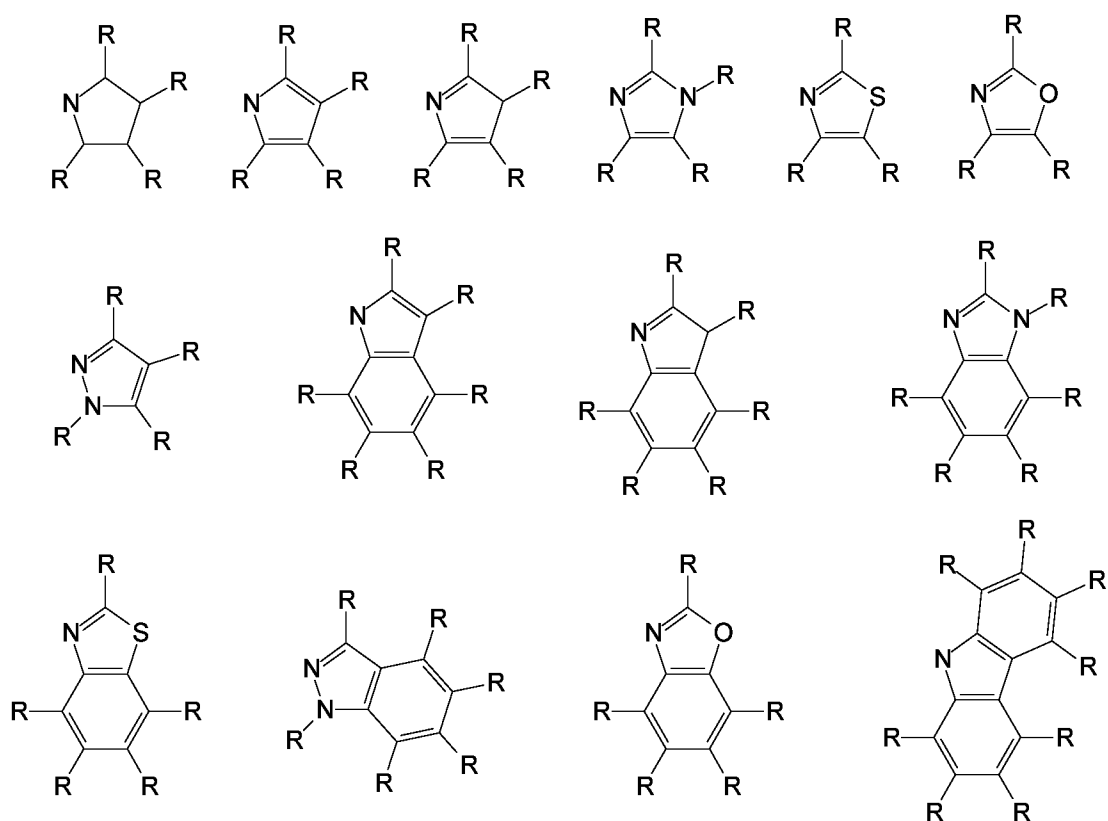
H denotes hydrogen atom;

N denotes nitrogen atom.

In the general formulae (I) and (II),

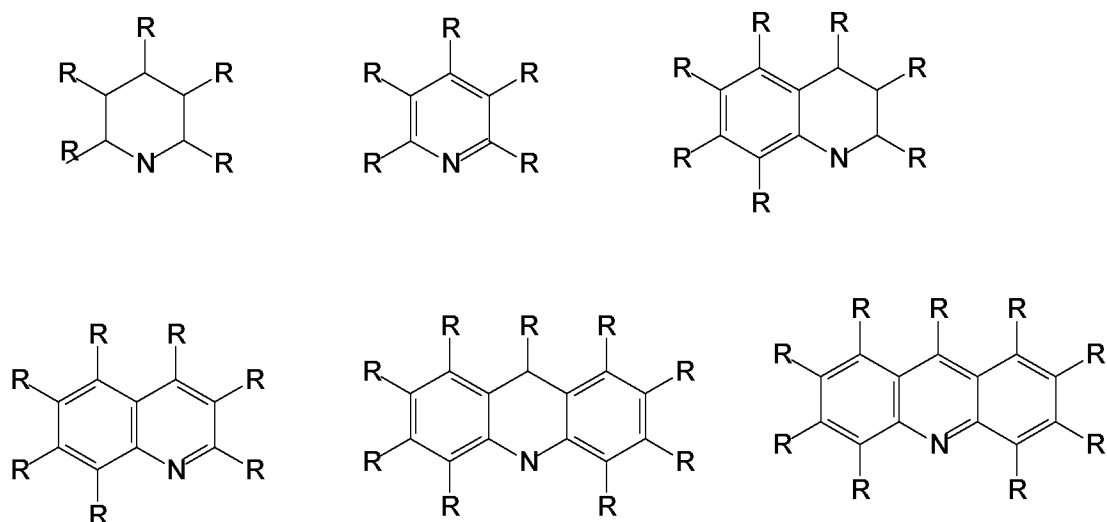
When R_3 is H, R_1 and R_2 can substitute separately or together form into various rings. The possible structures are as follows:

Five-membered heterocycles and benzoheterocycles thereof



wherein, R denotes H (hydrogen), methyl (CH_3), ethyl (C_2H_5) or other linear or branched alkyls with 1-10 carbons. R can be same or different, and the adjacent R groups can substitute separately or together form into ring.

Six-membered heterocycles and benzoheterocycles thereof



wherein, R denotes H (hydrogen), methyl (CH₃), ethyl (C₂H₅) or other linear or branched alkyls with 1-10 carbons. R can be same or different, and the adjacent R groups can substitute separately or together form into ring.

For general formulae (I) and (II), the temperature is in the range from room temperature (RT) to the maximum temperature (T_{max}) of the mixer which is commonly about 150 °C; rotation speed is in the range from zero to the maximum rotation speed (V_{max}) of the mixer which is commonly about 10000 round per minute (RPM).

The above-mentioned ionic liquid preparation can be performed within the apparatus of the present invention, and also can do within the containing chamber with both smooth surfaces.

Another aspect of the present invention relates to a method for processing ionic liquid, comprising the following steps: providing at least two kinds of ionic liquids; providing a containing chamber, which is formed by a first element and a second element arranged within the first element wherein the second element can rotate relatively to the first element under the action of external force; feeding said ionic liquids into said containing chamber to be processed.

In another embodiment, the surface of the first or second element toward said containing chamber can be smooth, and also can be non-smooth.

In another embodiment, the surface of the first or second element toward said containing chamber can be arranged with a disturbing part, and also can be without a disturbing part.

In another embodiment, the thickness of said containing chamber is on the order of micrometers.

Further, said apparatus of the present invention can also be used in any chemical reaction or green chemical reaction with ionic liquids as solvent or catalyst. Said

methods of the present invention can also be widely used to prepare inorganic substance, organic substance, medicament, catalyst, macromolecular polymer and the like.

Said chemical reaction or green chemical reaction system mainly involves hydrogenation reaction, hydroformylation reaction, carbonylation reaction, dimerization and oligomerization of olefins, Diels-Alder reaction, Friedel-Crafts reaction, acylation reaction, selective alkylation reaction, Heck reaction, Suzuki reaction, Stille coupling reaction, Trost-Tsuji coupling reaction, allylation reaction, oxidation reaction, nucleophilic displacement reaction, Baylis-Hillman reaction, Wittig reaction, Free radicals cycloaddition reaction, asymmetric ring opening reaction of epoxides, continuous multistep reaction, and enzyme catalyzed organic reaction and asymmetric synthesis reaction, and the like.

7. Application in cell disruption

A material processing apparatus with a narrow processing chamber and a rapidly rotating rotor can provide a high shear force, and therefore can be used to rupture cell walls. When used to rupture cell walls, the material processing apparatus is preferably equipped with an efficient cooling system for cooling the material processing apparatus and preventing it from being partially over-heated because over-heat may result in protein inactivation or coagulation during cell disruption. The material processing apparatus is capable of disrupting various amounts of cell (e.g. a small amount such as 1ml, or a large amount for continuous processing) and therefore can be widely employed for cell disruption both in lab-scale and in industrial-scale. A rotating rate of the rotor and a reaction time can be accurately adjusted and controlled. Experiments may be done at different conditions. For example, either the rotating rate of the rotor or the reaction time (or both) may be varied. Therefore conditions for cell disruption can be varied according to purposes of the research. For example, if the purpose is to achieve subcellular organelles, the rotor may be firstly set at a high rotating rate to produce a high shear force to rupture cell walls, and then the rotating rate of the rotor may be decreased and controlled to selectively rupture cell membrane.

In one embodiment, the cells used are yeast cells which can be bought from markets, such as Coomassie Brilliant Blue G-250 and Crystal Violet.

An example of experiment process is provided as follows:

The yeast cells are dispersed in a cell lysis solution. The cell lysis solution may include 50 mM Tris-HCl (pH8.5), 2 mM EDTA, and 100 mM NaCl (also, Triton X-100, urea and lysozyme may be added, depending on needs).

A temperature of the material processing apparatus is set at -5°C. The cell lysis solution containing the yeast cells is fed at a rate of 0.5mL/min. Disruption experiments are carried out respectively at rotor rotating rates of 0, 200, 500, 1000, 2000, 4000 and 8000 rpm. After each experiment, 1ml of sample is collected to

measure the protein content in the sample, so as to determine at which rotating rate a lowest cell disruption rate is achieved, and at which rotating rate equilibrium of cell disruption rate is achieved. Further, effects of different retention time can be researched at a same rotating rate.

A reference cell disruption experiment can be carried out by other methods for cell disruption, such as homogenate method by homogenizer and grinding method, using a same cell lysis solution. Protein yield is measured.

Protein yield can be an index for estimating the cell disruption efficiency. Effluent from the material processing apparatus is collected, separated by centrifuge. Protein content in the separated upper clean liquid is measured by the Bradford method, and the protein yield can be calculated. In addition, disruption degree can be observed by a microscope. The effluent is smeared, dyed with Gram crystal violet for 0.5min, and then is observed by the microscope.

Protein content can be measured by the Bradford method. The following is an example:

preparing a standard 0.5mg/mL BSA solution (dissolved in 25mM, pH 7.0 phosphate buffer solution);

having 0 μ L, 25 μ L, 50 μ L, 60 μ L, 80 μ L, 100 μ L and 150 μ L of the standard protein sample respectively added into different sample vessels;

adding phosphate buffer solution to the sample vessels until solution in each of the sample vessels is raised to 500 μ L;

adding 250 μ L of 0.1M HCl, 500 μ L of H₂O, and 1mL of 0.01% Coomassie G-250, Na;

mixing, reacting for 20min;

measuring absorbency at 595 nm and protracting standard curve;

having 500 μ L of upper clean liquid of the cell lysis solution reacted with the aforesaid reagent and measuring absorbency according to the aforesaid steps;

comparing with the standard curve to determine protein content.

Further, the apparatus of the present invention can also be used in pharmacy industry, particularly to produce injectable medicaments for external use or internal use.

The application in materials preparation by said apparatus of the present invention is suitable for homogeneous liquid reaction system, heterogeneous gas-liquid reaction system, and heterogeneous liquid-liquid reaction system.

In addition, in order to apply said apparatus of the present invention in a better way, said apparatus can be connected with computer software system which is used to

control the operation of the whole apparatus. Accordingly, rapid, accurate, automatic, continuous and batched sample preparation can be achieved. The connecting means can be any means in the art.

Further, the materials processing in the above-mentioned apparatus with computer software system comprises the following steps:

- (a) preparing raw materials;
- (b) feeding said raw materials into the containing chamber respectively through inlets 30,31;
- (c) designing the experimental procedure which involves mixing of raw materials, product collecting, cleaning and drying of the reaction system;
- (d) setting experimental parameters which involve mixing ratio of raw materials, flow rate of the raw materials at the two inlets, reactor temperature, shaft bearing temperature, rotation speed and collecting amount;
- (e) repeating steps (c) and (d) and changing experimental parameters as required, if it is desired to prepare mixing components in different conditions;
- (f) running the procedure, wherein after system self-examination is successfully fulfilled, the experimental procedure will run automatically and sequentially, and different mixing components will be collected;
- (g) ending the experimental procedure;
- (h) sample processing and analyzing;
- (i) ending the whole experiment.

Liquid raw material involved in the above-mentioned experimental steps can be a single substance; and also can be a mixture of two or more kinds of substances. Said mixture can be automatically prepared by an automatic liquid distributor; and also can be prepared by a multi-channel liquid feeding system arranged in front of the inlets of said apparatus.

The above-mentioned experimental procedure is programmed in system software. The order of the involved steps of the procedure can be adjusted if needed, for example it can orderly be mixing, collecting, cleaning and drying; or be cleaning, drying, mixing, collecting, cleaning and drying. Method for drying is blow-drying with an inert gas. The parameters can be selected or adjusted according to the following: the amount of the raw materials fed through the two inlets can be 1ml, 5ml, 10ml, 20ml, 25ml, 50ml, or the like; the type of mixing ratio can be mol ratio, volume ratio, mass ratio; rotation speed can be from zero to 12000 rounds per minute (RPM); flow rate can be from zero to 10 ml/min; the temperature of the feeding means can be from room temperature to 100 °C; the reactor temperature can be from room temperature to 250 °C; the shaft bearing temperature can be from room temperature

to 80 °C.

Cleaning solvent involved in said experimental procedure is selected according to the solubility of raw materials to be mixed and products, and it can be a single cleaning solvent, and also can be a mixture of cleaning solvents. The cleanness can be fulfilled through many steps with many different cleaning solvents for many times. The common cleaning solvents comprise n-hexane, methylene dichloride, chloroform, carbon tetrachloride, benzene, toluene, tetrahydrofuran, acetone, ethyl acetate, acetonitrile, methanol, ethanol, water and the like.

Said sample processing methods involved in said experimental procedure comprise solvent extraction, centrifugal separation, filtration, vacuum drying, column chromatography separation. Common solvents used in said solvent extraction are solvents that are insoluble in products but soluble in raw materials, especially with low boiling point and good volatility. Common organic solvents are n-hexane, methylene dichloride, chloroform, carbon tetrachloride, benzene, toluene, tetrahydrofuran, acetone, ethyl acetate, acetonitrile, methanol, and ethanol. Said column chromatography separation is used for crude separation of products, commonly comprising adsorption chromatography separation, gel permeation chromatography separation, ion exchange chromatography separation, in which the common stuffing is consisted of silica gel, alumina, silicon alkylation series gels, cellulose, polyamide, or the like.

Said sample analysis method involved in said experimental procedure mainly comprises Capillary Electrophoresis (CE), Gas Chromatography (GC), Liquid Chromatography (LC), Inductive Coupled Plasma Emission Spectrometer (ICP), Mass Spectrometry (MS or QMS), Fourier Transform Infrared Spectroscopic (FTIR) analysis, Nuclear Magnetic Resonance (NMR), X-ray Diffractive (XRD) analysis, Optical Microscopical image analysis (OM), Scanning Electron Microscopical image analysis (SEM), Atom Force Microscopical image analysis (AFM), Transmission Electron Microscopical image analysis (TEM). CE, GC and LC are suitable for separation analysis, qualitative analysis and quantitative analysis of mixing products; ICP is suitable for qualitative analysis and quantitative analysis of metallic elements in mixing products; MS, FTIR and NMR are suitable for molecular weight, structure and functional group analysis of mixing products; OM, SEM, AFM, TEM and XRD are suitable for shape and configuration inspection, such as color, particle size and uniformity. Analysis methods involved in the present invention can be used separately or in combination such as the combination of CE (or HPLC, GC) with MS, the combination of CE (or HPLC, GC) with FTIR. The combination of several analysis methods is good for rapid and accurate analysis of mixing products.

The material processing system of the present invention has many advantages. For example:

1. Continuousness: sample preparation by the combination of flow injection method and high speed shear mixing method, not only achieves the continuousness

without being interrupted in the whole preparation process (from raw materials in to products out), but also is good for continuous and batched industrial production, which is obviously different from the traditional “one-pot reaction” fixed mode.

2. Rapidness: due to the use of the high speed shear mixer, reactants can be rapidly and efficiently mixed at the beginning to make the mixing in thoroughly uniformity or the reaction tends to completeness. Further, because the whole process proceeds under a continuous flow condition, mixing time or reaction time is greatly shortened. In general, the whole process can be fulfilled within several minutes or about ten minutes, which is quicker than stirring mixing in the prior art.

3. Automatization: flow injection method is one form of automatization. It is connected with high speed shear mixing and then is used for sample preparation, which makes the whole preparation process comprise reaction time and speed can be controlled by a uniform system software. In this way, it is easy to control and operate and the preparation process is visual. Furthermore, efficiency has been improved and it is easy for industrialization.

4. Accuracy: all sampling and reaction condition are controlled by software, which is good not only for improving reproducibility of the experimental results, but also for the accuracy of the experimental results.

Example:

Referring to FIG. 6A, a detailed example of the material processing apparatus and its specific application are provided hereafter.

The first and second member 11 and 12 are made from stainless steel.

The first member 11 functions as a stator and the second member 12 functions as a rotor. The stator 11 has a smooth inner surface, and rotor 12 has an outer surface divided into a pre-processing section 121 formed with rectangular stripes and a smooth processing section 122. The pre-processing section 121 constitutes 40% of a total length of the pre-processing and processing sections.

The stripes have a width of 1mm, a height of 3.5mm. A distance between two adjacent stripes is 10mm.

Tops of the stripes on the pre-processing section 121 are 0.15mm from the inner surface of the stator 11, and the processing section 122 is 0.75mm from the inner surface of the stator 11.

A screw feeder 20 is connected to the first material inlet 113, and a syringe pump is connected to the second material inlet 114.

An application example of the material processing apparatus is to prepare ionic liquid of 3-ethyl-1-methyl imidazolium chloroaluminate salt from 3-ethyl-1-methyl imidazolium chloride and aluminum chloride (AlCl_3), by such a reaction:

$[\text{emim}]\text{Cl}(\text{s}) + n\text{AlCl}_3(\text{s}) - [\text{emim}]\text{Cl} - n\text{AlCl}_3(\text{l}) + Q$, wherein

$[\text{emim}]$ is 3-ethyl-1-methyl imidazolium,

(s) means solid,

n means a proportion larger than zero,

$[\text{emim}]\text{Cl} - n\text{AlCl}_3$ is 3-ethyl-1-methyl imidazolium chloroaluminate salt,

(l) means liquid, and

Q means heat.

It can be prepared by steps as follows:

- a. adding AlCl_3 powders to the screw feeder 20, heating solid 3-ethyl-1-methyl imidazolium into liquid and feeding it to the syringe pump;
- b. setting a temperature in the processing chamber 110 at 30°C , and setting a rotation rate of the rotor 12 to 3000rpm;
- c. starting the syringe pump and the screw feeder, and feeding the liquid 3-ethyl-1-methyl imidazolium and the AlCl_3 powders into the processing chamber 110;
- d. collecting products from the collecting outlet 115;
- e. cleaning the processing chamber 110 respectively by water and ethanol.

CLAIMS:

1. A material processing apparatus, comprising:
a first member and a second member rotatable relative to the first member and at least partially received within the first member, the first and second members forming a substantially annular processing passage,
wherein the processing passage includes a pre-processing zone and a processing zone, wherein a circumferential surface of the first member or the second member facing the pre-processing zone is provided with protruding or/and concave portions, while circumferential surfaces of the first and second members facing the processing zone are relatively smooth, and wherein the processing zone is configured such that materials in the processing zone can form Couette flow when a relative rotation speed between the first and second members reach a certain value.
2. The material processing apparatus according to claim 1, wherein the pre-processing zone provides an axial force directed from the pre-processing zone towards the processing zone for pushing materials in the pre-processing zone into the processing zone during relative rotation between the first and second members.
3. The material processing apparatus according to claim 2, wherein the first member serves as a stator, the second member serves as a rotor, a circumferential surface of the second member that faces the pre-processing zone is provided with protruding or/and concave portions, and a circumferential surface of the first member that faces the pre-processing zone is relatively smooth.
4. The material processing apparatus according to claim 2, wherein the protruding or/and concave portions are in form of stripes, or are arranged in form of stripes, and the stripes extend at an angle larger than 0 degree and smaller than 90 degrees from a axial direction of the second member.
5. The material processing apparatus according to claim 1, wherein the first member is provided with a first material inlet for allowing a material to be fed into the pre-processing zone.
6. The material processing apparatus according to claim 5, wherein the first member is further provided with a second material inlet beside the first material inlet and adjacent to the processing zone.
7. A material processing system including the material processing apparatus according to claim 6, further comprising a solid material feeding apparatus connected to the first material inlet and a fluid feeding apparatus connected to the second material inlet.
8. A material processing apparatus, comprising:
a first member and a second member rotatable relative to the first member and at least partially received within the first member, the first and second members forming a substantially annular processing passage,
wherein the processing passage includes a pre-processing zone and a processing

zone, wherein the pre-processing zone is configured such that it provides a force to push materials in the pre-processing zone toward the processing zone when the first and second members rotate relative to each other, and wherein the processing zone is configured such that materials in the processing zone forms Couette flow when a relative rotation speed between the first and second members reach a certain value.

9. The material processing apparatus according to claim 8, wherein the first member is provided with a first material inlet for allowing a first material to be fed into the pre-processing zone.
10. The material processing apparatus according to claim 9, wherein the first member is further provided with a second material inlet for allowing a second material to be fed into the pre-processing zone, and the second material inlet is beside the first material inlet and adjacent to the processing zone.
11. A material processing system including the material processing apparatus according to claim 10, further comprising a solid material feeding apparatus connected to the first material inlet and a fluid feeding apparatus connected to the second material inlet.
12. The material processing apparatus according to claim 1 or 8, further comprising a sealing member adapted to seal the processing passage from outside environment, the sealing member including a sealing chamber, a first port allowing a first fluid introduced into the sealing chamber, and a second port allowing fluids outputted from the sealing chamber.
13. The material processing apparatus according to claim 12, wherein the sealing member further comprises a first seal element sealing the processing passage from the sealing chamber, and a second seal element sealing the sealing chamber from the outside environment.
14. The material processing apparatus according to claim 13, wherein the first seal element is a single-lip seal with a lip protruding towards the processing passage.
15. The material processing apparatus according to claim 13, wherein the first seal element is a single-lip seal with a lip protruding inwards the sealing chamber.
16. The material processing apparatus according to claim 12, wherein the first fluid is a gas inert with respect to materials in the processing passage at a condition in the sealing chamber.
17. The material processing apparatus according to claim 1 or 8, wherein the relative rotation between the first and second members is magnetically driven.

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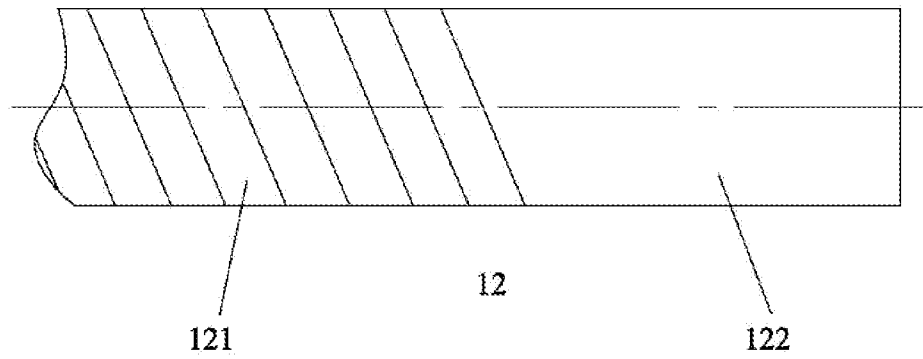


Fig. 1A

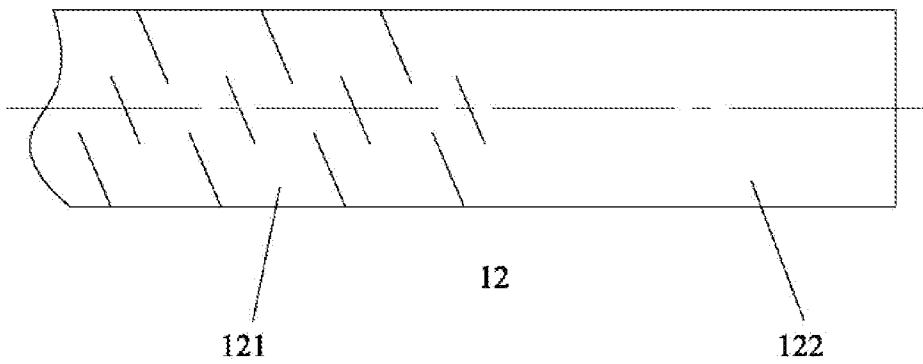


Fig. 1B

-2/22-

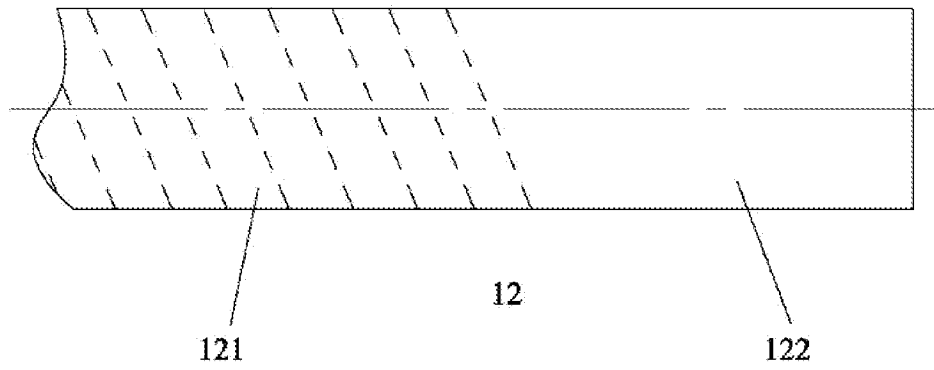


Fig. 1C

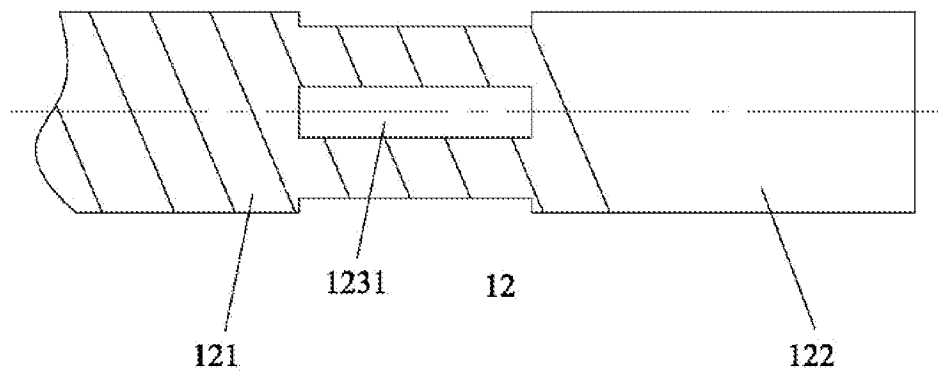


Fig. 1D

-3/22-

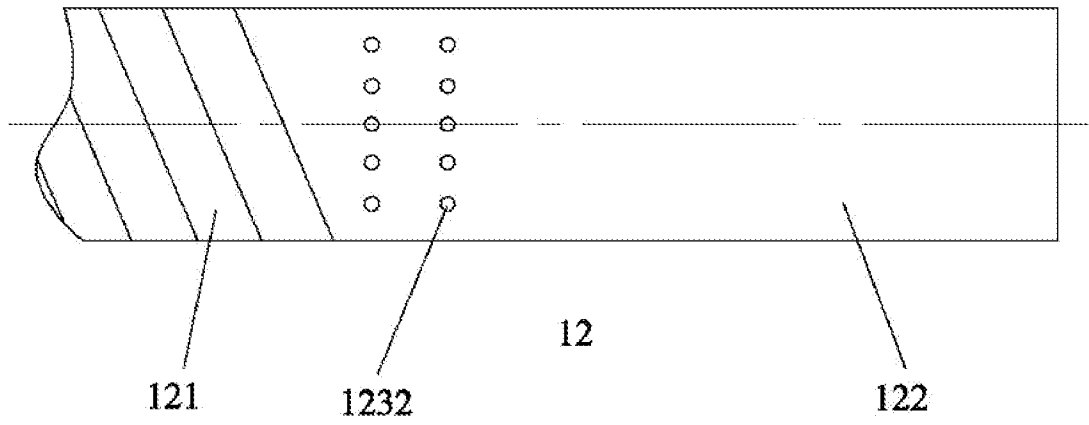


Fig. 1E

-4/22-

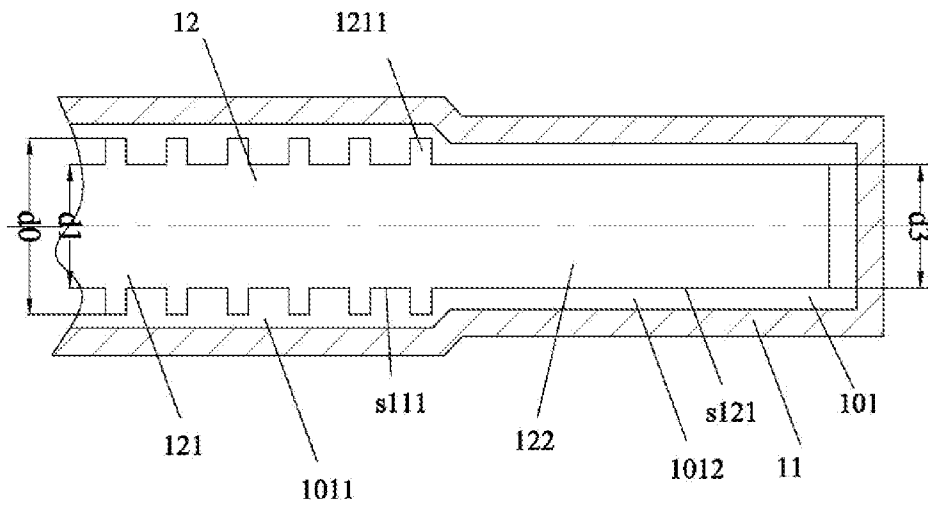


Fig. 2A

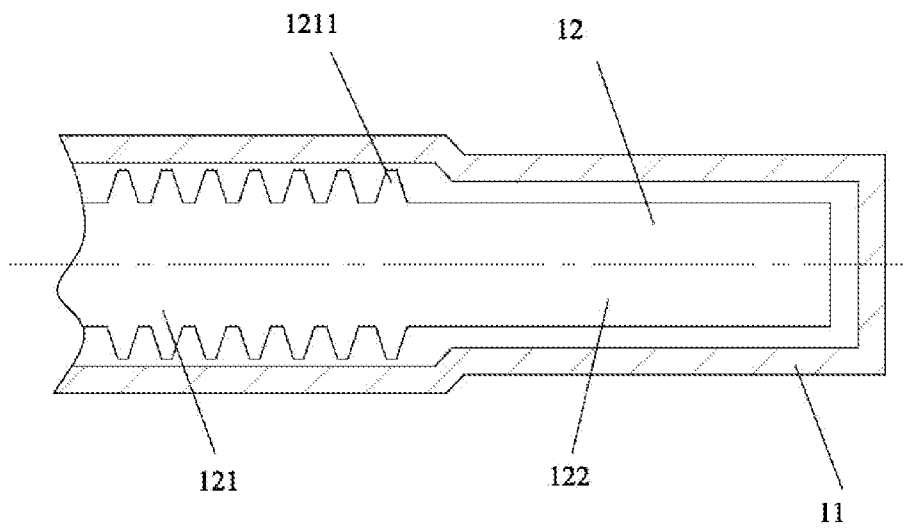


Fig. 2B

-5/22-

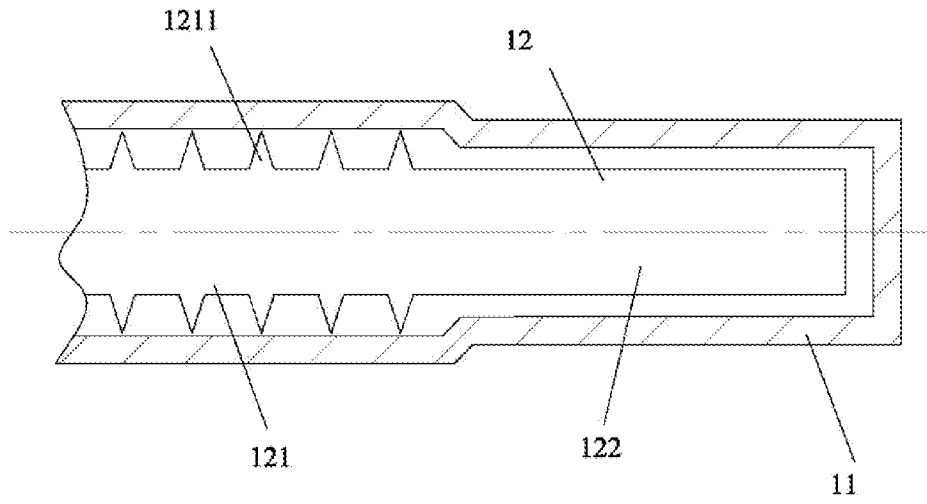


Fig. 2C

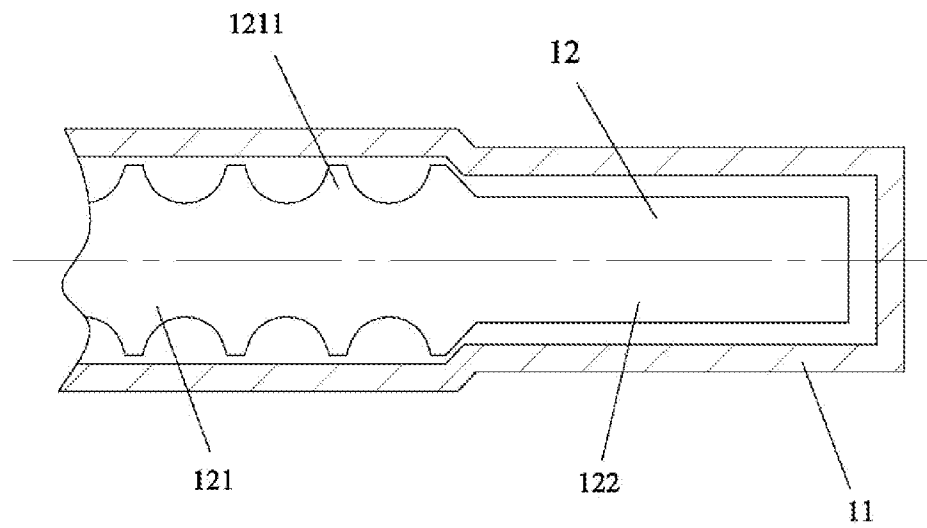


Fig. 2D

-6/22-

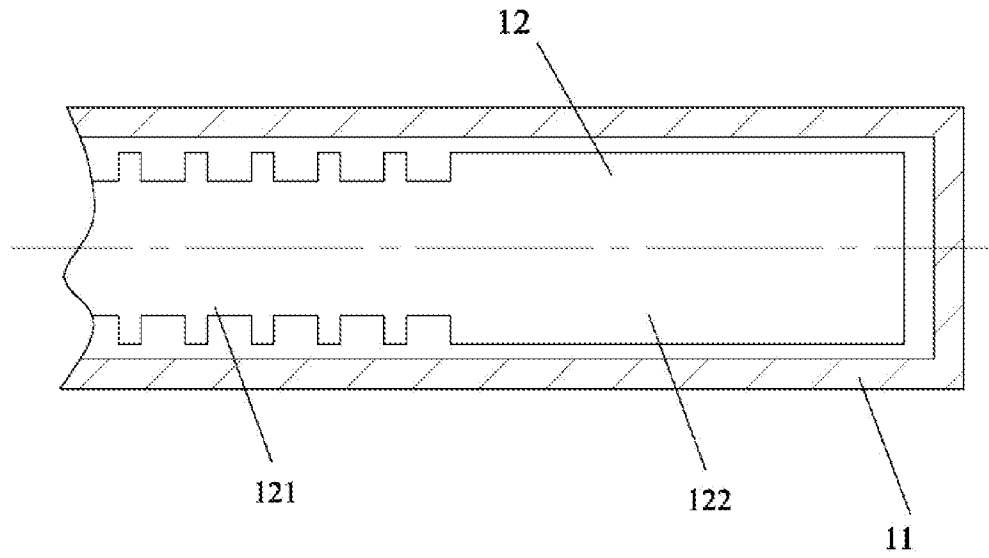


Fig. 2E

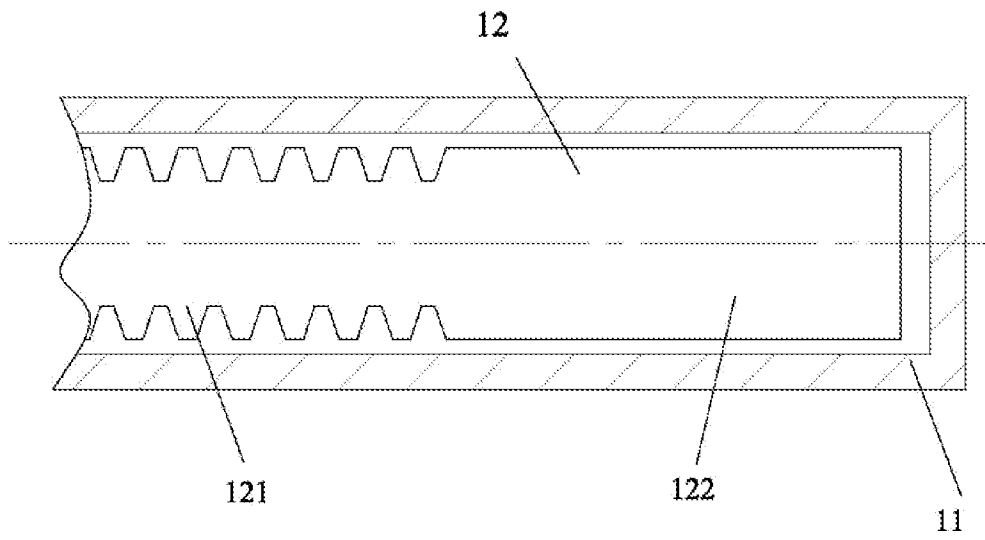


Fig. 2F

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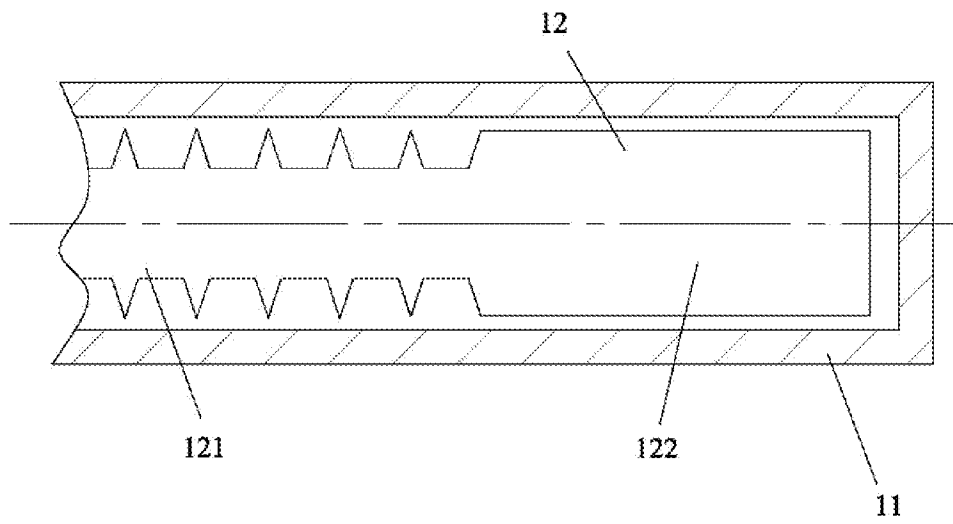


Fig. 2G

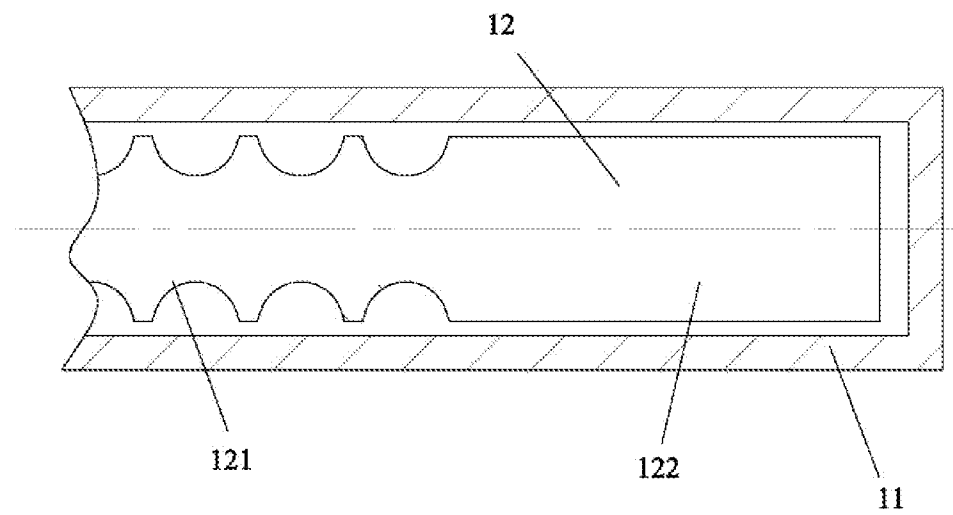


Fig. 2H

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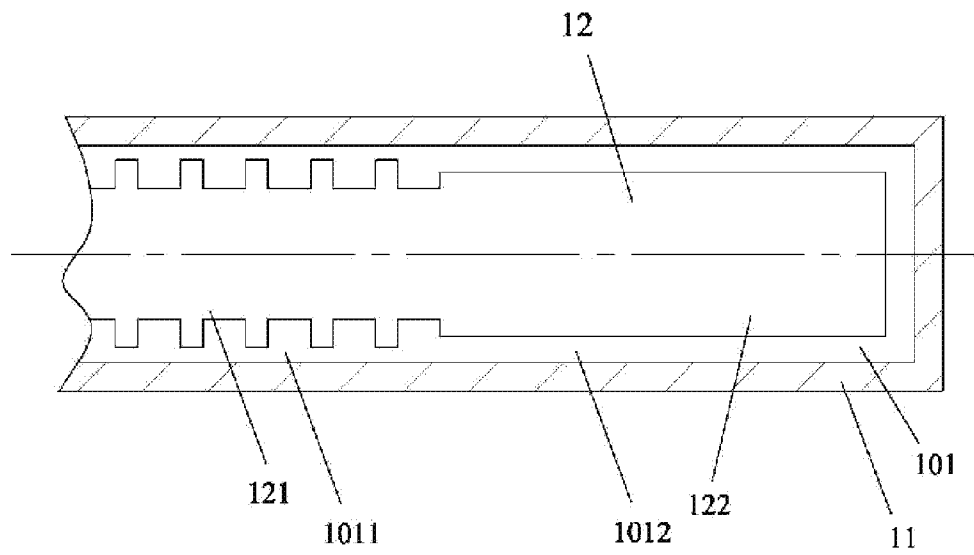


Fig. 2I

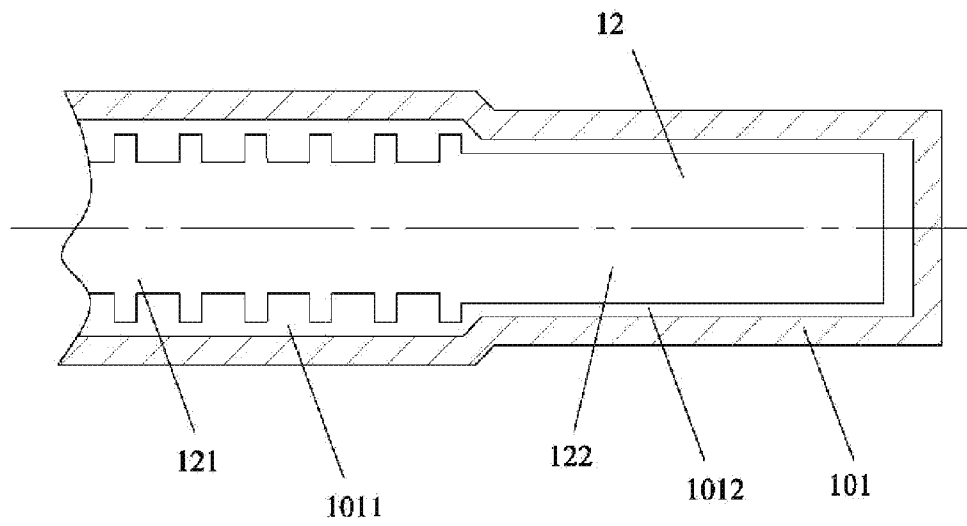


Fig. 2J

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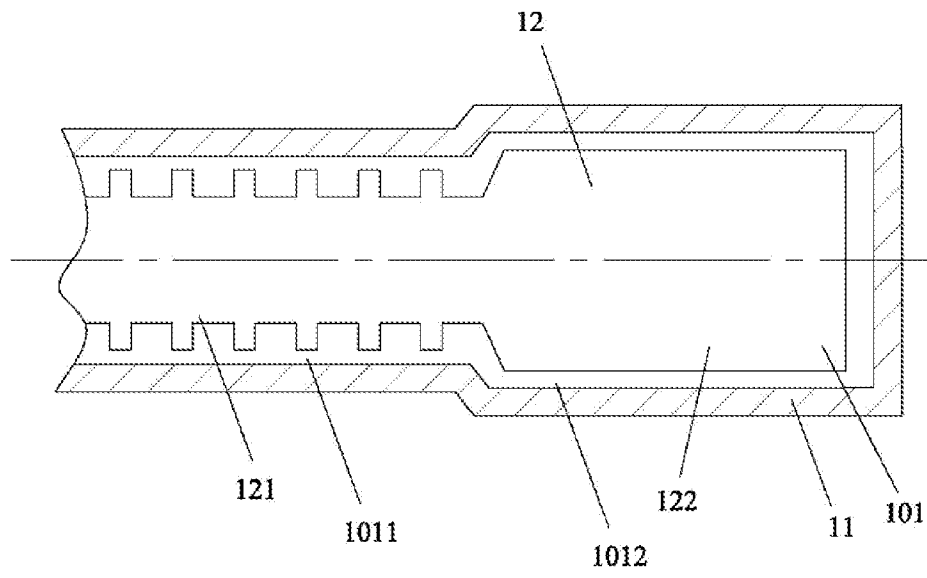


Fig. 2K

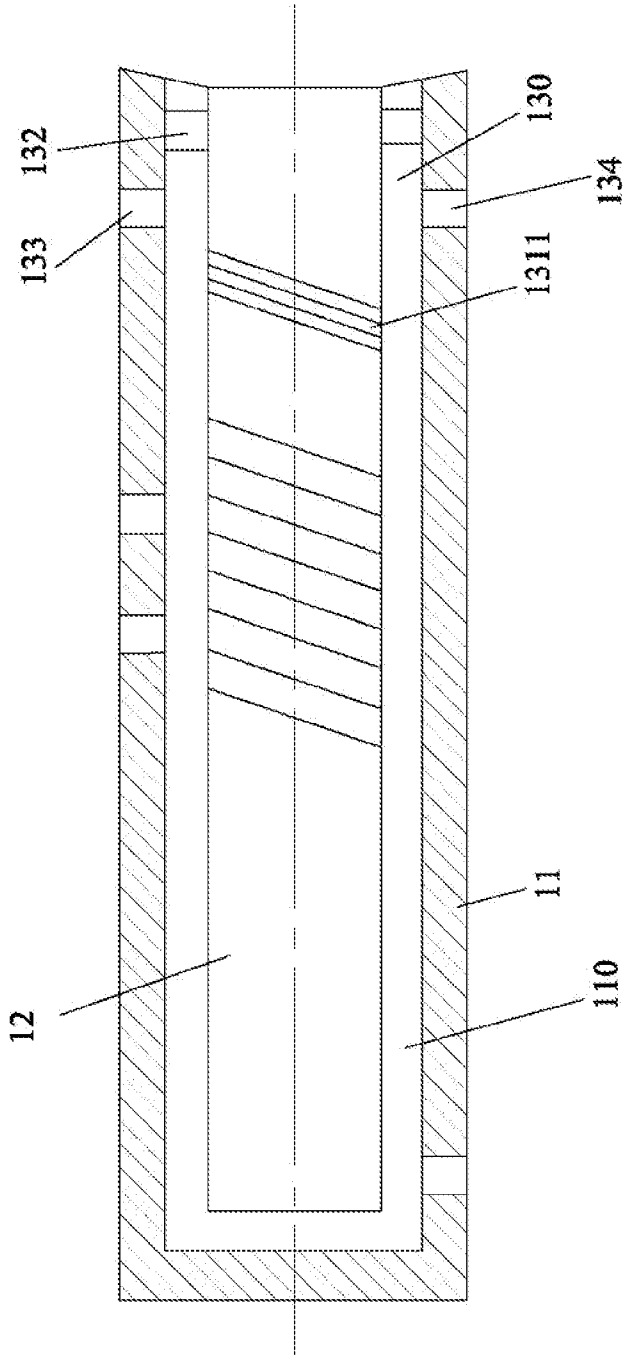


Fig. 3

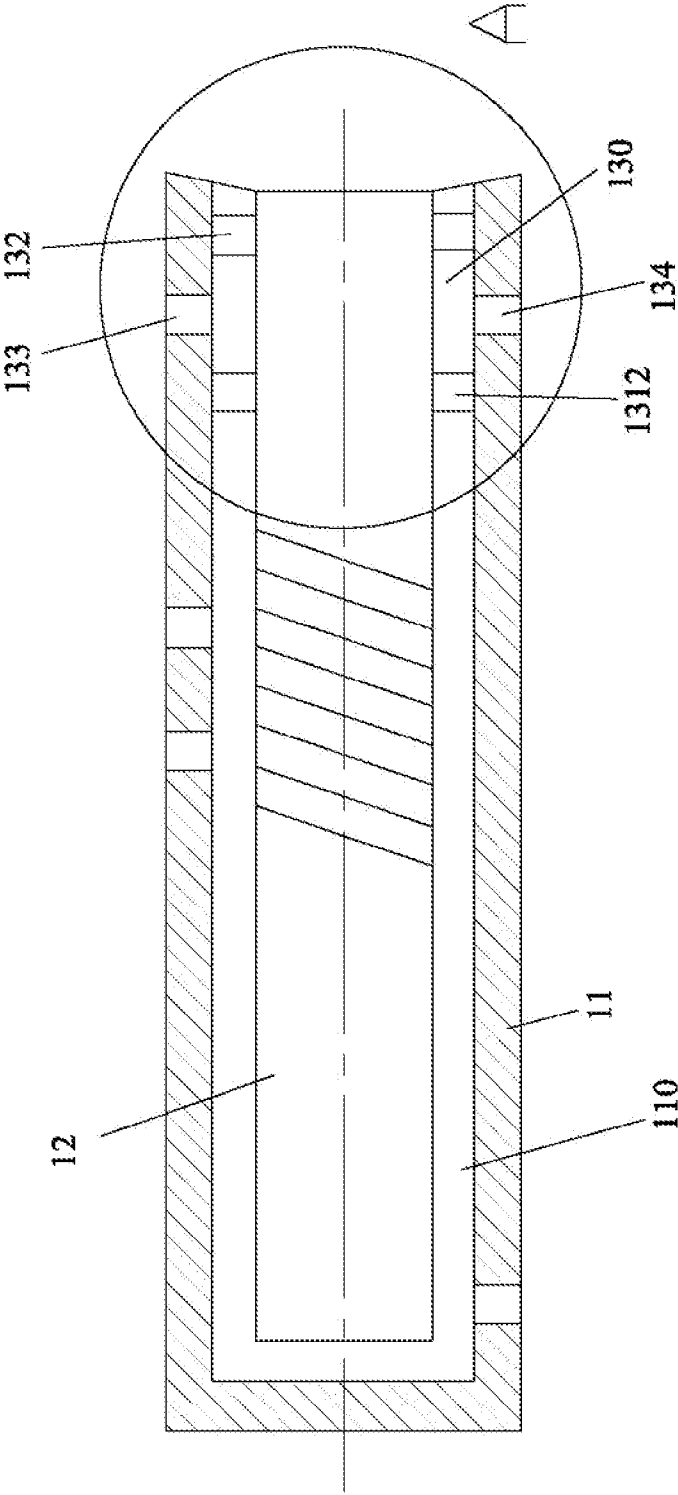


Fig. 4

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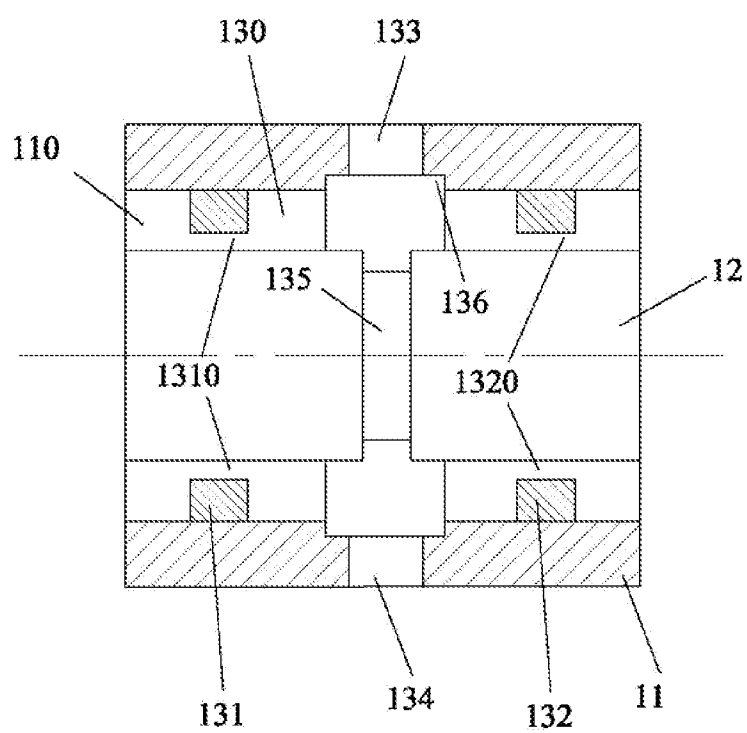


Fig. 5A

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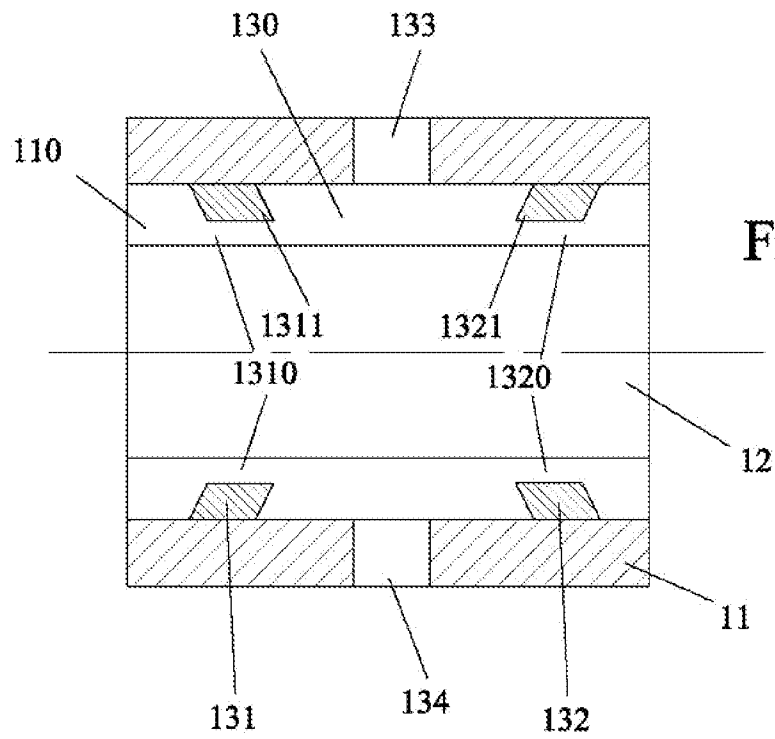


Fig. 5B

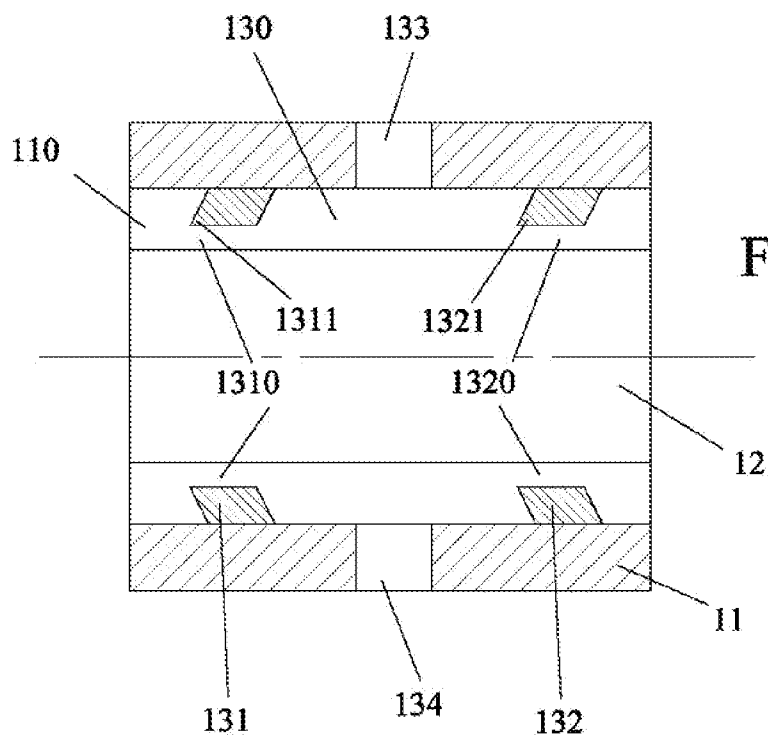


Fig. 5C

-14/22-

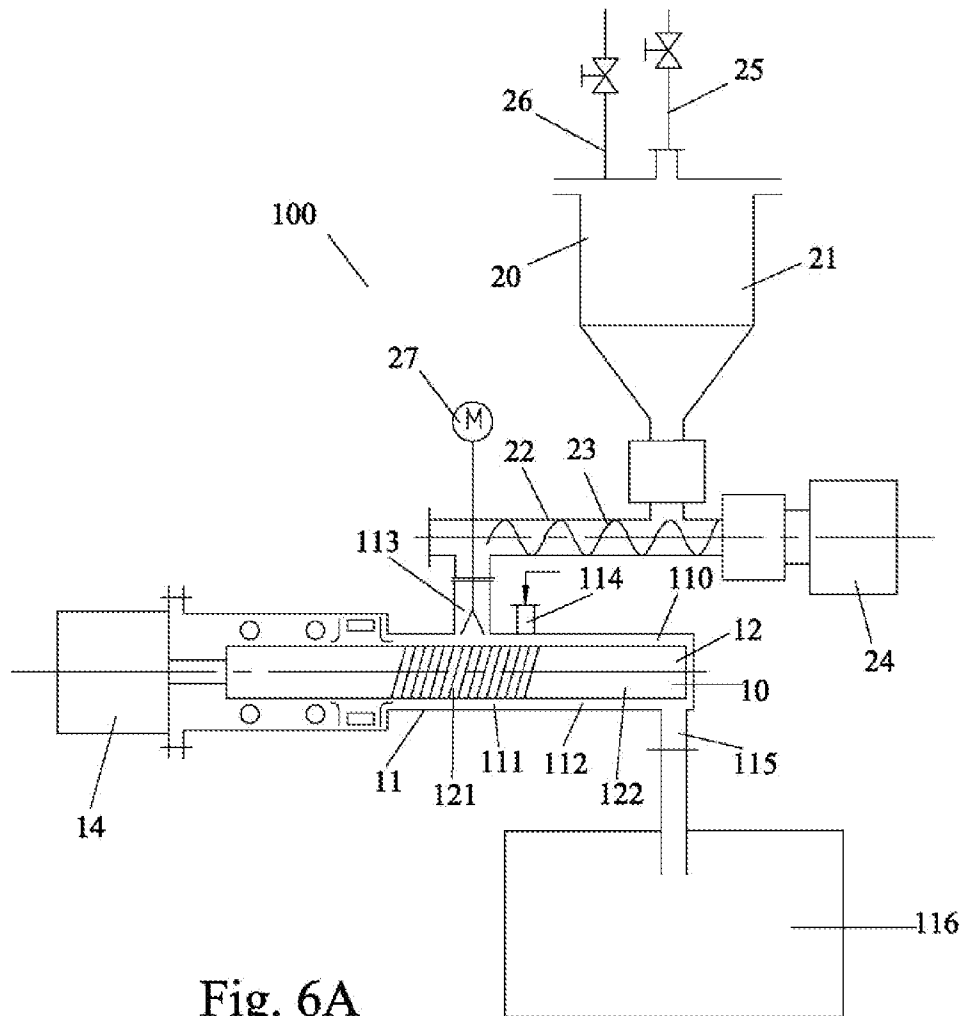


Fig. 6A

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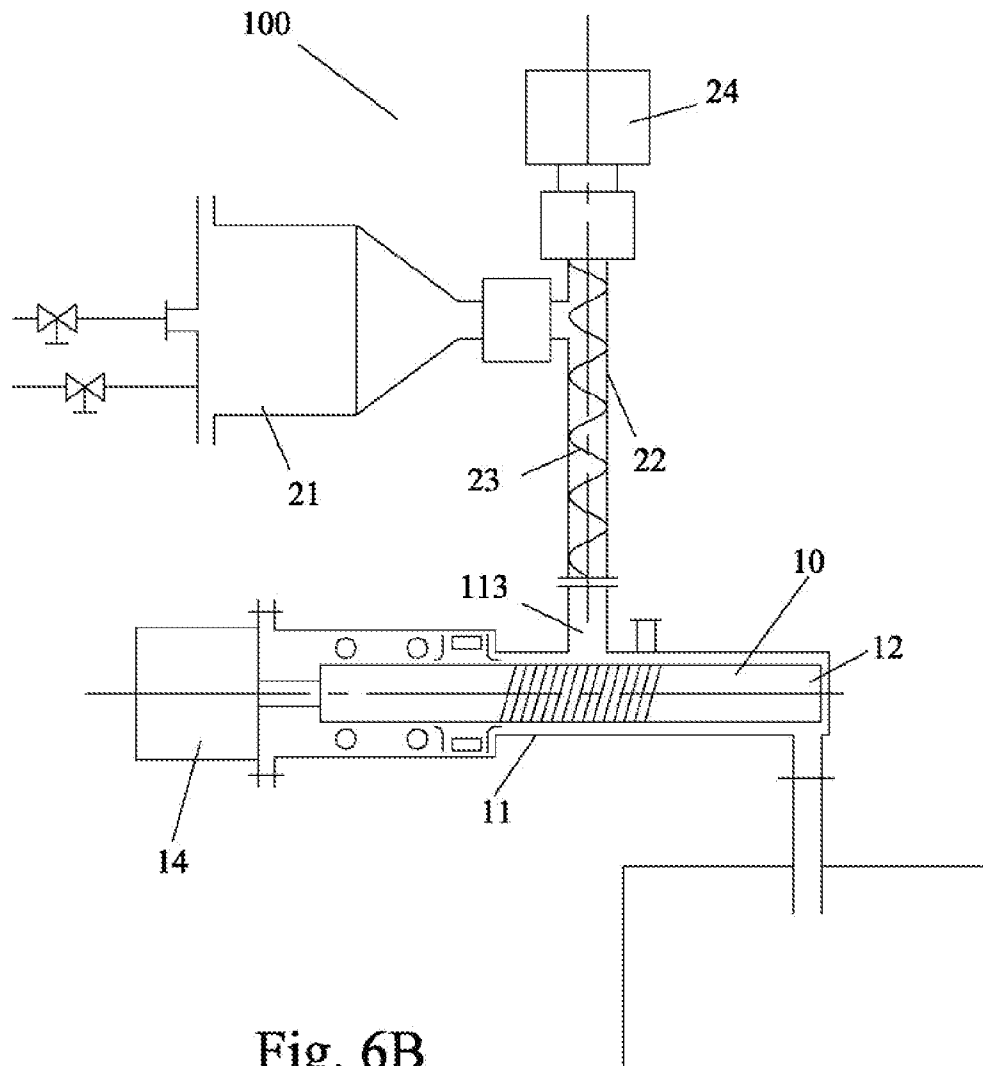


Fig. 6B

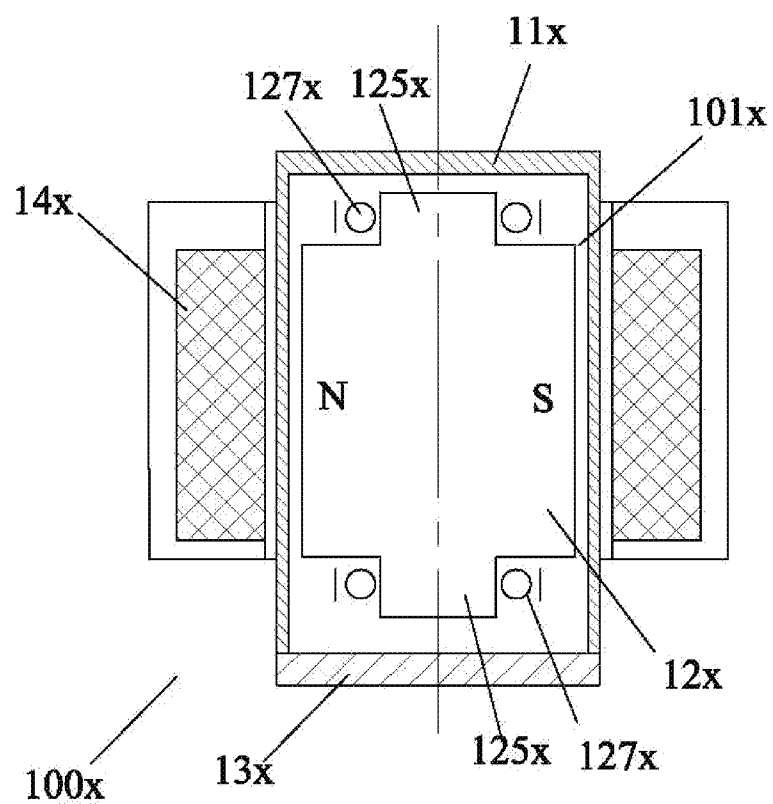


Fig. 7A

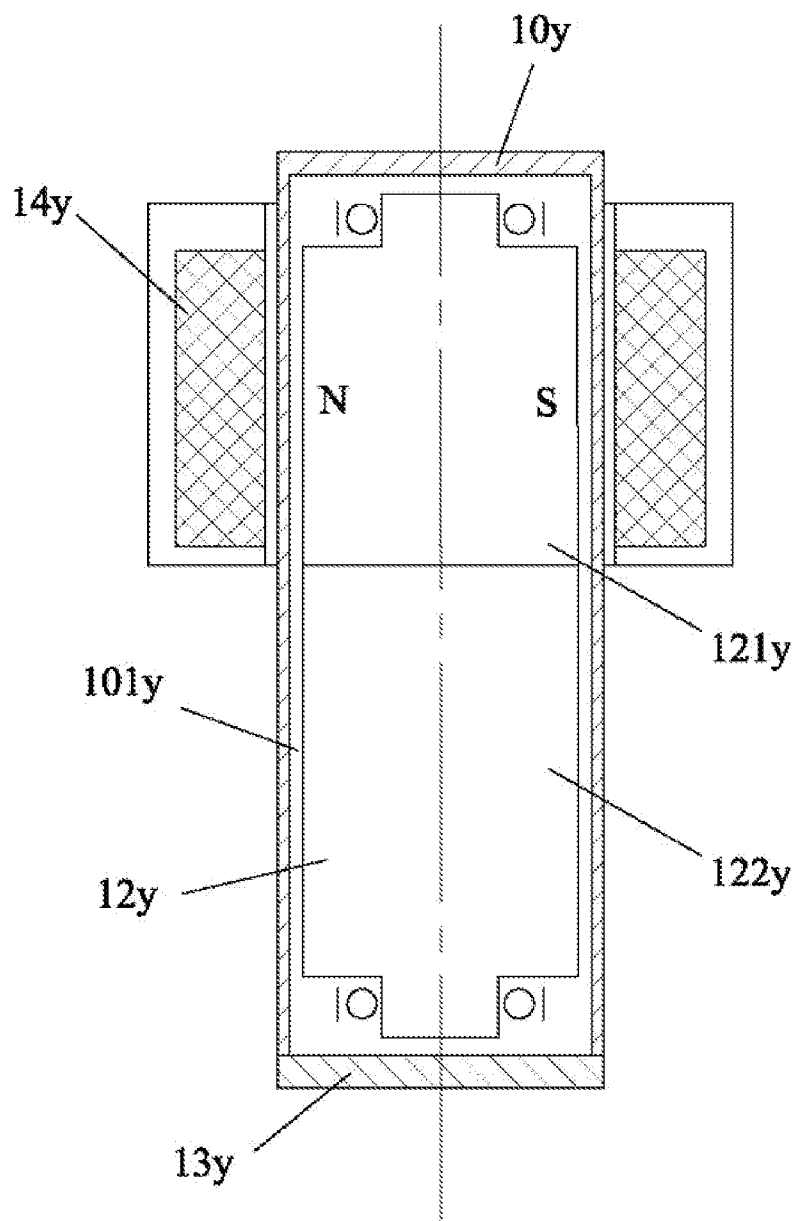


Fig. 7B

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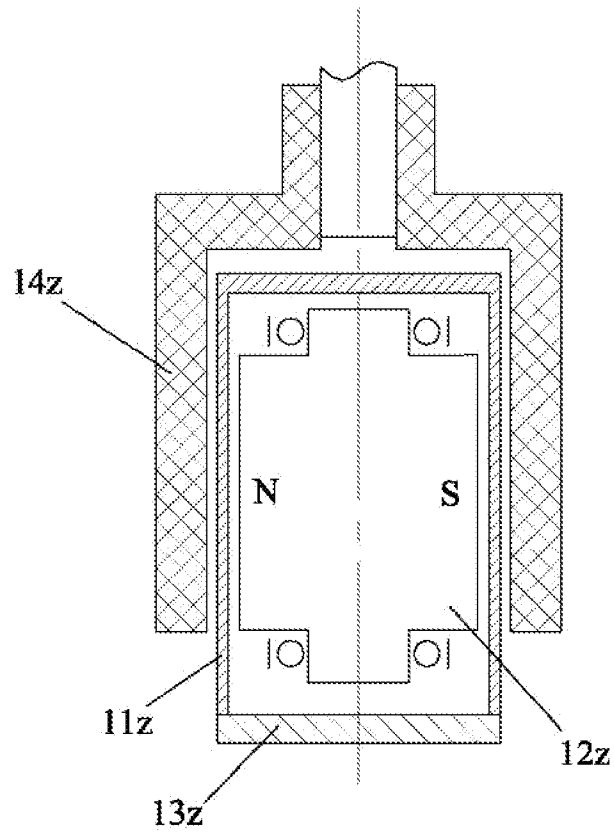


Fig. 7C

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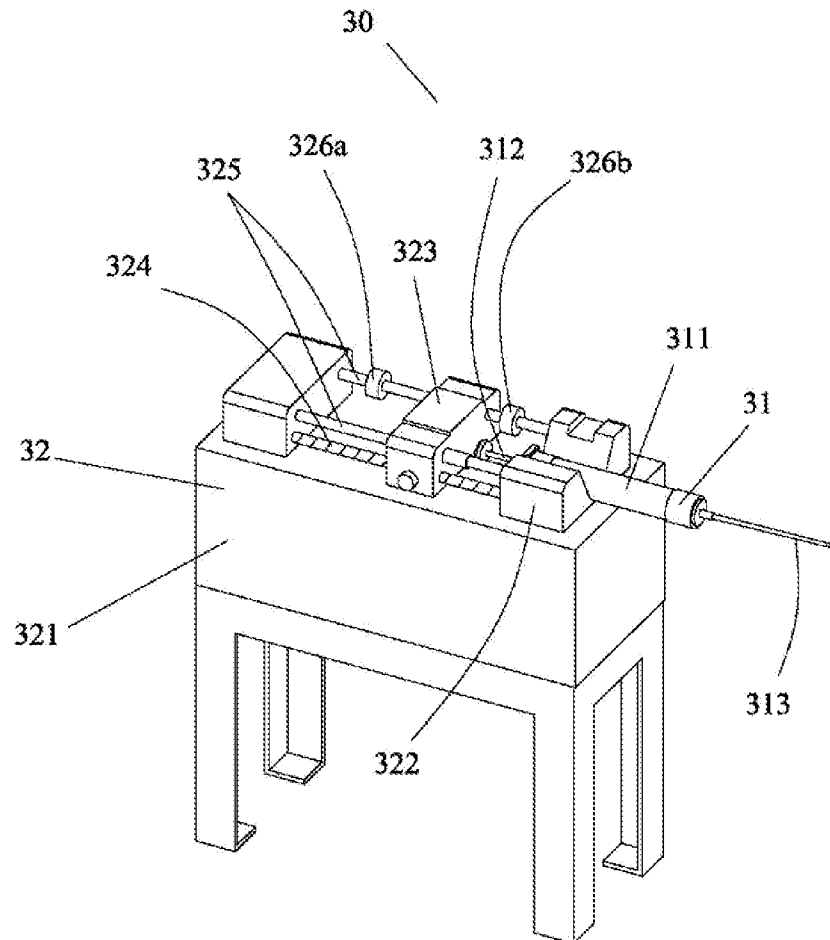


Fig. 8

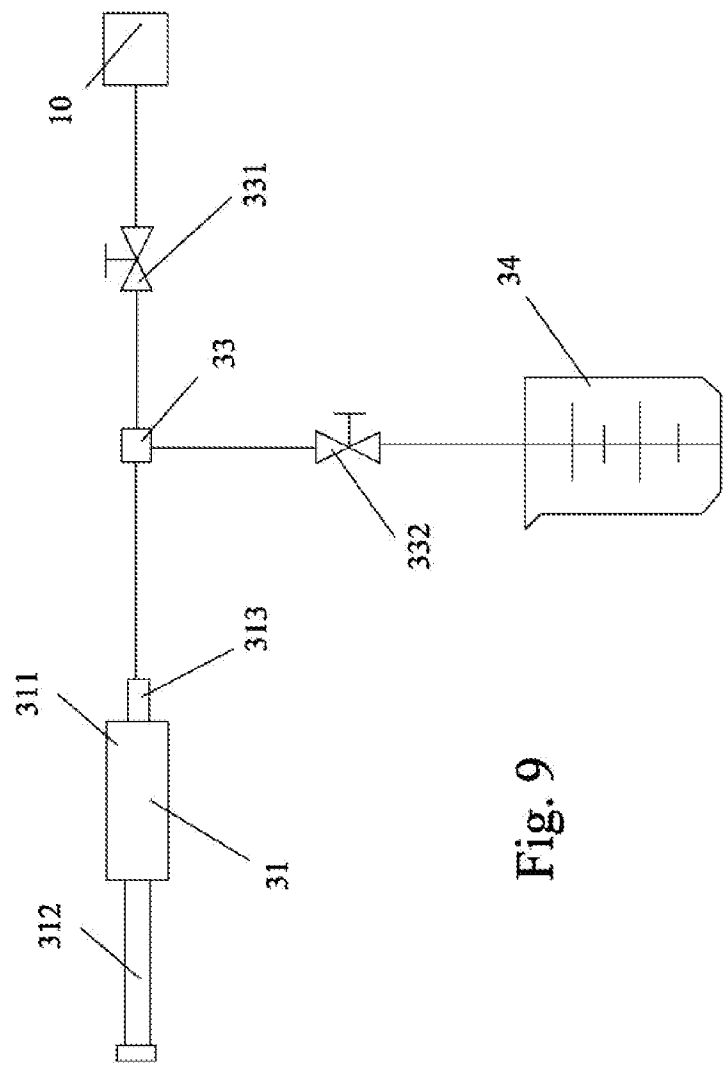


Fig. 9

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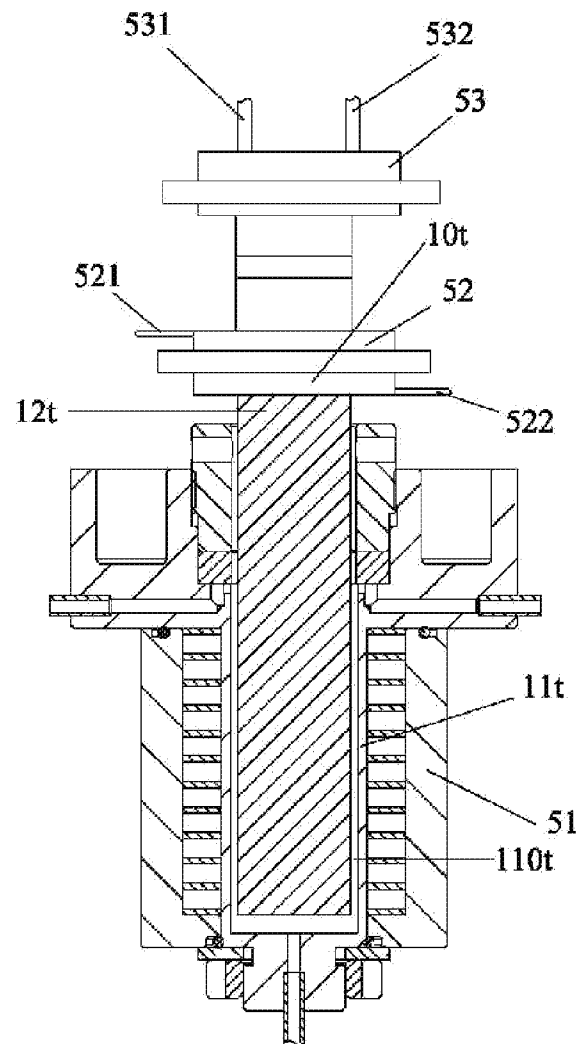
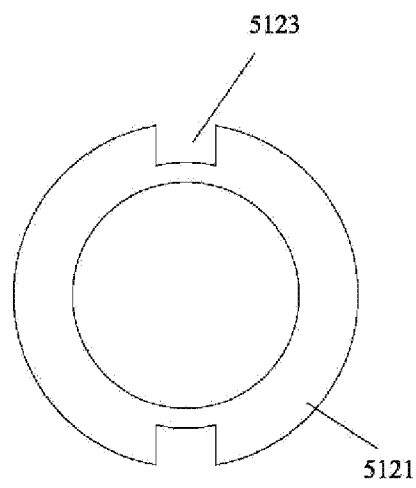
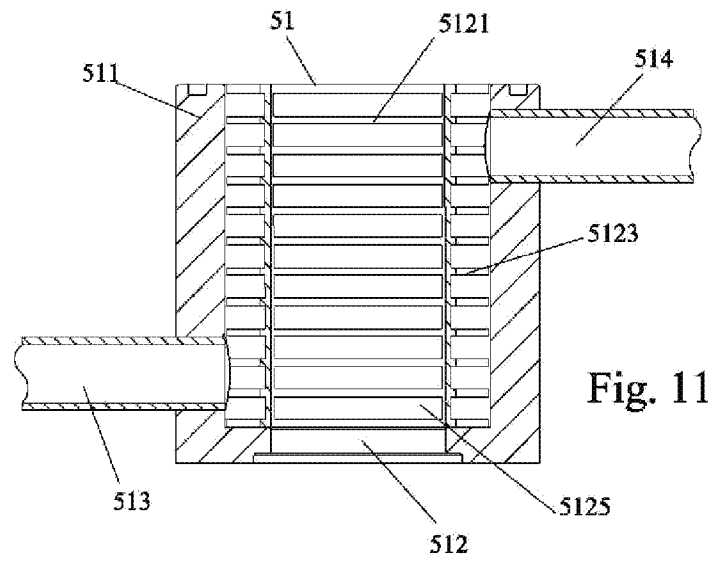


Fig. 10

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INTERNATIONAL SEARCH REPORT

International application No.

PCT/CN2007/071401

Box No. IV Text of the abstract (Continuation of item 5 of the first sheet)

A material processing apparatus (10) includes a first member (11) and a second member (12) rotatable relative to the first member (11) and at least partially received within the first member (11). The first and second members (11, 12) form a substantially annular processing passage (110) therebetween. The processing passage (110) includes a pre-processing zone (111) and a processing zone (112). A circumferential surface of the first member (11) or the second member (12) facing the pre-processing zone (111) has protruding and/or concave portions, while circumferential surfaces of the first and second members (11, 12) facing the processing zone (112) are relatively smooth. The processing zone (112) is configured such that materials in the processing zone (112) can form Couette flow when a relative rotation speed between the first and second members (11, 12) reaches a certain value.

INTERNATIONAL SEARCH REPORT

International application No.

PCT/CN2007/071401

A. CLASSIFICATION OF SUBJECT MATTER

See extra sheet

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

IPC: B01F B29B

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

CPRS,WPI,EPODOC,PAJ: mix+, processing, rotat+, axial force, annular, couette flow, drag flow, taylor vortices

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
Y	WO 2006/063516 A1 (ACCELERGY SHANGHAI R & D CENT ET AL.) 22 Jun. 2006 (22.06.2006) Pages 1-7 of the description, abstract, figures 1-4	1-17
Y	CN 1503690 A(HOLL TECHNOLOGIES CO) 09 Jun. 2004 (09.06.2004) claim 9, pages 1-6 of the description, figure 1	1-17
Y	CN 1324268 A(KALTOR LTD) 28 Nov. 2001(28.11.2001) page 4 and paragraphs 4-7 on page 2 of the description, figures 1a-7b	1-17

☐ Further documents are listed in the continuation of Box C.

☒ See patent family annex.

* Special categories of cited documents:	"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention
"A" document defining the general state of the art which is not considered to be of particular relevance	"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone
"E" earlier application or patent but published on or after the international filing date	"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art
"L" document which may throw doubts on priority claim (S) or which is cited to establish the publication date of another citation or other special reason (as specified)	"&"document member of the same patent family
"O" document referring to an oral disclosure, use, exhibition or other means	
"P" document published prior to the international filing date but later than the priority date claimed	

Date of the actual completion of the international search 27 Feb. 2008 (27.02.2008)	Date of mailing of the international search report 13 Mar. 2008 (13.03.2008)
Name and mailing address of the ISA/CN The State Intellectual Property Office, the P.R.China 6 Xitucheng Rd., Jimen Bridge, Haidian District, Beijing, China 100088 Facsimile No. 86-10-62019451	Authorized officer GUO, Yanhua Telephone No. (86-10)62084842

INTERNATIONAL SEARCH REPORT
Information on patent family members

International application No.

PCT/CN2007/071401

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INTERNATIONAL SEARCH REPORT
Information on patent family members

International application No.

PCT/CN2007/071401

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International application No.

PCT/CN2007/071401

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INTERNATIONAL SEARCH REPORT

International application No.

PCT/CN2007/071401

CONTINUATION OF A: CLASSIFICATION OF SUBJECT MATTER

B01F 3/12 (2006.01) i

B01F 3/20 (2006.01) i

B01F 7/00 (2006.01) i

B29B 7/14 (2006.01) i