

(19)



(11)

EP 2 096 628 A1

(12)

EUROPEAN PATENT APPLICATION

(43) Date of publication:

02.09.2009 Bulletin 2009/36

(51) Int Cl.:

G10K 15/00 (2006.01)

(21) Application number: **08003841.7**

(22) Date of filing: **29.02.2008**

(84) Designated Contracting States:

**AT BE BG CH CY CZ DE DK EE ES FI FR GB GR
HR HU IE IS IT LI LT LU LV MC MT NL NO PL PT
RO SE SI SK TR**

Designated Extension States:

AL BA MK RS

(71) Applicant: **ETH Zurich**

8092 Zürich (CH)

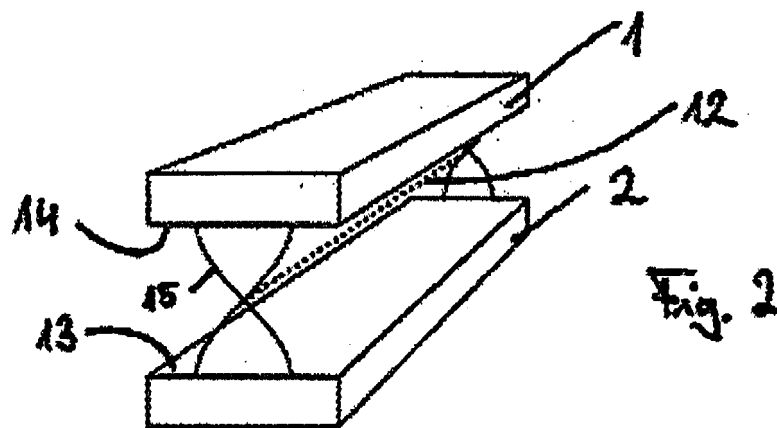
(72) Inventors:

- **Dorrestijn, Marko**
8152 Glattpark-Opfikon (CH)
- **Kurtcuoglu, Vartan**
8400 Winterthur (CH)
- **Poulikakos, Dimos**
8702 Zollikon (CH)
- **Vidic, Jovo**
8405 Winterthur (CH)

(54) **Acoustic levitation system**

(57) The present invention derives from the technical area of object levitation; it relates to an acoustic levitation system comprising an emitter (2) and a reflector (1) with in-between an object (19), respectively matter is levitated due to a standing acoustic pressure wave (15). According

to the invention the standing acoustic pressure wave (15) provides a line-shaped pressure node (12) between the corresponding to that line-shaped pressure node (12) formed emitter (2) and reflector (1), so that the object, respectively matter (19) is able to move along the line-shaped pressure node (12).



Description

FIELD OF THE INVENTION

[0001] The present invention derives from the technical area of object levitation; it relates to an acoustic levitation system comprising an emitter and a reflector with in-between an object, respectively matter is levitated due to a standing acoustic pressure wave.

BACKGROUND OF THE INVENTION

[0002] Common levitation methods are based on acoustic pressure (ultrasonic standing wave or near-field ultrasonics), electric forces (electrostatic or electrodynamic), magnetic forces, optical pressure, or aerodynamics. However, electric levitation requires an intricate control loop monitoring the vertical position of the particle. Magnetic levitation is limited to diamagnetic materials; water is diamagnetic, but magnetic particles, which are commonly used in micro-fluidics, would remain localized at the droplet edge. Optical levitation is limited to transparent particles suspended in liquid. Aerodynamic levitation provides poor lateral stability and is prone to contamination of the levitated object. Near-field acoustic levitation is limited to planar objects. In contrast, acoustic standing wave levitation is applicable to any material in any gaseous or liquid medium. It requires no control loop and it inherently provides lateral stability (Bernoulli force).

[0003] Acoustic levitation systems are well known for levitation of objects by using standing acoustic pressure waves between an emitter generating these waves and a reflector. Typically, a standing acoustic wave pattern is developed with a length of half of its wavelength between a usually planar emitter surface and a concave reflector with a preferentially spherical surface section providing significantly higher levitation forces compared to flat reflector surfaces. Besides single-axis configurations (with one emitter-reflector pair) multi-axis configurations are common as well.

[0004] In such acoustic levitation systems objects are held for investigative purpose in a node of the standing acoustic wave pattern against gravity forces or acceleration forces.

[0005] In the US 4,520,656 an acoustic levitation system is provided for acoustically levitating an object, by applying a single frequency from a transducer into a resonant chamber surrounding the object. The chamber includes a stabilizer location along its height, where the side walls of the chamber are angled so they converge in an upward direction to a concave reflector. When an acoustic standing wave pattern is applied between the top and bottom of the chamber, a levitation surface within the stabilizer does not lie on a horizontal plane, but instead is curved with a lowermost portion near the vertical axis of the chamber. As a result, an acoustically levitated object is urged by gravity towards the lowermost location on the levitation surface, so the object is kept away from

the side walls of the chamber.

[0006] The US 4,777,823 reveals a single axis levitator with a planar emitter surface and a spherical surface section reflector. The vibrating emitter surface creates incoming plane acoustic waves, which are reflected off the concave surface of the reflector to produce a curved reflected wave front. The incoming wave and the reflected wave interfere to produce a levitation location, which is spaced a distance equal to $W/4$, where the W is the wavelength of the acoustic energy created by a transducer for the emitter.

[0007] These known levitation systems using standing acoustic pressure waves are able to keep an object like a droplet in one node point of the wave, but they are not in a position to transport such a droplet.

[0008] In US 5,810,155 ultrasonic waves are used for levitation of planar objects. A typical near-field levitation application is shown, with which such planar objects are transported by applying further acoustic waves with so-called ultrasonic radiators, for example, or through inclining the whole levitator system so that gravity forces does no longer appear perpendicular to the objects. US 6,575,669 discloses also a near-field levitator application with a number of transporting vibrators, which can be inclined to each other for transporting reason.

[0009] All common near-field levitation systems are able to transport planar object, but they also share the restriction to these planar object; they are for example not in a position to put droplets in a levitation condition.

SUMMARY OF THE INVENTION

[0010] It is there an object of the present invention to provide a levitation system that is applicable to any material, respectively matter in any gaseous or liquid medium, with which such matter not only is stably kept in or close to a standing acoustic wave node, but furthermore with which the matter is able to be transported.

[0011] This object of the invention is solved with the features of independent claim 1; further embodiments of the invention are subjects of the dependent claims 2 to 17.

[0012] According to the present invention an acoustic levitation system comprises an emitter and a reflector with in-between an object, respectively matter is levitated due to a standing acoustic pressure wave, whereas the standing acoustic pressure wave provides a line-shaped pressure node between the corresponding to that line-shaped pressure node formed emitter and reflector, so that the object, respectively the matter is able to move along the line-shaped pressure node. The core of the invention is seen in the use of a line-shaped pressure node in order to allow free translation of matter along this nodal line (track). The line-shaped pressure node is of a standing acoustic wave formed between two opposing solid surfaces, at least one of which is oscillating. Preferably, one of the surfaces, the "emitter", oscillates, whereas the other surface, the "reflector", is stationary.

[0013] In a preferred embodiment of the invention, the emitter and the reflector have a straight or curved elongation in parallel to each other. From such emitter and reflector tracks, networks can be built in order to form two-dimensional systems or even three-dimensional systems. Tracks can be straight or curved; for example, a circular track can be used to keep objects in motion. Motion can be unidirectional or of alternating directionality (e.g. oscillatory). It is also possible that the reflector is formed as a plane that covers not only the emitter track but also border areas; furthermore it is conceivable that the reflector is made of a transparent material. For optical access it may be preferred to have a planar top window acting as the reflector. The emitter should preferably be fabricated from light but stiff materials (e.g. polymers) in order to achieve efficient oscillatory motion. It is advantageous if the reflector has an optically operative reflector surface on that side of the reflector that is turned away from the line-shaped pressure wave node to improve the optical access to levitated objects.

[0014] One further embodiment of the invention shows in a sectional view perpendicular to the line-shaped pressure node a planar or concave curved emitter surface and/or reflector surface opposite to each other.

[0015] A further embodiment of the invention comprises an object supply device, which supplies the acoustic levitation system with object, respectively matter. Such an object supply device is provided in terms of a liquid or solid particle injector or a distributor. Liquid droplets can be introduced into the levitation system by release from a capillary tube or other channel, or from any structure to which a volume of liquid is attached. Release is possible by sudden movement of the structure holding the liquid or by force applied to the liquid. Preferred methods are vertical capillary injection and inkjet technology.

[0016] With vertical capillary injection, a capillary penetrates the top boundary of the resonance cavity. As liquid is pushed out of the capillary (e.g. using a syringe pump), gravity will release a droplet when the weight of the injected liquid dominates the surface tension forces. An array of capillaries can be arranged in parallel, preferentially along the axis of the track; thus, multiple liquids or solutions can be injected without cross-contamination. Cross-contamination can also be avoided by washing the capillaries (for example using acidic or basic solutions) or by using dispensable capillaries or dispensable capillary arrays.

[0017] In inkjet technology, the liquid is driven out of a channel by pressure applied by a piezo-electric actuator, as is well known to specialists in the field. Liquid droplets can be introduced into the levitation system by one or more inkjet nozzles. Multiple nozzles can be used to introduce multiple liquids without cross-contamination. Cross-contamination can also be avoided by washing the nozzles (for example using acidic or basic solutions) or by using dispensable nozzles or dispensable nozzle arrays.

[0018] In a preferred embodiment of inkjet injection, a

dispensable array of nozzles can be attached to and aligned with an array of pressure-based actuators (e.g. piezo-electric actuators as in state-of-the-art inkjet technology). The spacing between nozzles is selected to match the spacing between sample wells in an industry-standard microtiter plate, e.g. a 96-, 384-, 1536-, or 9600-well plate. To interface with such microtiter plates, inkjet nozzles fill by applied negative pressure and/or by capillary force when they enter the solutions in the wells (the shape of the nozzles can be conical to increase the capillary force). The dispensable nozzle array is filled before or after attachment to the actuator array. The actuator array can be translated or tilted away from the levitation device to accommodate replacement of the nozzles. The actuator array can also be translated in the plane of the nozzle array as to align different nozzles with a single levitation track.

[0019] To rapidly distribute levitated objects or droplets to a two-dimensional array of locations (the "screen"), a technology similar to a scanner in a cathode ray tube can be used. A laterally-oriented electric field (or magnetic field, or flow of medium) can control the angle under which particles leave the confinement of the acoustic levitation field. Distribution of objects or droplets onto a screen can be used for microfabrication, for sorting of the objects or droplets, and/or for organizing the objects or droplets in a plane for improved access (optical, tactile, electric, magnetic, chemical, etc). On the screen, particles can be fixed in place by adhesive forces, chemical bonds, electric forces, magnetic forces, etc., and/or by a subsequent process such as photopolymerization, annealing, electroless deposition; etc. Particles can also be distributed as colloids inside droplets. The locations on the screen can also be pre-treated before distribution: for example, for (bio)chemical binding assays; for example, different capture antibodies or single-stranded nucleotide sequences can be immobilized at different locations by using the distributor or an external spotter robot; subsequently, droplets containing analyte can be directed to these locations; after washing the screen, the bound analyte remains and can be detected optically, electrochemically, etc. Instead of immobilizing different molecule species on different locations, different concentrations thereof can be applied, for example to determine the sensitivity of an assay or to quantify the concentration of an analyte.

[0020] In a further embodiment of the invention it is intended to arrange a driving force device beside, above and/or under the line-shaped acoustic pressure wave node, that urges the object, respectively matter to a motion. Levitated matter can be transferred with relatively low force. Nonetheless, the force should be large enough to compensate for gravity when the channels are not levelled. When the device is portable, it should also be able to withstand a certain amount of mechanical vibrations or accelerations. Levitated objects can be transported by a host of driving forces such as electric forces, magnetic forces, flow of the medium, radiation pressure, momen-

tum from the injection/insertion, etc. Electrical methods include dielectrophoresis. This method is a preferred method because it can be applied to any dielectric material, including water. The object or droplet need not be electrically charged, magnetic, or optically transparent. Drawbacks of actuation by flow of the medium are that it requires mechanical components (incl. a pump and valves) and that it is prone to contamination.

[0021] A second preferred method is the use of the momentum from injection/insertion, injection referring to liquids and insertion to solid objects. Droplets gain momentum when injected for example with inkjet technology. Solid objects can be propelled upon insertion into the system. The use of initial momentum is a preferred method for systems where the velocity of the levitated matter need not be actively controlled very precisely. Combining or merging of levitated matter is possible by controlled timing of the injection/insertion of two or more particles or droplets. Combination can occur where two tracks cross or on a single track when the particles or droplets are injected/inserted at different velocities.

[0022] In a further embodiment of the invention a humidity control device is comprised, that controls actively or passively environmental humidity of the acoustic levitation system. Such humidity control devices are for example a piezoelectric humidifier or an open liquid reservoir. Furthermore, it is possible to prevent droplet evaporation, if the droplet is levitated in a liquid medium. Important is that the droplet and the liquid medium must be immiscible. For aqueous droplets, for example, silicone oil can be used as a medium to prevent evaporation; the transfer of such droplets is nonetheless efficient.

[0023] Furthermore, the invention offers the possibility that droplets can be merged at a point where two tracks cross or at any point on a single track by propelling droplets with different velocities. The latter can be achieved by using position-dependent translation force.

[0024] After two droplets of different constituents are merged, they can be stirred in several different ways. One way is to use ultrasonic agitation, e.g. using the same actuator used for levitation. The agitation can be optimized by varying pressure amplitude and/or frequency. If the desired frequency differs from the frequency used for levitation, a second frequency can be superposed.

[0025] Another method is magnetic stirring. Magnetic particles can be added to one or both of the merged droplets. When the direction of an applied magnetic field is varied over time, e.g. oscillatory, stirring can occur.

[0026] Further methods include electric stirring (using a varying electric field on a droplet containing ionic species) and stirring by using alternating radiation pressure from different directions.

[0027] The disclosed technology is promising for many fields of application. We will discuss two exemplary devices: personalized medicine and an early warning system for biological-defence:

[0028] A contact-less microfluidics platform can be uti-

lized in personalized medicine, e.g. for cancer screening. Both diagnostics of a biopsy (figure below) and testing of candidate drugs on the biopsy can be performed in the levitation system. In both cases, (diluted) biopsy samples are introduced into the levitation system by inkjet technology. Evaporation control may be necessary depending on droplet size and incubation times. To reduce incubation times, droplets are stirred after mixing, which is realized ultrasonically. Droplets are transported and positioned by dielectrophoresis.

[0029] For diagnostics, the cell walls are lysed by mixing with a droplet containing a lysant (e.g. sodium hydroxide) or by ultrasonic agitation of the droplet, thus releasing proteins and nucleotides (DNA, mRNA, etc.). If necessary, a droplet with pH buffer is added to restore physiological pH. If necessary, nucleotides are amplified by PCR; preferably, low-temperature PCR is applied to better control the evaporation of the droplet. If necessary, the droplet is mixed with a droplet containing a biochemical label. Depending on the nature of the label, a signal can already be obtained directly from the solution; for example, if the label is a metal colloid functionalized with capture antibodies or single-stranded oligonucleotides, a colour shift can be observed upon binding of analyte due to plasmon resonance, as is well known in the field. Alternatively, the droplet can be sent onto a screen using a distributor (distributor and screen as described earlier) for subsequent detection. If no label was added yet, a second droplet containing a label molecule can be distributed to the same location on the screen to create a sandwich structure, which is well known to specialists in the field.

[0030] Advantages of the levitation platform over existing microfluidic networks include:

- High reliability due to zero cross-talk between samples
- High sensitivity due to zero loss of analyte to the walls
- Rapid diagnosis due to small sample volumes
- High throughput due to absence of washing step (no walls and dispensable inkjet nozzles)
- Low cost of chemical labels (e.g. fluorescent oligonucleotides) due to small volumes and zero loss

[0031] After diagnosis, candidate therapeutic agents can be tested on the diseased cells from the biopsy before treating the patient. Droplets containing the cells enter a track of the levitation system in sequence. Each is mixed with a different drug candidate and incubated while being levitated. Morphology changes can be observed using microscopy. In addition, a droplet with fluorescent antibodies can be added to test for changes in the protein population. Cells treated with a drug candidate can also be lysed and diagnosed as described above; the presence or concentration of certain mRNA sequences, for example, can reveal insightful information about the response of the cells to a drug.

[0032] In bioterrorism and bio warfare, pathogens can

be released into the air. Early warning systems are currently under investigation. It involves the challenging task of capturing pathogens from the air, bringing them into aqueous solution, and characterizing them based on their genomic or proteomic content. Dust particles must not clog the system.

[0033] A levitated droplet has a high surface to volume ratio, thus making it an efficient capture body. The absence of channel walls ensures that pathogens are transported with the liquid and not remain attached to a wall (which can occur even when anti-fouling coatings are applied). An important advantage is that there are no channels that can get clogged with dust particles, which significantly increases the long-term reliability of the system.

[0034] A circular track can be used to increase the effective capture area of the droplet. When a droplet is made to rotate in circles, it can cover an area as large as the droplet diameter times the diameter of the circular track, hereafter called the "virtual cross section". Ambient air preferably flows in a direction parallel to the plane of the circular track. If the velocity of the spinning droplet is much larger than the velocity of the air flow, and if in addition the mass density of the pathogens is much larger than the density of air, all particles passing the virtual cross section will be captured by the droplet. This will allow the manufacturer to quantify the capture rate of the device for a given pathogen concentration in the air.

[0035] A further embodiment of the invention is characterized in that beside the line-shaped pressure node a further line-shaped pressure node is arranged with the standing acoustic pressure wave, so that objects/matter can be levitated and transported on different line-shaped pressure nodes. With advance the wavelength of the standing acoustic pressure wave is adjustable, so that levitated objects/matter on the line-shaped pressure nodes separated in this manner can be brought onto the same line-shaped pressure node by increasing the wavelength of the standing acoustic pressure wave, thus merging the line-shaped pressure node with the further line-shaped pressure node.

BRIEF DESCRIPTION OF THE DRAWINGS

[0036] The understanding of the invention described herein will be aided by the detailed description and the accompanying drawings below, which should not be considered as limiting the invention described in the appended claims:

It shows

- Fig. 1 a side view of an acoustic levitation system according to the invention;
- Fig. 2 a three-dimensional view of the acoustic levitation system with a line-shaped pressure node of a standing

acoustic pressure wave between an emitter and a reflector;

Fig. 3a, b, c examples of different shapes of emitter and/or reflector in sectional view;

Fig. 4a, b examples of different shapes of emitter and/or reflector tracks in top view;

Fig. 5 the acoustic levitation system with driving force devices for transport of object/matter;

Fig. 6a, b field lines excited by driving force devices, and

Fig. 7 the acoustic levitation system according to Fig. 2 with an additional line-shaped pressure node.

Detailed- Description of the Figures

[0037] Fig. 1 shows in a side view the acoustic levitation system according to the invention comprising an acoustic reflector 1 with a reflector surface 14, a solid emitter surface 13 acting as an acoustic wave emitter 2, a rigid mount 3, a transducer 4 that converts an electrical current or voltage to mechanical motion and an AC power source 5. The transducer 4 is preferably of magnetostrictive nature or of piezoelectric nature. In connection with Fig. 2 an acoustic standing pressure wave 15 -excited between the emitter surface 13 and the reflector surface 14- is shown. This acoustic standing wave 15 pattern is developed with a length of half of its wavelength between the planar emitter surface 13 and the planar reflector surface 14. Due to the inventive design of emitter 2 and reflector 1 the acoustic standing wave 15 forms in-between a line shaped pressure node 12, in which objects 19, respectively matter is levitated.

[0038] An object/matter 19 is supplied to the acoustic levitation system by an object supply device 18. Such an object supply device 18 is provided in terms of a liquid or solid particle injector or a distributor. Liquid droplets can be introduced into the levitation system by release from a capillary tube or other channel, or from any structure to which a volume of liquid is attached. Release is possible by sudden movement of the structure holding the liquid or by force applied to the liquid.

[0039] On the one hand, levitated objects 19 are adhered to that line-shaped pressure node 12 and furthermore, on the other hand it is possible to transport objects 19 along that standing wave node line. Therefore, the present invention offers firstly the transport of any object 19, respectively matter along a track, whereas this object/matter 19 is levitated in the standing wave node line; advantages of this invention are discussed in not limiting examples of embodiments above.

[0040] The acoustic levitation system comprises fur-

thermore a humidity control device 21 that controls actively or passively environmental humidity of the acoustic levitation system; such a humidity control device 21 can be constructed in form of a piezoelectric humidifier or an open liquid reservoir.

[0041] In sectional views Fig. 3a, b, c a variety of shapes of the emitter surface 13 and the reflector surface 14 is shown; Fig. 3a reveals cylindrically curved, concave surfaces 13, 14 of the emitter 2 and the reflector 1, Fig. 3b in addition a cylindrically convex outer emitter surface 16 and an equally formed outer reflector surface 17; a further embodiment is shown in Fig. 3c with planar emitter surface 13, planar outer emitter surface 16, planar outer reflector surface 17 and cylindrically concave curved reflector surface 14. Without leaving the core of the invention further geometries are thinkable and therefore covered by the present invention.

[0042] Especially for optical studies of transported levitated objects/matter 19 the emitter 2 and/or the reflector 1 is made of a transparent material, e.g. glass/PMMA. For improving such optical studies the outer emitter surface 16 and/or outer reflector surface 17 is optically operative designed like illustrated and described in connection with Fig. 3b. In this case the outer emitter surface 16 and/or outer reflector surface 17 operates like an optical lens. In addition, it is possible to install a backlighting system (not shown in the figures) in the body of a transparent emitter 2 or under emitter 2.

[0043] Fig. 4a, b illustrate exemplary geometries of the whole acoustic levitation system in top view. Emitter tracks (2a, b) and reflector tracks (1a, b) are defined by the geometry of the reflector 1 and/or the emitter 2. Crossed tracks 6 shown in Fig. 4a are preferred for merging levitated objects/matter 19. Circular tracks 7 in Fig. 4b are preferred for keeping objects/matter 19 in motion or for accelerating them. In a preferred embodiment, the shown track geometry is defined only by the emitter 2 or the reflector 1 and the corresponding counterpart (reflector 1/emitter 2) being simply a rectangular planar surface that is larger than the track-defining part (emitter 2/reflector 1).

[0044] For transport purpose a driving force device (20) is installed adjacent to emitter (2) and reflector (1). For example electrodes 8, 9 in Fig. 5, 6a, b are arranged along the tracks of emitter 2, reflector 1 as driving force device 20. These electrodes 8, 9 cause dielectrophoretic or electrostatic transport of object/matter 19. Along tracks of emitter 2/reflector 1, electrodes 8, 9 can be planar, cylindrical or wire-like. At the crossing points of crossed tracks 6 in Fig. 5, however, electrodes 8, 9 are preferably planar in horizontal planes above and/or below the tracks (1a, b, 2a, b) as to avoid collision with levitated objects/matter 19. It is beneficial to have electrodes 8, 9 at the crossing point in order to be able to bring objects/matter 19 to a halt before they collide/merge; that makes timing less critical and gives better control over the forces involved in the collision.

[0045] In Fig. 6a the driving force is explained by

means of dielectrophoresis. An electrostatic field 10 is generated between electrodes 8, 9 (solid bars), as shown by field lines (curved). The electrostatic field 10 induces electric dipoles in a dielectric particle 11, effectively causing the left and right surfaces to be charged with opposite signs. Since the left surface is exposed to a higher field strength than the right surface, the particle experiences a net force F to the left. This phenomenon works for all dielectric particles 11, i.e. all non-metals, including droplets of dielectric liquids (e.g. water). In summary, dielectric particles are pulled in the direction of increasing field strength. Reversing the direction of the force F can be achieved by inverting the geometry of the electrostatic field 10 lines.

[0046] Fig. 6b illustrates a setup in which the directionality of the dielectrophoretic force F can be reversed. Here, the electrode setup is symmetrical as to allow for inversion of the electric field 10. Electrodes 8, 9 can be planar, wire-like, cylindrical, circular wire-like, or any other shape that allows for a divergent electric field 10. Cylindrical and circular electrodes 8, 9 preferably have their axis coinciding with the axis along which the particle 11 moves. The (solid) electrodes 8, 9 can reflect acoustic waves and should be designed such as to minimize interference with the standing acoustic wave. Also, the electrodes 8, 9 should be designed as to minimize shielding of the electric field 10 by non-active electrodes. Transparent electrodes 8, 9 can be preferred for optical access - a suitable material is for example indium titanium oxide (ITO).

[0047] In Fig. 7 a further embodiment of the invention is shown by using two line-shaped pressure nodes 12, 12a of the standing acoustic pressure wave 15, on which separated line-shaped pressure nodes 12, 12a objects/matter 19 can be levitated and separately transported. With advantage the wavelength of the standing acoustic pressure wave 15 is adjustable, so that levitated objects/matter 19 on the line-shaped pressure nodes 12, 12a, separated in this manner can be brought onto one and the same line-shaped pressure node by increasing the wavelength of the standing acoustic pressure wave 15, thus merging the line-shaped pressure node 12 with the further line-shaped pressure node 12a.

References

[0048]

1	reflector
1a, b	reflector track
2	emitter
2a, b	emitter track
3	rigid mount
4	transducer
5	power source
6	crossed tracks
7	circular tracks
8	electrode

9	electrode
10	electrostatic field
11	dielectric particle
12, 12a	line-shaped pressure node
13	emitter surface
14	reflector surface
15	standing acoustic pressure wave
16	outer emitter surface
17	outer reflector surface
18	object supply device
19	object/matter
20	driving force device
21	humidity control device
F	force

Claims

1. An acoustic levitation system comprising an emitter (2) and a reflector (1) with in-between an object, respectively matter (19) is levitated due to a standing acoustic pressure wave (15),
characterized in that the standing acoustic pressure wave (15) provides a line-shaped pressure node (12) between the corresponding to that line-shaped pressure node (12) formed emitter (2) and reflector (1), so that the object, respectively matter (19) is able to move along the line-shaped pressure node (12).
2. Acoustic levitation system according to claim 1, **characterized in that** the emitter (2) and the reflector (1) have a straight or curved elongation in parallel to each other.
3. Acoustic levitation system according to claim 2, **characterized in that** the emitter (2) and the reflector (1) have a two-dimensional and/or three-dimensional elongation in parallel to each other.
4. Acoustic levitation system according to one of the claims 2 or 3, **characterized in that** the emitter (2) and/or the reflector (1) comprises a first and second emitter track (2a, b) and/or reflector track, (1a, b) which cross each other.
5. Acoustic levitation system according to one of the claims 2 or 3, **characterized in that** the emitter (2) and/or the reflector (1) exhibits a circular shape.
6. Acoustic levitation system according to one of the preceding claims, **characterized in that** the emitter (2) has in a sectional view perpendicular to the line-shaped pressure node (12) a planar or concave curved emitter surface (13) opposite to the reflector (2).
7. Acoustic levitation system according to one of the

preceding claims, **characterized in that** the reflector (1) has in a sectional view perpendicular to the line-shaped pressure node (12) a planar or concave curved first reflector surface (14) opposite to the emitter (2).

8. Acoustic levitation system according to one of the preceding claims, **characterized in that** the emitter (2) and/or reflector (1) is made of a transparent material.
9. Acoustic levitation system according to claim 8, **characterized in that** emitter (2) and/or reflector (1) has an optically operative outer emitter surface (16), respectively outer reflector surface (17) on a side that is turned away from the line-shaped pressure wave node (12).
10. Acoustic levitation system according to one of the preceding claims, **characterized in that** an object supply device (18) is comprised, that supplies the acoustic levitation system with object, respectively matter (19).
11. Acoustic levitation system according to claim 10, **characterized in that** the object supply device (18) is an inkjet nozzle or a capillary tube or scanner.
12. Acoustic levitation system according to one of the preceding claims, **characterized in that** a driving force device (20) is arranged beside, above and/or under the line-shaped acoustic pressure wave node (12) that urges the object, respectively matter (19) to a motion.
13. Acoustic levitation system according to claim 12, **characterized in that** the force driving the object, respectively matter of the driving force device (20) is an electric force, magnetic force, flow of a medium, radiation pressure, momentum force or a combination of the mentioned forces.
14. Acoustic levitation system according to one of the preceding claims, **characterized in that** a humidity control device (21) is comprised, that controls actively or passively environmental humidity of the acoustic levitation system.
15. Acoustic levitation system according to claim 14, **characterized in that** the humidity control device (21) is a piezoelectric humidifier or an open liquid reservoir.
16. Acoustic levitation system according to one of the preceding claims, **characterized in that** beside the line-shaped pressure node (12) a further line-shaped pressure node (12a) is arranged with the standing acoustic pressure wave (15), so that objects/matter

(19) can be levitated and transported on different line-shaped pressure nodes (12, 12a).

17. Acoustic levitation system according to claim 16, **characterized in that** the wavelength of the standing acoustic pressure wave (15) is adjustable, so that levitated objects/matter (19) on the line-shaped pressure nodes (12, 12a) separated in this manner can be brought onto the same line-shaped pressure node by increasing the wavelength of the standing acoustic pressure wave (15), thus merging the line-shaped pressure node (12) with the further line-shaped pressure node (12a).

5
10
15

20

25

30

35

40

45

50

55

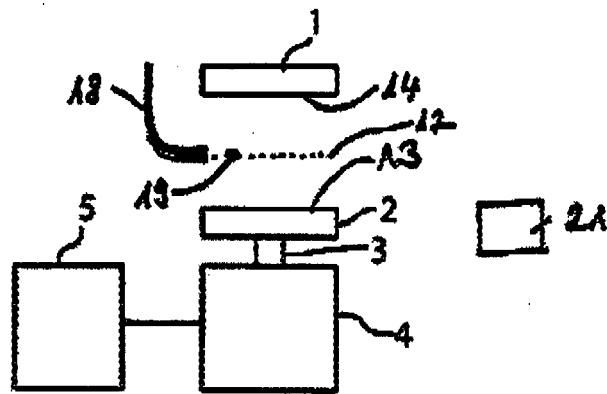


Fig. 1

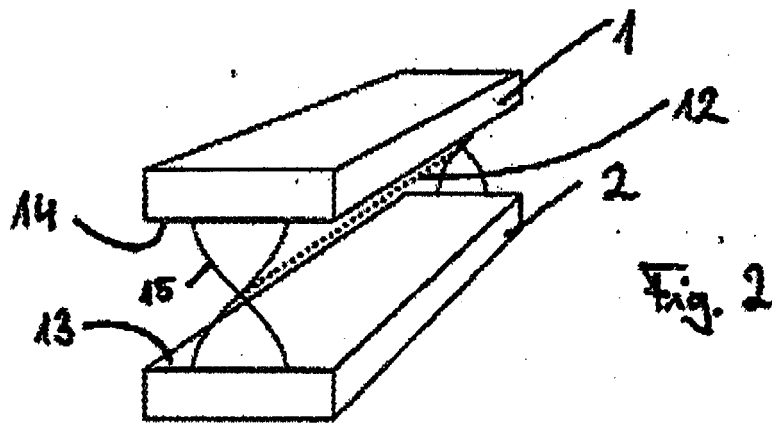


Fig. 2

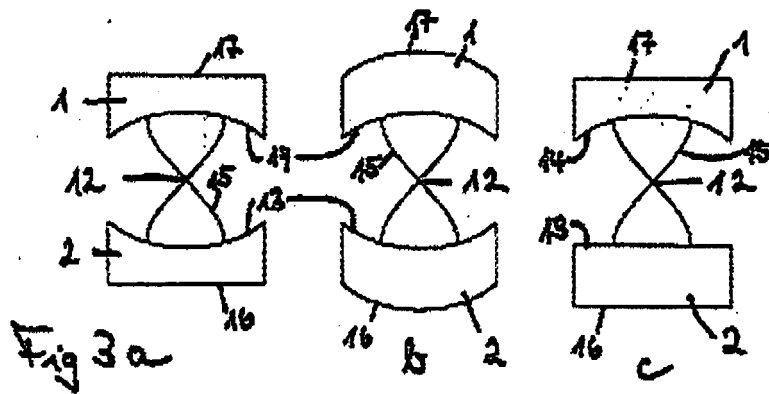


Fig 3a

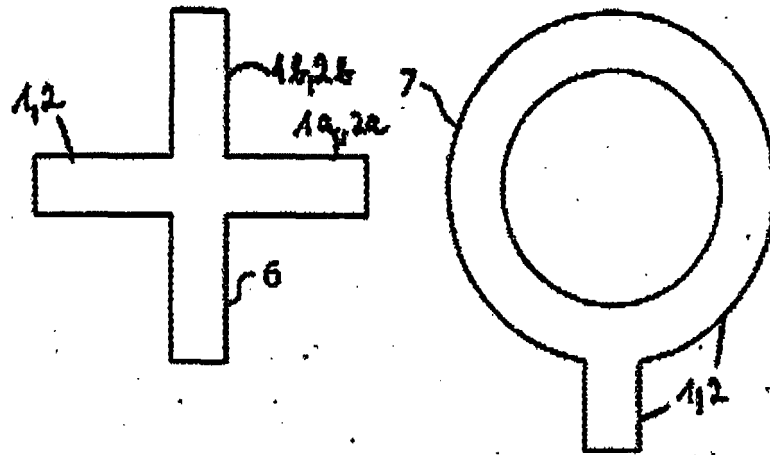


Fig. 4a

b

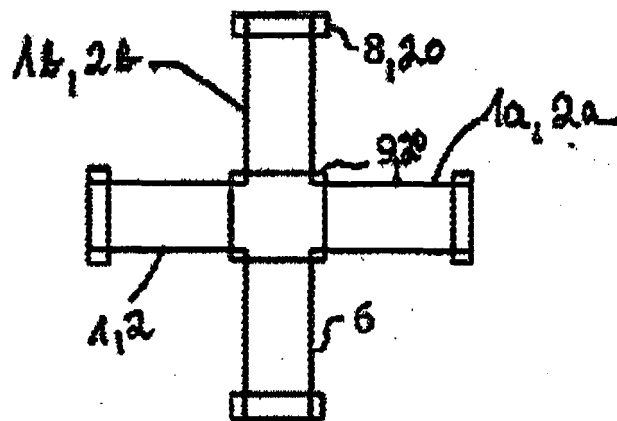


Fig. 5

Fig. 4

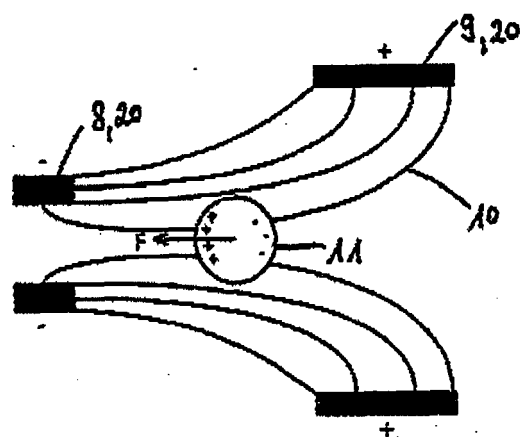


Fig. 6a

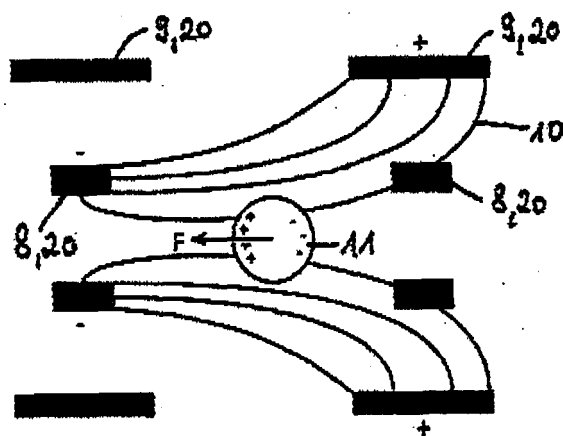


Fig. 6b

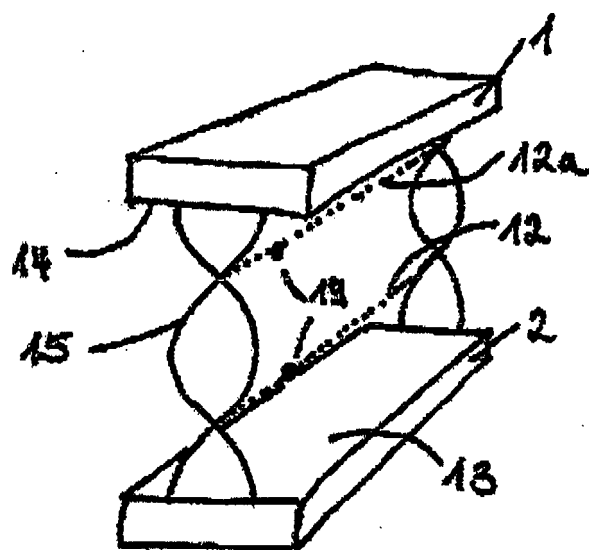


Fig. 7



European Patent
Office

EUROPEAN SEARCH REPORT

Application Number
EP 08 00 3841

DOCUMENTS CONSIDERED TO BE RELEVANT			
Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (IPC)
A	US 4 402 221 A (LEE MARK C [US] ET AL) 6 September 1983 (1983-09-06) * abstract * * figures 2,5 * * column 1, lines 40-64 * * column 4, lines 28-68 *	1-7	INV. G10K15/00
A	DE 199 16 922 A1 (TU MUENCHEN [DE]) 26 October 2000 (2000-10-26) * column 2, lines 40-46 * * column 2, line 53 - column 3, line 61 *	4,12,13	
A	EP 0 064 593 A (IBM [US]) 17 November 1982 (1982-11-17) * page 6, line 18 - page 7, line 3 * * page 4, lines 2-13 * * figures 4,8 *	4	
A	STEPHENS TERRANCE ET AL: "Three-axis acoustic device for levitation of droplets in an open gas stream and its application to examine sulfur dioxide absorption by water droplets" REVIEW OF SCIENTIFIC INSTRUMENTS, AIP, MELVILLE, NY, US, vol. 78, no. 1, 5 January 2007 (2007-01-05), pages 014901-1-014901-8, XP012103612 ISSN: 0034-6748 * pages 014901-3, right-hand column, lines 5-10 *	14,15	TECHNICAL FIELDS SEARCHED (IPC) G10K
A	US 4 929 400 A (REMBAUM ALAN [US] ET AL) 29 May 1990 (1990-05-29) * column 6, lines 21-35 * * column 5, lines 54-57 * * figures 1,2 *	10,11	
The present search report has been drawn up for all claims			
Place of search The Hague		Date of completion of the search 5 August 2008	Examiner Meyer, Matthias
CATEGORY OF CITED DOCUMENTS X : particularly relevant if taken alone Y : particularly relevant if combined with another document of the same category A : technological background O : non-written disclosure P : intermediate document T : theory or principle underlying the invention E : earlier patent document, but published on, or after the filing date D : document cited in the application L : document cited for other reasons & : member of the same patent family, corresponding document			

 4
EPO FORM 1503 03.82 (P04C01)



European Patent
Office

EUROPEAN SEARCH REPORT

Application Number
EP 08 00 3841

DOCUMENTS CONSIDERED TO BE RELEVANT			
Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (IPC)
A	US 5 831 166 A (KOZUKA TERUYUKI [JP] ET AL) 3 November 1998 (1998-11-03) * column 10, lines 39-50 * * column 14, line 65 - column 15, line 6 * * figures 1,4,12 *	16,17	
A	US 6 216 538 B1 (YASUDA KENJI [JP] ET AL) 17 April 2001 (2001-04-17) * column 20, lines 1-33 * * figures 19a,19b *		
A	WO 2004/079716 A (ETH ZUERICH [CH]; HAAKE ALBRECHT [CH]; DUAL JUERG [CH]) 16 September 2004 (2004-09-16) * abstract * * page 4, lines 9-36 * * page 13, line 34 - page 14, line 3 *	8,9	
			TECHNICAL FIELDS SEARCHED (IPC)
The present search report has been drawn up for all claims			
Place of search The Hague		Date of completion of the search 5 August 2008	Examiner Meyer, Matthias
CATEGORY OF CITED DOCUMENTS X : particularly relevant if taken alone Y : particularly relevant if combined with another document of the same category A : technological background O : non-written disclosure P : intermediate document T : theory or principle underlying the invention E : earlier patent document, but published on, or after the filing date D : document cited in the application L : document cited for other reasons & : member of the same patent family, corresponding document			

4
EPO FORM 1503 (03.02) (P04C01)

**ANNEX TO THE EUROPEAN SEARCH REPORT
ON EUROPEAN PATENT APPLICATION NO.**

EP 08 00 3841

This annex lists the patent family members relating to the patent documents cited in the above-mentioned European search report.
The members are as contained in the European Patent Office EDP file on
The European Patent Office is in no way liable for these particulars which are merely given for the purpose of information.

05-08-2008

Patent document cited in search report		Publication date	Patent family member(s)	Publication date
US 4402221	A	06-09-1983	NONE	
DE 19916922	A1	26-10-2000	AU 5206900 A WO 0061475 A1	14-11-2000 19-10-2000
EP 0064593	A	17-11-1982	DE 3265967 D1 JP 57189948 A	10-10-1985 22-11-1982
US 4929400	A	29-05-1990	NONE	
US 5831166	A	03-11-1998	JP 2700058 B2 JP 9193055 A	19-01-1998 29-07-1997
US 6216538	B1	17-04-2001	NONE	
WO 2004079716	A	16-09-2004	AU 2003270259 A1 US 2006049114 A1	28-09-2004 09-03-2006

EPO FORM P0459

For more details about this annex : see Official Journal of the European Patent Office, No. 12/82

REFERENCES CITED IN THE DESCRIPTION

This list of references cited by the applicant is for the reader's convenience only. It does not form part of the European patent document. Even though great care has been taken in compiling the references, errors or omissions cannot be excluded and the EPO disclaims all liability in this regard.

Patent documents cited in the description

- US 4520656 A [0005]
- US 4777823 A [0006]
- US 5810155 A [0008]
- US 6575669 B [0008]