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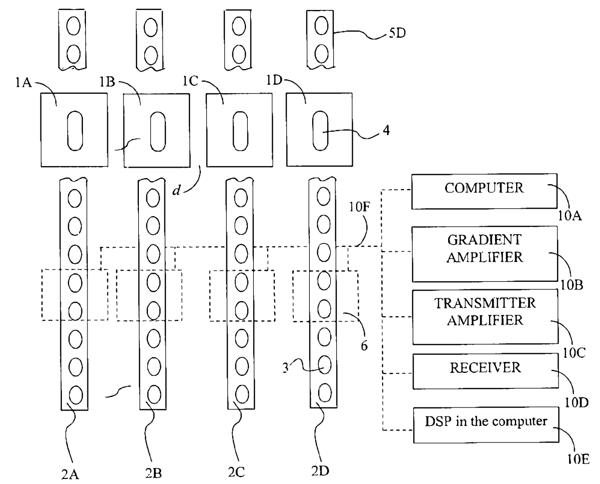
(54) Title: A PORTABLE QUALITY AND PROCESS CONTROL SYSTEM FOR SIMULTANEOUS MAGNETIC RESONANCE IMAGING OF MULTIPLE SAMPLES



(57) Abstract: The present invention discloses a portable industrial quality and process control (QPC) system for imaging over a large field of view and subsequently imaging over a portion thereof at higher resolution, comprising inter alia at least one packed array of multi-streamed magnetic resonance devices (1A-1D) of substantially no fringing magnetic fields, adapted to analyze adjacent lines of objects (3) optionally in situ simultaneously ;and optionally comprising an improved feeding system comprising at least two adjacent feeding streams carrying a plurality of objects to be detected or analyzed simultaneously or in any predetermined sequence. The present invention also discloses a method for performing magnetic resonance imaging, performing measurements on a plurality of streams of samples and optionally feeding at least two adjacent feeding streams carrying a plurality of objects (3) to be detected or analyzed simultaneously or in any predetermined sequence.

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A PORTABLE QUALITY AND PROCESS CONTROL SYSTEM AND A MAGNETIC RESONANCE METHOD OF ANALYZING ADJACENT LINES OF OBJECTS SIMULTANEOUSLY

FIELD OF THE INVENTION

[0 The present invention generally relates to a portable industrial quality and process control (QPC) system comprising *inter alia* at least one packed array of multi-streamed magnetic resonance devices of substantially no fringing magnetic fields, adapted to analyze adjacent lines of objects optionally *in situ* simultaneously and a method thereof.

BACKGROUND OF THE INVENTION

[0 Electromagnetic based instruments for measuring properties of matter or identifying its composition are well known. Magnetic resonance spectroscopy is one of the principal measuring techniques used to obtain physical, chemical and structural information about a molecule.

[0 A nuclear magnetic resonance imaging system produces an image of a sample which is based upon its molecular structure. The sample is subjected to a polarizing magnetic field which has the effect of aligning the spins of all the atomic nuclei of the sample. Radio waves at a frequency close to the Larmor frequency of the nuclei are then used to excite the nuclei such that their magnetic alignment is reversed. Once the excitation is removed the nuclei return to their original state by emitting characteristic radio signals. It is these radio signals that can be used to image the sample.

[04] The exact Larmor frequency is dependent upon the precise magnetic field. By creating a magnetic field gradient within the sample cavity the source of these signals can be located such that an overall image of the sample can be constructed.

[05] The efficiency of this process depends upon the consistency of the magnetic field strength within the sample cavity. This field is typically controlled to within 5 parts per million. The extent of the uniformity of the magnetic field determines the accuracy with which the Larmor frequency can be measured. This allows for the resolution of smaller chemical shifts.

[06] Uniformity of magnetic fields to less than 5ppm is very difficult to achieve over a large volume. A targeted magnetic resonance device, however, images a much smaller region of

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interest, over which it becomes easier to achieve very high uniformity such that very small chemical shifts can be resolved.

[0 In order to overcome fluctuations in the permanent magnetic field produced by a surrounding magnetic circuit, a variety of shimming methods may be used, such as the inclusion of ferromagnetic material of specific shapes at specific locations for example as described in patent no. GB 2,378,763 or the use of oddly shaped shimming coils whose magnetic fields can be adjusted by controlling the current passing through them.

[0 In order to superimpose a magnetic field gradient onto the uniform magnetic field in the sample cavity, additional gradient coils are used. The higher the magnetic gradient that can be produced by the gradient coils, the higher the resolution of the image acquired, however in order for the gradient to cover the whole sample cavity requires a large coil.

[0 The larger the coils the greater the power required to generate a given magnetic gradient. In addition, large coils have high inductance which reduces the slew rate which can be achieved with them.

[1 When a live sample, such as human patient is subject to a changing magnetic field, nerve stimulation can result from a induced potential within the neurones leading to undesired physiological effects. A magnetic resonance device which exposes only the field of interest to a changing magnetic field would limit the scope of such effects as the region not being imaged is not subject to any stimulating field.

[1 There is thus a long felt need in the art for a cost effective multilayered magnetic resonance device and method of performing high resolution imaging over a portion of its total field of view. More particularly to a magnetic resonance device adapted for the inclusion of a human head which produces high resolution images over the area of interest without exposing the whole sample to high magnetic field gradients.

[12] Moreover, in order to introduce a plurality of samples into a single magnetic resonance device a conveying mechanism is necessary. Such a mechanism is often the source of inefficiency in the system where the conveying mechanism passes through the region of uniform magnetic field as the region occupied by the conveying mechanism is not available for the introduction of a sample to be measured. A conveying mechanism is therefore necessary which introduces the sample into the region of uniform magnetic field without itself occupying said region.

[1? In order to measure a fluid sample a measurement pipe is provided around which a gradient coil is wound. It is thus possible to perform magnetic resonance measurements on any sample passing through said pipe. In order to measure a plurality of different fluids it is necessary to provide a manifold comprising a system of feeder pipes each connected via a valve to the measurement pipe. Each separated fluid is then introduced into the measurement pipe individually. This set up is problematic as passing many fluids through the same measurement pipe is time consuming especially where the need for cleaning the pipe between samples is taken into consideration. A system providing many measurement pipes which can be operated simultaneously would be of significant benefit particularly in industrial settings. There is thus a long felt need in the art for a cost effective multi-streamed magnetic resonance device and method thereby of simultaneously measuring a plurality of samples.

[1 Furthermore, most of the commercially available magnetic resonance devices are non-portable. They generate a powerful external magnetic field while analyzing items in their inner volume. Such undesired fringing magnetic fields eliminate the option of installing magnetic resonance device side-by-side.

[1 Nowadays, significantly reduced magnetic forces are obtained outside a few magnetic resonance devices, i.e., ASPeCT TM devices, claimed to achieve up to two Tesla magnetic field with uniformity suitable for sub-ppm magnetic resonance analysis and over 400 mm usable air gap between the pole pieces.

[1(Methods and apparatus for analyzing objects by magnetic resonance technique are various and well-known but currently available non-portable devices cannot determine the properties of said objects *in situ* and provide an analyze of a plurality of adjacent lines of objects simultaneously.

[17] One typical use of the magnetic resonance techniques is for agricultural products, in order to detect any abnormalities in the goods in a non-destructive manner. WO Pat No02059586 presents an apparatus and methods for analyzing and improving agricultural products. In this present application, the examination of the agricultural sample is not proceeding *in situ*. In order to improve and to control the quality of the goods and to determine the right time of picking vegetables or fruits, a portable magnetic resonance quality and process control device is thus necessary.

[18] Another typical use of the magnetic resonance techniques is for spectroscopy on patients, in order to detect abnormalities in living cell tissue.

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US Pat No 2005204473 discloses an imaging tomography apparatus, such as an x-ray computed tomography apparatus or a magnetic resonance tomography apparatus, has a patient bed that can be driven into a tunnel-shaped or annular data acquisition device. To increase comfort for the patient and accessibility by medical personnel, the patient bed has a pivotable backrest connected to a seat.

Trauma patients require specialized care, including stabilization, surgery and often blood transfusion. Many deaths which could have been prevented by appropriate care occur in relatively short time after injury at the site of injury. Emergency medical technicians, paramedics, and sometimes veterinary surgeons, use stabilization techniques to improve the chances of a trauma patient surviving the ambulance trip to the hospital. The neck and back are secured before moving the immobilized patients to ensure that the injured person is not disabled by unnecessary movement of the spine.

In order to diagnose the damage caused by the injury, the medical team has to transfer the patients to hospital's magnetic resonance rooms, and proceed to a magnetic resonance spectroscopy, where the devices are fixed in order to perform. But, during the pre-hospitalization, intra-hospitalization and post-hospitalization investigations, all superfluous movement is unnecessary and potentially harmful. This is why a portable magnetic resonance quality and process control device to diagnose patient *in situ* is thus a long felt need.

Methods and apparatus for analyzing objects by magnetic resonance technique are various and well-known but currently available non-portable devices cannot determine the properties of said objects *in situ*.

References to prior art in this specification are provided for illustrative purposes only and are not to be taken as an admission that such prior art is part of the common general knowledge in Australia or elsewhere.

Throughout the specification, unless the context requires otherwise, the word “comprise” or variations such as “comprises” or “comprising”, will be understood to imply the inclusion of a stated integer or group of integers but not the exclusion of any other integer or group of integers. Likewise the word “preferably” or variations such as “preferred”, will be understood to imply that a stated integer or group of integers is desirable but not essential to the working of the invention.

SUMMARY OF THE INVENTION

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It is therefore one object of the present invention to present a portable industrial quality and process control (QPC) system for imaging over a large field of view and subsequently imaging over a portion thereof at higher resolution, comprising inter alia at least one packed array of multi-streamed magnetic resonance devices of substantially no fringing magnetic fields, adapted to analyze adjacent lines of objects optionally in situ simultaneously ;and optionally comprising an improved feeding system comprising at least two adjacent feeding streams carrying a plurality of objects to be detected or analyzed simultaneously or in any predetermined sequence. This system is comprised of a plurality of magnets installed side by side with virtually zero gap between the magnets, and thus it is utilizable in an industrial

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environment whereat objects selected in a non-limiting manner from products, materials, bulk of powders, a predetermined measure of liquids etc in the upstream or downstream production stages are placed on a conveyor belt or the like, or in pipes or the like, and maneuvered simultaneously towards the magnets for analysis.

Another object of the present invention is to disclose a cost effective and industrially oriented method for performing magnetic resonance imaging over a large field of view and subsequently imaging over a portion thereof at higher resolution, analyzing simultaneously a multiple adjacent lines of objects *in situ* by means of a portable QPC, performing measurements on a plurality of streams of samples and optionally feeding at least two adjacent feeding streams carrying a plurality of objects to be detected or analyzed simultaneously or in any predetermined sequence. This method and system are adapted to save installation space, provided with a large system output, i.e., effectively analyze lines of good in parallel.

Another object of the present invention is to provide an industrial quality and process control (QPC) system adapted to analyze adjacent lines of goods said QPC comprising at least one packed array of MRI/NMR devices, said packed array comprising a plurality of i adjacently positioned MRI/NMR devices installed side by side with virtually zero gap between the magnets; said array characterized by dimensions of x, y, and z, where i is an integer not less than 2, and x, y, and z are integers not less than 0; wherein each of said MRI/NMR devices provides magnetic shielding from the other MRI/NMR devices and wherein each MRI/NMR device comprises a magnet, a gradient coil, and an RF coil such that said QPC system comprises in total not less than i independent magnets, i independent gradient coils, and i independent RF coils; further wherein the analysis of said lines of goods is performed simultaneously and independently by each of said MRI/NMR devices.

A further object of the present invention is to provide a method for analyzing a multiple adjacent lines of objects simultaneously, comprising steps of:

a. obtaining at least one QPC;
b. feeding said goods into said MRI/NMR, each line is directed towards a single device;
c. analyzing said goods by said MRI/NMR; and,
d. evacuating said goods from the MRI/NMR.

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Another object of the present invention is to provide an industrial quality and process control (QPC) system adapted to analyze adjacent lines of goods, said QPC comprising a plurality of i MRI/NMR devices installed side by side with virtually zero gap between the magnets; wherein each of said MRI/NMR devices provides magnetic shielding from the other MRI/NMR devices; and wherein each MRI/ NMR device includes a magnet, a gradient coil and an RF coil such that said QPC system includes no less than i independent magnets, i independent gradient coils, and i independent RP coils; and further wherein each MRI/NMR device receives goods from at least one of said adjacent lines of goods and is adapted to analyze said goods and outputs of said goods wherein said analysis is performed independently of the other MRI/NMR devices.

BRIEF DESCRIPTION OF THE INVENTION

[In order to understand the invention and to see how it may be implemented in practice, few preferred embodiments will now be described, by way of non-limiting example only, with reference to the accompanying drawing, in which

[figure 1 presents a packed array of magnetic resonance devices according to one embodiment of the present invention, adapted for analyzing adjacent lines of objects simultaneously; and,

[figures 2A-2C schematically illustrate various stacks of magnetic resonance devices according to yet another embodiment of the present invention, wherein in figure 2A i equals 2, $x = 2$, $y = 1$ and $z = 0$; in figure 2B 2A i equals 6, $x = 3$, $y = 2$ and $z = 0$; and in figure 2C i equals 24, $x = 4$, $y = 3$ and $z = 2$;

[figure 3A schematically represents a cross section of the magnetic resonance device according to one embodiment of the current invention;

[29] figure 3b schematically represents a top view of the magnetic resonance device showing the positions of the global and local gradient coils (304) according to one embodiment of the current invention;

[3 figure 4a schematically represents a cross section through the magnetic resonance device showing the magnetic field in the sample cavity produced by the closed magnetic circuit magnets, according to another embodiment of the current invention;

[3 figure 4b schematically represents a top view of the magnetic resonance device showing the magnetic field in the sample cavity produced by the closed magnetic circuit magnets, according to another embodiment of the current invention;

[3 figure 5 schematically represents the magnetic field gradient throughout the sample cavity produced by the global gradient coil, according to another embodiment of the current invention;

[3 figure 6 schematically represents the magnetic field gradient, in the field of interest, produced by a local gradient coil, according to another embodiment of the current invention;

[3 figure 7 schematically represents the magnetic field gradient, produced by a local gradient coil, passing through the head of a patient which has been introduced into the sample cavity, according to another embodiment of the current invention;

[3 figure 8 schematically presents schematically presenting a stratificated feeding system in a magnetic resonance device (1000) according to one embodiment of the present invention;

[3 figures 9A to 9E illustrate schematic out of scale top views of the cavity inside a magnetic resonance device 1000;

[3 figure 10 schematically represents one embodiment of the current invention wherein the pole pieces are situated to the sides of the conveyor belt which lies wholly outside the region of uniform magnetic field;

[38] figure 11 schematically represents another embodiment of the current invention wherein two orthogonal layers of parallel pipes pass through the region of uniform magnetic field;

[39] figure 12 schematically represents a single fluid imaging unit showing the pipe, gradient coil and direction of fluid flow; and,

[40] figure 13 schematically presents a diagram of the portable quality and process control device.

DETAILED DESCRIPTION OF PREFERRED EMBODIMENTS

[4 The following description is provided, alongside all chapters of the present invention, to enable any person skilled in the art to make use of said invention and sets forth the best modes contemplated by the inventor of carrying out this invention. Various modifications, however, will remain apparent to those skilled in the art, since the generic principles of the present invention have been defined specifically to provide a portable industrial quality and process control (QPC) system comprising *inter alia* at least one packed array of multi-streamed magnetic resonance devices of substantially no fringing magnetic fields, adapted to analyze adjacent lines of objects optionally *in situ* simultaneously and a method thereof

[4 The term '**magnetic resonance device**' applies hereinafter to a device such as an NMR, ESR, NQR or MRI device, adapted to measure the radio signals emitted from the nuclei of the atoms within a sample when said nuclei are excited by electromagnetic radiation.

[4 The term '**packed array**' refers hereinafter to an array of two or more magnetic resonance devices of substantially no fringing magnetic fields, wherein the distance between said devices is respectively small, such that a plurality of feeding lines are directed to said array, and a rapid analysis of a mass (i.e., industrial scale) of objects is provided simultaneously.

[4 The term ' **QPC** ' refers hereinafter to a magnetic resonance device adapted to analyze the properties, compositions or shape of objects *in situ*, as well as processes and reactions, wherein the terms '**analysis**' and/or '**QPC**' are denoted hereinafter to any detection, analysis, control, measurement, study, observation or study of a given matter or process by a means of a magnetic resonance device.

[45] The term '**field of view**' applies hereinafter to a volume over which a magnetic gradient is applied.

[46] The term '**resolution**' applies hereinafter to a device's ability to distinguish between two elements such as the magnetic resonance device's ability to distinguish the distance between two signals.

[47] The term '**multilayered cage**' applies hereinafter to an envelope surrounding a cavity comprising a plurality elements arranged in layers.

[48] The term '**sample cavity**' applies hereinafter to a cavity within a containing envelope within which a sample is introduced.

[4 The term '**magnetic circuit**' applies hereinafter to the path of magnetic flux from north to south magnetic poles.

[5 The term '**shimming mechanism**' applies hereinafter to any mechanism for correcting the inhomogeneities of a magnetic field due to imperfections in the magnet or the presence of external ferromagnetic objects. A shimming mechanism may include, inter alia, passive shimming elements, active shimming elements, feedback controlled shimming, CPU controlled shimming, superconducting shimming elements.

[5 The term '**shim coils**' or "**active shimming elements**" applies hereinafter to coils positioned around the magnets in order to correct any inhomogeneities of the magnetic field.

[5 The term '**passive shimming elements**' applies hereinafter to pieces of ferromagnetic material positioned around the magnets in order to correct inhomogeneities of the magnetic field.

[5 The term '**gradient coil**' applies hereinafter to a coil used to create a magnetic gradient over at least a portion of the sample cavity.

[5 The term '**tracks**' applies hereinafter to any means of moving one element relative to another, such as rails upon which a gradient coil slides relative to the sample cavity.

[5 The term '**slew rate**' applies hereinafter to the rate of increase or decrease of a magnetic gradient from zero to its maximum absolute value.

[5 The term '**sample imaging units**' applies hereinafter to a device adapted to provide a means of measuring the magnetic resonance of a sample within a uniform magnetic field.

[57] The term '**fluid imaging units**' applies hereinafter to a device adapted to provide a means of measuring the magnetic resonance of a fluid sample within a uniform magnetic field.

[58] The term '**switching rate**' applies hereinafter to the number of separated devices which are activated in a given time period.

[59] The term '**pole piece**' applies hereinafter to an element of high permeability material used to shape the uniformity of the magnetic flux from a permanent magnet. In one such example a pole piece is constructed from small granules of ferromagnetic material, the diameter of each granule is of the order of one micron. Said granules are embedded within a plastic coating which serves to strengthen the granules and prevent distortion of their shapes. The material is cut into small cubes which are stuck together with non-conducting glue and with spacers

between the granules. Such a construction prevents the formation of large eddy currents within the pole piece, thereby increasing the efficiency of the magnet.

[6 The term '**side wall magnets**' applies hereinafter to permanent magnets arranged around the sides of pole pieces that maintain the uniformity of the magnetic field from the permanent magnet.

[6 The term '**plurality**' applies hereinafter to any integer greater than or equal to one.

[6 The term '**portable**' applies hereinafter to any hand-held or wearable devices. Said device can be carried or worn by the human body on a belt or in a pocket.

[6 The term '**mobile**' applies hereinafter to any vehicular, aircraft or ship-based systems, wireless systems in trucks, vans, cars, boats, or motorcycles.

[6 The term '**platform**' refers hereinafter to any mobile vehicle, aircraft or ship-based systems. For example, the term refers also to tractors, caterpillars, draglines, loaders, especially wheel loaders, shovels, cranes, powder lift trucks .

[6 The term '**citrus**' refers in the present invention to any clementines, mandarin, oranges, grapefruit, pomelo, rangpur, sweet orange, lime, citron tangerine or lemon. Specifically and in a non-limiting manner, the term citrus further refers to amanatsu, bergamot orange, bitter orange (seville orange),calamondin (calamansi), golden lime - hybrid between the genus citrus and the genus fortunella, dancy, ichang lemon, kaffir lime, key lime, kumquat - in the related genus fortunella, not citrus; forms hybrids with citrus, limequat, mandarin lime, mandarin orange, meyer lemon, mikan, minneola, orangelo (chironja), orangequat, persian lime (tahiti lime), rough lemon, satsuma, shekwasha (taiwan tangerine), sweetie, tachibana orange, tangelo, tangor ugliy; yuzu etc .

[66] The term '**drupe**' refers in the present invention to any peach, pear, plum or apricot. In botany, a drupe is a type of fruit in which an outer fleshy part (exocarp or skin and mesocarp or flesh) surrounds a shell (the pit or stone) of hardened endocarp with a seed inside. These fruits develop from a single carpel, and mostly from flowers with superior ovaries. The definitive characteristic of a drupe is that the hard, lignified stone (or pit) derives from the ovary wall of the flower. Specifically and in a non-limiting manner, the term drupe further refers to coffee, jujube , mango, olive, all members of the genus *Prunus*, including the almond (in which the mesocarp is somewhat leathery), apricot, cherry, peach, nectarine, plum etc.

[67 The term **'climacteric fruit'** refers in the present invention to any fruit that continues to ripen after harvest. Fruits and vegetables can be classified as climacteric or non-climacteric. Climacteric fruit continues to ripen after harvest, whereas non-climacteric does not. Ripening is a process that includes development of color, flavor and texture (softening). This means that the ripening process continues after abscission (when the fruit drops).

[6 The term **'ripening'** refers in the present invention to a process in fruit that causes them to become more edible. As fruits ripen, they get sweeter, less acidic, less green and softer .

[6 This system comprising *inter alia* at least one packed array of *i* magnetic resonance devices of substantially no fringing magnetic fields, adapted to analyze up to *i* lines of objects simultaneously, wherein *i* is an integer number higher or equal 2.

[7 It is in the scope of the present invention wherein said packed array is a stack comprising a plurality of *i* magnetic resonance devices, characterized by the dimensions of *x*, *y* and *z* magnetic resonance device; and further wherein *i* is an integer number higher or equal 2, and *x*, *y* and *z* are integer numbers higher or equal 0, such that in case those values higher or equal 1, $x*y*z$ equals *i*. The shape of at least a portion of the stack is preferably polygonal, circular or any combination thereof.

[7 It is also in the scope of the present invention wherein at least a portion of the objects are fed into the magnetic resonance devices by means of a conveyor belt or the like, by means of tunnels, conduits or pipes or any combination thereof. The system is further adapted to operate either continuously or in a batch wise manner.

[72] It is also in the scope of the present invention wherein the magnets of the magnetic resonance devices are passively shielded and/or actively shielded by means of an RF and/or magnetic shielding.

[73] The QPC system defined above is preferably comprising additional computerized means, adapted for time sharing of at least one of the group consisting in a non-limiting manner gradient power supplying; RF transmitting and/or amplifying; RF receiving; digital signal processing or any combination thereof.

[74] Reference is made now to figure 1, schematically presenting an industrial QPC system, comprising *inter alia* at least one array of magnetic resonance devices of substantially no fringing magnetic fields (1A-1D). Here the magnetic resonance devices are arranged in parallel such that the distance (*d*) between devices (1A-1D) is short and determined mainly

by the feeding requirements, e.g., the optimum distance between the various feeding conveyor belts (e.g., 2B and 2C).

[7 According to this example and in a non-limiting manner, said four magnetic resonance devices (1A-1D) are fed by four parallel conveyor belts (2A-2D), each conveyor transports into one of the magnetic resonance devices a continuous, segmented or pulsed series of objects (3) to be examined.

[7 Various models are possible, such as a sorting facility adapted for sorting incubator's avian eggs, e.g., divide lines of eggs to gender of the embryo; a system adapted for selective elimination of fertilized eggs from product line, evacuating eggs characterized with improper size or condition, or provided with predetermined physiological condition. .

[7 Another example is sorting fruits and other agricultural products and raw materials, and especially utilizing in citrus packing house to be QPC for the inspection of presence of seeds, presence of a hollow core inside the fruit, defining over ripped stages, mold damages, freeze damages sugar level, water level and pH etc. This example is further provided useful for other feeding systems, such as wherein the objects are in a liquid state, e.g., QPC of oil refinery industry; wherein multiple pipes comprising flowing oil in its various refining process is enforce to flow into the magnetic resonance devices for analysis. According to this embodiment of the present invention, each feeding line (e.g., 2D) is entering the magnetic resonance device (1D, frontal view) *via* at least one inflow aperture (4), and exiting (5D) said magnetic resonance device *via* at least one outflow aperture (not shown). The QPC is provided either continuously or in a batch wise manner, e.g., by stopping the line to a predetermined short period of times before magnetic resonance analysis the objects.

[78] It is hence according to one aspect of the present invention wherein the QPC as defined above is adapted for sorting incubator's avian eggs, and especially sorting the gender of embryo; selectively eliminating fertilized eggs from product line; or evacuating eggs characterized with improper size or physiological condition or any combination thereof.

[79] It is hence according to another aspect of the present invention wherein the QPC as defined above is adapted for sorting fruits and other agricultural products and raw materials, and especially for utilizing in citrus packing house to inspect presence of seeds, locating a hollow core inside the fruit, defining over ripped stages, scanning mold damages, determining freeze damages sugar level, evaluating water level or determining fruit's acidity or any combination thereof.

[8 It is according to yet another embodiment of the present invention wherein the said magnetic resonance device enabled QPC further comprises computerized means (10A), enabling *inter alia* time sharing of gradient power supply (10B), time sharing of RF transmitter and/or amplifier (10C), time sharing of RF receiver (10D), time sharing of digital signal processing (10E). Said QPC is preferably yet not exclusively provided by window (6, top view). It is acknowledged in this respect that any combination of time sharing as defined above with one, few or all magnetic resonance devices is possible.

[8 Reference is made now to figures 2A, 2B and 2C illustrating in a non-limiting manner various stacks, wherein 2A and 2B describes a front view of a polygonal stack, and figure 2C presents a lateral view of the same.

[8 It is further in the scope of the present invention wherein the analyzed objects are either solid or liquid matter; and especially wherein the analyzed objects are selected from agricultural raw materials or products, cosmetics, chemicals, powders, gases, enveloped items, medicaments, industrial matters, metal ware or any other continuous or discrete members or combination of solid, liquid and gas.

[8 It is according to one embodiment of the current invention to present a magnetic resonance device for imaging over a large field of view and subsequently imaging over a portion thereof at higher resolution. This device comprises a multilayered cage containing the sample cavity into which a sample is introduced and imaged. The cage comprises a closed magnetic circuit constructed from strong permanent magnets, and where necessary for the maintenance of a uniform magnetic field, a shimming mechanism selected from an array of shim coils, passive shimming elements or any combination thereof. The cage additionally comprises a global gradient coil and an array of local gradient coils. Said device provides images selected from low-resolution images over a large field of view, high-resolution images over a smaller field of view, or any combination thereof.

[84] It is according to another embodiment of the current invention to present a magnetic resonance device wherein adjacent local gradient coils overlap such that each portion of the sample cavity is situated within the field of view of at least one local gradient coil.

[85] It is according to a further embodiment of the current invention to present a magnetic resonance device additionally comprising tracks upon which at least one local gradient coil is manoeuvred such that its field of view covers any portion of the sample cavity.

[8 It is according to yet another embodiment of the current invention to present a magnetic resonance device, adapted such that the either one large sample or a plurality of smaller samples are introduced into the sample cavity and any section of total sample is imaged therein.

[8 It is according to yet another embodiment of the current invention to present a magnetic resonance device for the imaging of a large sample extending over a plurality of local gradient coils, wherein the local gradient coils are characterized by a fast slew rate such that a plurality of images are acquired sequentially from a plurality of local gradient coils.

[8 It is according to a further embodiment of the current invention to present a magnetic resonance device wherein the closed magnetic circuit is characterized by two pole pieces and an array of side wall magnets, which lock the magnetic flux within the magnet structure and sample cavity.

[8 It is according to another embodiment of the current invention to present a magnetic resonance device wherein the field of view of the global gradient coil covers the whole volume of the sample cavity.

[9 It is according to a further embodiment of the current invention to present a magnetic resonance device wherein the shimming mechanism comprises an array of passive shim elements.

[9 It is according to a further embodiment of the current invention to present a magnetic resonance device wherein the shimming mechanism comprises an array of tuneable shim coils, which can be tuned to create a uniform magnetic field over the field of view of at least one local gradient coil such that a high-resolution nuclear magnetic spectrum of a sample situated within this field of view is obtained.

[92] It is according to a further embodiment of the current invention to present a magnetic resonance device wherein the shimming mechanism comprises an array of tuneable shim coils, which are tuned to create a uniform magnetic field over a limited region of the whole sample.

[93] It is according to another embodiment of the current invention to present a magnetic resonance device adapted for the imaging of a human head additionally comprising a cavity of dimensions suitable for the accommodation of the shoulders and upper torso such that the

magnetic field changes only over the field of interest thereby preventing nerve stimulation outside the field of view of the local gradient coil..

[9 It is according to another embodiment of the current invention to present a magnetic resonance device wherein the array of sidewall magnets is bent such that the magnetic field remains uniform within the volume adapted to accommodate the head and shoulders.

[9 It is according to another embodiment of the current invention to present in a multi-layered portable QPC, a multi-streamed magnetic resonance device comprising the following elements. A cage comprising a closed magnetic circuit constructed from strong permanent magnets and an optional shimming mechanism selected from an array of active shim coils, passive shimming elements or any combination thereof, a contained cavity within which the magnetic field strength is approximately uniform and a means, such as a plurality of conveyor belts, pipes or any other transportation means by which a plurality of samples are introduced into the region of uniform magnetic field. This device is allows for magnetic resonance measurements to be made on a plurality of samples within the region of the said uniform magnetic field.

[9 It is according to another embodiment of the current invention to present in a multi-layered portable QPC a multi-streamed magnetic resonance device wherein the closed magnetic circuit is characterized by two pole pieces and an array of side wall magnets, which lock the magnetic flux within the magnet structure and sample cavity.

[9 It is according to a further embodiment of the current invention to present in a multi-layered portable QPC a multi-streamed magnetic resonance device additionally comprising a plurality of sample imaging units. Each sample imaging unit comprises a conveyor belt which transports a sample into the region of uniform magnetic field, a gradient coil around said conveyor belt and a magnetic resonance measurement probe. In addition a means, such as a CPU, allows the gradient coils of each sample imaging unit to be activated in rapid succession such that magnetic resonance measurements are made on a plurality of discrete samples within the region of uniform magnetic field.

[98] It is according to a further embodiment of the current invention to present in a multi-layered portable QPC a multi-streamed magnetic resonance device wherein a plurality of sample imaging units are situated parallel to each other such that a plurality of samples are conveyed into the region of uniform magnetic field simultaneously along a plurality of streams.

[9 It is according to another embodiment of the current invention to present in a multi-layered portable QPC a multi-streamed magnetic resonance device wherein the pole-pieces of the magnetic circuit are orientated horizontally to the sides of the contained cavity such that at least one conveyor belt is situated outside the region of uniform magnetic field whilst conveying the sample into the region of uniform magnetic field.

[1 It is according to a further embodiment of the current invention to present in a multi-layered portable QPC a multi-streamed magnetic resonance device wherein the pole-pieces of the magnetic circuit are orientated horizontally to the sides of the contained cavity such that at least one conveyor belt is situated beneath the region of uniform magnetic field whilst conveying the sample into the region of uniform magnetic field.

[1 It is according to another embodiment of the current invention to present in a multi-layered portable QPC a multi-streamed magnetic resonance device wherein the pole-pieces of the magnetic circuit are orientated horizontally to the sides of the contained cavity such that at least one conveyor belt is situated above the region of uniform magnetic field whilst conveying the sample into the region of uniform magnetic field.

[1 It is according to a further embodiment of the current invention to present in a multi-layered portable QPC a multi-streamed magnetic resonance device adapted for the measurement of fluid samples comprising a plurality of fluid imaging units. Each fluid imaging unit comprises a pipe within which a fluid sample flows through the region of uniform magnetic field, a gradient coil around said pipe and a magnetic resonance measurement probe. In addition a means, such as a CPU, allows the gradient coils of each sample imaging unit to be activated in rapid succession such that magnetic resonance measurements are made on a plurality of discrete fluid samples within the region of uniform magnetic field.

[103] It is according to another embodiment of the current invention to present in a multi-layered portable QPC a multi-streamed magnetic resonance device wherein at least two fluid imaging units are orientated orthogonally such that the gradient coils of both units can be activated simultaneously with no interference.

[104] It is according to a further embodiment of the current invention to present in a multi-layered portable QPC a multi-streamed magnetic resonance device wherein at least two fluid imaging units are orientated near orthogonally such that the switching time between activation of the gradient coils of each of the units can be activated almost simultaneously with a small switching time between them.

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[1 Reference is made now to figure 3a, schematically presenting a cross section of a targeted magnetic resonance device according to one embodiment of the current invention. A closed magnetic circuit, 301, comprises a large permanent magnet, 301a, a pole piece, 301b and an array of side wall magnets, 301c, surrounding a central sample cavity, 305. A shimming mechanism, 302, is used to maintain uniform magnetic field within the cavity. A global gradient coil, 303, extends along the length of the sample cavity. An array of local gradient coils, 304, are positioned at intervals along the length of the cavity and overlap such that any volume section within the sample cavity is within the field of at least one of the local gradient coils.

[1 Reference is made now to figure 3b, schematically presenting a top view of the magnetic resonance device according to one embodiment of the current invention. This diagram shows the positions of the global gradient coil, 303, and the local gradient coils, 304, the central local gradient coil, 304b, overlaps with the other local gradient coils. It is acknowledged that the local gradient coils, 304, represented in this figure as squares, may take any shape such as circular, cylindrical or any regular or irregular geometry.

[1 Reference is made now to figure 4a, schematically representing a cross section through the magnetic resonance device showing magnetic field lines, 306, in the sample cavity produced by the closed magnetic circuit, 301, comprising a large permanent magnet, 301a, a pole piece, 301b and an array of side wall magnets, 301c, according to another embodiment of the current invention.

[1 Reference is made now to figure 4b, schematically representing a top view of the magnetic resonance device showing the magnetic field, 306, in the sample cavity produced by the closed magnetic circuit magnets, 301, according to another embodiment of the current invention.

[109] Reference is made now to figure 5, schematically representing the magnetic field gradient, 307, throughout the sample cavity of the magnetic resonance device, produced by the global gradient coil, 303, according to another embodiment of the current invention.

[110] Reference is made now to figure 6, schematically representing the magnetic field, 308, within the field of interest in one volume section of the sample cavity, produced by one local gradient coil, 304b, according to another embodiment of the current invention.

[111] Reference is made now to figure 7, schematically representing the magnetic field gradient, 309, produced by one local gradient coil, 304c, passing through the head of a patient, 311,

which has been introduced into the sample cavity, according to another embodiment of the current invention. The high magnetic field is directed only over the field of interest reducing exposure and nerve stimulation elsewhere in the brain of the patient.

[1 In a magnetic resonance device, the present invention discloses an improved feeding system comprising at least two adjacent feeding streams carrying a plurality of objects to be detected or analyzed simultaneously or in any predetermined sequence. More specifically and according to one embodiment of the present invention, the said stratificated magnetic resonance device comprising at least two feeding systems as defined above said at least two feeding systems are relatively oriented in one plane (2D). Additionally or alternatively, a stratificated magnetic resonance device comprising at least two feeding systems as defined above is disclosed; said at least two feeding systems are oriented in a plurality of planes thus being in a 3D orientation. Said streams are possibly yet not exclusively in a parallel orientation, perpendicular orientation or a combination thereof.

[1 Reference is made now to figure 8, schematically presenting a stratificated feeding system in a magnetic resonance device (1000) according to one embodiment of the present invention. Here for example and in a non-limiting manner, magnetic resonance device comprising two adjacent feeding systems 100 and 200 being in a respectively perpendicular orientation such that lines 103 and 104 are directed along the main Z axis while line 203 and 204 are simultaneously directed along the main X axis of the device. Lines 203 and 204, as lines 104 and 103 are illustrated hereby as an example for a plurality of *n* parallel lines, wherein *n* is any integer number equal or greater than 1. In this example and only for illustrating the technology in a non-limiting manner, *n* of both X lines and Z lines equals 2. In one embodiment *n* is between 2 and 6. In another embodiment *n* is between 4 to 10. In another embodiment *n* is significantly grater than 8.

[114] Lower layer 200 comprising thus two feeding lines 203 and 204, adapted to carry objects, here eggs, by a means of two rotating conveyor belts. Said conveyor belts are parallel, such as objects of belt 203 enter portion 200 in magnetic resonance device 1000 via aperture 201 or 211, while objects of belt 204 enter portion 200 in magnetic resonance device 1000 via aperture 202 or 212. Hence, the feeding directions of belts 203 and 204 may be parallel, opposite, and in a case that *n* is grater than 2, any combination thereof. It is acknowledged in this respect that conveyor belts or their like are selected in a non exclusive manner from a linear shape, curved shaped, zigzag, U shape or a combination thereof. Even though a 2D root is hereby illustrated, a 3D advancing root of the belt is also in the scope of the present

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invention. Hence for example, a possible U-belt 203 may enter cavity 200 via aperture 201 and exit the same via cavity 202 and vice versa.

[1 In a very similar manner, conveyor belts 103 and 104 are linear and parallel belts carrying objects, e.g., oranges, via apertures 101 and 102, throughout cavity portion 100 of device 1000 to leave via apertures 112 and 113, respectively.

[1 It is further in the scope of the present invention wherein the stratification of magnetic resonance device 1000 is characterized by more than two layers, forming more than two detecting volumes 100 and 200. It is hence another embodiment of the present invention wherein said magnetic resonance device comprises a plurality of *m* detecting volumes, wherein *m* is any integer number greater or equal 2. In one embodiment *m* is between 2 and 6. In another embodiment *m* is between 4 to 10. In another embodiment *m* is significantly grater than 8.

[1 It is further in the scope of the present invention wherein the objects detected in each conveyor belts or their like is similar to objects detected in adjacent belt. Nevertheless, it is well in the scope of the present invention wherein various objects either in solid, liquid and/or gas phases are simultaneously detected by means of magnetic resonance device 1000. The term simultaneously refers in this respect to an identical detecting effort or time, or a sequence of detection provided in a rapid course of detecting events. Said detections as well as feeding parameters are hence may be subject of processing means adapted to control and coordinate the same.

[1 Reference is made now to figures 9A to 9E illustrating a schematic out of scale top view of the cavity inside a magnetic resonance device 1000. Said device comprises one feeding system, two or more adjacent feeding systems or a stratification of the same (e.g., both systems 100 and 200). For the sake of simplicity, a system comprising three parallel feeding lines is always drowned. Fig. 9A shows a rectangled device, comprising nine objects to be detected simultaneously or in a predetermined sequence. The feeding lines are parallel to the main longitudinal axis of the rectangle. Fig. 9B shows the same rectangle system wherein the streams are parallel to the width, comprising six objects to be detected simultaneously or in a predetermined sequence. Fig. 9C shows the same rectangle system wherein the streams are parallel to one main diagonal, comprising eight objects to be detected simultaneously or in a predetermined sequence. In this case most objects are detected in the main longitudinal system (fig. 9A), yet the introduction of samples into the non uniform region of the magnetic

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field for an extended time provides for the nuclei of the sample to reach a stable orientation before being introduced into the region of uniform magnetic field. Fig. 9D shows a symmetrical cubic device, wherein the three streams are parallel to the main axis X or Y, comprising six objects to be detected simultaneously or in a predetermined sequence. Fig. 9E shows the same symmetrical cubic device, wherein the three streams are parallel to diagonal of the device, comprising seven objects to be detected simultaneously or in a predetermined sequence, i.e., about 15% more objects.

[1 Reference is made now to figure 10, schematically presenting one embodiment of the current invention wherein the pole pieces, 1001a and 1001b, are situated to the sides of the conveyor belt, 1002, which lies wholly outside the region of uniform magnetic field, 1003.

[1 Reference is made now to figure 11, schematically presenting another embodiment of the current invention wherein two orthogonal layers, 1004 and 1005, of parallel pipes pass through the region of uniform magnetic field, 1003. This orientation enables the gradient coil of any pair of orthogonal pipe for example the pair 1004a and 1005a, to be activated simultaneously.

[1 Reference is made now to figure 12, schematically presenting a single fluid imaging unit showing the pipe, 1006, gradient coil, 1007 and direction of fluid flow, 1008.

[1 The present invention discloses a portable quality and process control device (QPC) for *in situ* analyzing of objects, comprising; a magnetic resonance device (1) adapted to analyze objects; a mobile platform (2) being a base of said magnetic resonance; and a controller (3), activated by an operator (4), operating said magnetic resonance device and activating said mobile platform.

[123] It is in the scope of the present invention wherein said magnetic resonance device is a packed array comprising a plurality of magnetic resonance devices being arranged in either 2D or 3D array .

[124] It is further in the scope of the present invention wherein said platform is a mobile base of a plurality of adjustable and maneuverable articulated arms (5) each of which carries at least one magnetic resonance device. Said platform is adapted to be maneuvered in either an active or a passive motion and is activated by a hydraulic means. The said controller is automatically activated.

[125] Reference is made now to figure 13, presenting a schematic presenting an agricultural QPC, comprising *inter alia* at least one magnetic resonance device (1). Here for example, the

magnetic resonance device is positioned below the tree such that the distance between the device and the fruit is short. According to this embodiment and in a non-limiting manner, said magnetic resonance is encloses in a cage (6) fixed on a plurality of adjustable and maneuverable articulated arms (5), connected to a mobile platform (2). A computerized or micro-processor containing controller (3) is activated by an operator (4), operating said magnetic resonance device and activating said mobile platform. A trash trap (7) is intended to capture unwanted material that can disturb the analysis. For example, the said device can check, in a cherry tree, if the ratio between the sugar and the acidity is suitable to pick said cherry.

[1 An example of this present invention is the inspection of a multilayered fruit, such as an orange, to control the presence and the size of the seeds.

[1 According to another embodiment of the present invention, another example is the examination of a multilayered fruit, such as a pear, to control the maturity of the fruit despite of the peel hardness.

[1 Still another example of the present invention is the identification and disinfection of insects, by transmitting microwave radiation, e.g., at a frequency of approximately 2.45 GHz.

[1 It is further in the scope of the present invention wherein the portable QPC additionally comprising time sharing of at least one of the group of gradient power supplement; RF transmitter and/or amplifier; RF receiver; digital signal processing means or any combination thereof.

[1 It is further in the scope of the present invention wherein the feeding of analyzed objects is adapted for either solid or liquid matter or gas or any combination thereof.

[131] It is further in the scope of the present invention wherein the analyzed objects are vertebrate or invertebrate, human, mammal, birds, fish, insect or reptile patients, adapted for medical or veterinary uses, in order to proceed to a medical diagnostic *in situ*, especially at the accident place, in their hospital's room or at home.

[132] It is further in the scope of the present invention wherein the analyzed objects are either solid, liquid, gas or a combination thereof; and especially wherein the analyzed objects are selected from agricultural raw materials or products, chemicals, powders, gases, industrial matters, metal ware.

[1 The agricultural raw materials or products thereof are selected in a non-limiting manner from fruits; vegetables; plants; trees; creepers; weeds seeds; cereals from grasses including barley, maize, oats, rice, rye, and wheat; cereals from non-grasses, including buckwheat, amaranth, and quinoa; legumes, including beans, peas, and lentils; nuts, including coconuts, almonds, and pine nuts; oilseeds, including sesame, sunflower, and hemp; root vegetables, including potatoes, cassava, and turnips ;leaf vegetables, including amaranth, spinach, and kale; sea vegetables, including dulse, kombu, and dabberlocks; stem vegetables, including bamboo shoots, nopales, and asparagus; inflorescence vegetables, including globe artichokes, broccoli, and daylilies; fruit vegetables, including pumpkin, okra, and eggplant; herbs and spices.

[1 Still in a non-limiting manner, the agricultural raw materials or products thereof are also selected from dairy products including milk; eggs, including roe and caviar; insects, including honey; meat, including beef, frogs' legs, gaegogi, goat, horse, kangaroo, lamb, mutton, pork, veal, rodents; offal, including blood; poultry, including chicken, turkey, duck, goose, pigeon or dove, ostrich, guinea fowl, pheasant, quail; seafood, including finfish such as salmon and tilapia, and shellfish such as mollusks and crustaceans, snails, game. The analyzed objects are also selected from cosmetics, medicaments, industrial, chemicals raw materials or products thereof.

[1 Another aspect of the present invention is to provide a QPC as defined above, especially adapted to inspect presence of roe in fish and marine invertebrates.

[1 Another aspect of the present invention is to provide a QPC as defined above, especially adapted to evaluate quantity of injected water in meat.

[137] Another aspect of the present invention is to provide a QPC as defined above, especially adapted to determine infection, rotting or presence of free radicals in analyzed objects.

[138] Another aspect of the present invention is to provide a QPC as defined above, especially adapted to determine freezing level of examined product.

[139] Another aspect of the present invention is to provide a QPC as defined above, wherein the analyzed objects are vegetables or fruits.

[140] The fruits are possibly, yet not exclusively selected from the citrus family, or kiwi, pomegranate, drupes, apple, melon, banana, avocado pineapple, mango, tomato, pistachio, persimmon, almond, grapes, blueberries or any other fruit.

[1 It is further in the scope of the present invention wherein the analyzed objects are layered, conglomerated, coated, enveloped, continuous or discrete members.

[1 Various modules are possible, such as a sorting facility especially adapted for sorting fruits and other agricultural products and raw materials, and especially for sorting fruits before or after their picking for the inspection of presence of seeds, the determination of their numbers and sizes; for the detection of the presence of a hollow core, its length, width or volume or any combination thereof inside the fruit; for defining ripe level, mold damage, freeze damage, internal insects damage; for determining dryness; for evaluating water level, water activity, oil level or total liquid in the fruit; for determining number of sections present in the fruit; for determining the deformation or the bruises of the fruit; for determining peel thickness or separation from the fruit section, air cavities ,internal rotting of said fruit; for measuring the textures of the fruit especially hardness or floury texture; for evaluating chemical content as sugar level, fruit's acidity, pH, any magnetic resonance spectroscopy detectable composition or any combination thereof.

[1 It is another embodiment of the present invention to provide a device adapted to identify the presence of insects or other pathogens and to eradicate the same by activating a high frequency radiation. This non-chemical disinfection prevents damage in fruits and is not toxic for the human ingestion. The frequency domain is ranges for example from about 2 to about 4 GHz.

[1 It is acknowledged in this respect that the term insect refers to any microorganism, organisms or pathogens, especially plant or animal pathogens, e.g., organisms selected in a non-limiting manner from viruses, bacteria, fungi, molds, insects, flies, bacteria, nematodes, protozoa, microsporidia, algae, muscae etc.

[145] According to one embodiment of the present invention, electrical energy is obtained through the operation of the platform, wherein a mobile section operated by the user (manual operation) or automatically. The system may also include various auxiliary and complementary mechanical and/or electronic modules, making it possible to transform movement created by the user into electrical energy and using it such energy immediately, prior to transformation to the desired voltage and then storing it in storage batteries

[146] Another aspect of the present invention is to provide a feed-backed QPC as defined above, being especially adapted to identify the presence of insects or other pathogens and to activate disinfecting means for eradicate the same.

[1 Another aspect of the present invention is to provide a QPC as defined above, particularly adapted to locate parameters inside the fruit selected from a hollow core, length, width or volume or any combination thereof.

[1 Another aspect of the present invention is to provide a QPC as defined above, especially adapted to define a ripe level.

[1 Another aspect of the present invention is to provide a QPC as defined above, especially adapted to scan mold or freeze damages.

[1 Another aspect of the present invention is to provide a QPC as defined above, especially adapted to determine dryness.

[1 Another aspect of the present invention is to provide a QPC as defined above, especially adapted to evaluate water level, water activity (a_w), oil level or total liquid in the examined fruit.

[1 Another aspect of the present invention is to provide a QPC as defined above, especially adapted to determine number of sections present in the examined fruit.

[1 Another aspect of the present invention is to provide a QPC as defined above, especially adapted to determine the deformation or the bruises of the examined fruit.

[1 Another aspect of the present invention is to provide a QPC as defined above, especially adapted to determine internal or external insects' damage.

[1 Another aspect of the present invention is to provide a QPC as defined above, especially adapted to determine peel thickness or separation from the fruit section.

[156] Another aspect of the present invention is to provide a QPC as defined above, especially adapted to determine air cavities in analyzed objects.

[157] Another aspect of the present invention is to provide a QPC as defined above, especially adapted to determine internal rotting of examined fruit.

[158] Another aspect of the present invention is to provide a QPC as defined above, especially adapted to analyze chemical content as sugar level, fruit's acidity, pH, any magnetic resonance spectroscopy detectable composition or any combination thereof.

[159] Another aspect of the present invention is to provide a QPC as defined above, especially adapted to measure the textures of the examined fruit and especially hardness or floury texture.

[1 A magnetic resonance device comprising: a means of producing a large uniform magnetic field around a sample, such as a large permanent magnet and shimming mechanism selected from active or passive shimming elements, a means of producing a magnetic field gradient around the sample; and a magnetic resonance sensing probe comprising an inductance coil and capacitor connected to a radio antenna.

[1 The present invention discloses a method for performing magnetic resonance imaging over a large field of view and subsequently imaging over a portion thereof at higher resolution, *in situ* analyzing simultaneously a multiple adjacent lines of objects (3) by means of a portable QPC, performing measurements on a plurality of streams of samples and optionally feeding at least two adjacent feeding streams carrying a plurality of objects (3) to be detected or analyzed simultaneously or in any predetermined sequence.

[1 The present invention also discloses a cost effective method of analyzing a multiple lines of objects simultaneously. This method comprising *inter alia* the steps of obtaining at least one packed array of magnetic resonance devices of substantially no fringing magnetic fields; feeding said objects into said magnetic resonance devices, each line is directed towards a single device; analyzing said objects by said magnetic resonance devices; and then evacuating said objects from the magnetic resonance devices.

[1 This method is especially useful wherein it comprises the step or steps of feeding the objects into the magnetic resonance devices by means of a plurality of conveyor belts or the like, or by a means of plurality of tunnels, conduits or pipes. Hence, the feeding of analyzed objects is adapted for either solid and/or liquid matter or gas

[1 It is in the scope of the present invention wherein the feeding and/or analyzing steps are provided either continuously or batch wise. This method may additionally comprise passive and/or active shielding of the magnetic resonance's magnets by RF and/or magnetic shielding means. Moreover, the method may additionally comprise of the step or steps of time sharing of at least one of the group of gradient power supplement; RF transmitter and/or amplifier; RF receiver; digital signal processing means or any combination thereof.

[165] It is according to another embodiment of the current invention to teach a method of performing magnetic resonance imaging over a large field of view and subsequently imaging over a portion thereof at higher resolution. Said method comprises providing a closed magnetic circuit constructed from strong permanent magnets, a sample cavity and, where necessary to maintain a uniform magnetic field, a shimming mechanism and thereby a uniform magnetic field within the sample cavity into which a sample is introduced. A global

gradient coil and an array of local gradient coils are provided, a global magnetic field gradient is applied over the whole imaging volume and a strong magnetic field gradient is applied over a localized volume section. Said method provides images selected from low-resolution images over a large field of view, high-resolution images over a smaller field of view, or any combination thereof.

[1 It is according to another embodiment of the current invention to teach a method of performing magnetic resonance additionally providing overlapping local gradient coils such that each portion of the sample cavity is situated within the field of view of at least one local gradient coil.

[1 It is according to a further embodiment of the current invention to teach a method of performing magnetic resonance additionally providing tracks upon which at least one local gradient coil is manoeuvred such that its such that its field of view covers any portion of the sample cavity.

[1 It is according to yet another embodiment of the current invention to teach a method of performing magnetic resonance over a large sample extending over a plurality of local gradient coils, providing local gradient coils characterized by a fast slew rate such that a plurality of images are acquired sequentially from a plurality of local gradient coils.

[1 It is according to another embodiment of the current invention to teach a method of performing magnetic resonance providing a closed magnetic circuit characterized by two pole pieces and an array of side wall magnets, which lock the magnetic flux within the magnet structure and sample cavity.

[170] It is according to a further embodiment of the current invention to teach a method of performing magnetic resonance providing a global magnetic field gradient covering the whole volume of the sample cavity.

[171] It is according to a further embodiment of the current invention to teach a method of performing magnetic resonance providing an active shimming mechanism comprising tuneable shim coils, which can be tuned to create a uniform magnetic field over the field of view of at least one local gradient coil and thereby obtaining a high-resolution nuclear magnetic spectrum of a sample situated within this field of view.

[172] It is still according to another embodiment of the current invention to teach a method of performing magnetic resonance of a human head, additionally providing a cavity of

dimensions suitable for the accommodation of the shoulders and upper torso such that nerve stimulation is prevented outside the field of view of the local gradient coil.

[1 It is lastly according to another embodiment of the current invention to teach a method of performing magnetic resonance of a human head, additionally bending the array of sidewall magnets and thereby providing a uniform magnetic field within the volume adapted to accommodate the head and shoulders.

[1 It is according to another embodiment of the current invention to teach a method of performing magnetic resonance measurements on a plurality of streams of samples comprising providing a closed magnetic circuit constructed from strong permanent magnets, providing an optional shimming mechanism selected from an array of active shim coils, passive shimming elements or any combination thereof, providing a contained cavity within which the magnetic field strength is approximately uniform and introducing a plurality of samples into the region of uniform magnetic field, thereby providing magnetic resonance measurements on a plurality of samples within the region of uniform magnetic field.

[1 It is according to a further embodiment of the current invention to teach a method of performing magnetic resonance measurements on a plurality of streams of samples additionally comprising; conveying a plurality of sample streams into the region of uniform magnetic field, providing a means, such as a CPU, by which the gradient coils of each sample imaging unit are activated in rapid succession, providing a magnetic field gradient around each sample stream, transmitting a stimulating radiation and receiving response signals from the samples by means of a magnetic resonance measurement probe, thereby providing magnetic resonance measurements on a plurality of discrete samples within the region of uniform magnetic field.

[176] It is according to another embodiment of the current invention to teach a method of performing magnetic resonance measurements on a plurality of streams of samples by simultaneously conveying a plurality of samples into the region of uniform magnetic field along a plurality of parallel streams.

[177] It is according to a further embodiment of the current invention to teach a method of performing magnetic resonance measurements on a plurality of streams of samples by orientating the pole-pieces of the magnetic circuit horizontally to the sides of the contained cavity and thereby situating at least one conveyor belt outside the region of uniform magnetic field whilst conveying the sample into the region of uniform magnetic field.

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[17 It is according to another embodiment of the current invention to teach a method of performing magnetic resonance measurements on a plurality of streams of samples by orientating the pole-pieces of the magnetic circuit horizontally to the sides of the contained cavity and thereby situating at least one conveyor belt beneath the region of uniform magnetic field whilst conveying the sample into the region of uniform magnetic field.

[1 It is according to a further embodiment of the current invention to teach a method of performing magnetic resonance measurements on a plurality of streams of samples by orientating the pole-pieces of the magnetic circuit horizontally to the sides of the contained cavity and thereby situating at least one conveyor belt above the region of uniform magnetic field whilst conveying the sample into the region of uniform magnetic field.

[1 It is according to another embodiment of the current invention to teach a method of performing magnetic resonance measurements on a plurality of streams of samples additionally comprising; providing a plurality of fluid carrying pipes within the region of uniform magnetic field, providing a gradient coil around each of said pipes, flowing a plurality of sample streams through said pipes within the region of uniform magnetic field, providing a means, such as a CPU, by which the gradient coils around each pipe are activated in rapid succession, providing a magnetic field gradient around each sample stream, transmitting a stimulating radiation and receiving response signals from the samples by means a magnetic resonance measurement probe, thereby providing magnetic resonance measurements on a plurality of discrete fluid samples within the region of uniform magnetic field.

[181] It is still according to another embodiment of the current invention to teach a method of performing magnetic resonance measurements on two streams of fluid samples simultaneously by orientating at least two fluid imaging units orthogonally such that the magnetic fields produced by the activated gradient coils do not interfere with each other.

[182] It is lastly according to another embodiment of the current invention to teach a method of performing magnetic resonance measurements on two streams of fluid samples almost simultaneously by orientating at least two fluid imaging units near orthogonally and activating their gradient coils successively with a short switching time between them.

[183] The present invention also discloses a cost effective method of analyzing simultaneously a multiple adjacent lines of objects *in situ* by means of a portable QPC. This method comprising *inter alia* the steps of obtaining at least one packed array of magnetic resonance

devices of substantially no fringing magnetic fields; positioning at least one magnetic resonance device adjacent to the object to be analyzed; inserting at least an effective portion of said object inside said magnetic resonance device; and analyzing said objects by said magnetic resonance devices and after a short term, evacuating the same and moving toward another object, in order to analyze it.

[1 This method is especially useful wherein it comprises the step or steps of feeding the objects into the magnetic resonance devices by means of a plurality of conveyor belts or the like, or by a means of plurality of tunnels, conduits or pipes. Hence, the feeding of analyzed objects is adapted for either solid and/or liquid matter or gas

[1 It is in the scope of the present invention wherein the feeding and/or analyzing steps are provided either continuously or batch wise. This method may additionally comprise passive and/or active shielding of the magnetic resonance magnets by RF and/or magnetic shielding means. Moreover, the method may additionally comprise of the step or steps of time sharing of at least one of the group of gradient power supplement; RF transmitter and/or amplifier; RF receiver; digital signal processing means or any combination thereof.

[1 The present invention also discloses a method of analyzing objects *in situ* by means of a portable QPC. The method comprises the following steps of positioning at least one magnetic resonance device adjacent to the object to be analyzed; inserting at least an effective portion of said object inside said magnetic resonance device; analyzing the same; and after a short term, evacuating the same and moving toward another object, in order to analyze it.

[1 Another object of the present invention is to provide a cost effective and easy to operate method of analyzing objects *in situ* by means of a portable QPC. This method comprising step or a plurality of steps selected from positioning at least one magnetic resonance device adjacent to the object to be analyzed; inserting at least an effective portion of said object inside said magnetic resonance device; and analyzing the same.

[188] Another aspect of the present invention is to provide the method as defined above, comprising positioning of at least one magnetic resonance packed array comprises a plurality of magnetic resonance devices being arranged in either 2D or 3D array adjacent to the object to be analyzed wherein said magnetic resonance device is obtaining a platform which is a mobile base of a plurality of adjustable and maneuverable articulated arms (5) each of which carries at least one magnetic resonance device.

[1 Another aspect of the present invention is to provide the method as defined above, comprising activating the controller automatically.

[1 Another aspect of the present invention is to provide the method as defined above, wherein the analyzed objects are vertebrate or invertebrate.

[1 Another aspect of the present invention is to provide the method as defined above, wherein the analyzed objects are human, mammal, birds, fish, insect or reptile patients adapted for medical or veterinary uses.

[1 Another aspect of the present invention is to provide the method as defined above, wherein the analyzed objects are selected from agricultural raw materials or products thereof.

[1 Another aspect of the present invention is to provide the method as defined above, wherein the analyzed objects are layered, conglomerated, coated, enveloped, continuous or discrete members.

[1 Another aspect of the present invention is to provide the method as defined above, comprising step or a plurality of steps for analyzing objects that are vegetables or fruits.

[1 Another aspect of the present invention is to provide the method as defined above; said method is especially useful for sorting fruits and other agricultural products and raw materials, and especially for sorting fruits before or after fruit picking.

[1 Another aspect of the present invention is to provide the method as defined above; said method comprising analyzing fruits that are selected from the citrus family, kiwi, pomegranate, apple, melon, drupes, banana, avocado pineapple, mango, tomato, pistachio, persimmon, almond, grapes, blueberries.

[197] Another aspect of the present invention is to provide the method as defined above; said method is especially useful for inspecting presence of seeds, their number and their size.

[198] Another aspect of the present invention is to provide the method as defined above; said method is especially useful for identifying the presence of insects or pathogens and for eradicating the same by activating an effective measure of high frequency radiation.

[199] Another aspect of the present invention is to provide a feed-backed method as defined above; said method is especially useful for identifying the presence of insects or other pathogens, comprising a step or a plurality of steps of activating disinfecting means for eradicate the same.

[200] Another aspect of the present invention is to provide the method as defined above; said method comprising locating parameters inside the fruit, especially wherein said parameters are selected from a hollow core, length, width or volume or any combination thereof.

[201] Another aspect of the present invention is to provide the method as defined above which is useful for comprising defining a ripe level.

[202] Another aspect of the present invention is to provide the method as defined above comprising scanning mold or freeze damages.

[203] Another aspect of the present invention is to provide the method as defined above comprising determining dryness.

[204] Another aspect of the present invention is to provide the method as defined above comprising evaluating water level, water activity, oil level or total liquid in the fruit.

[205] Another aspect of the present invention is to provide the method as defined above comprising determining number of sections present in the fruit.

[206] Another aspect of the present invention is to provide the method as defined above comprising determining the deformation or the bruises of the fruit.

[207] Another aspect of the present invention is to provide the method as defined above comprising determining internal or external insects' damage.

[208] Another aspect of the present invention is to provide the method as defined above comprising determining peel thickness or separation from the fruit section.

[209] Another aspect of the present invention is to provide the method as defined above comprising determining air cavities in analyzed objects.

[210] Another aspect of the present invention is to provide the method as defined above comprising determining internal rotting of fruit.

[211] Another aspect of the present invention is to provide the method as defined above comprising evaluating chemical content selected from sugar level, fruit's acidity, pH, any magnetic resonance spectroscopy detectable composition or any combination thereof.

[212] Another aspect of the present invention is to provide the method as defined above comprising measuring the textures of the fruit, especially its hardness or its floury texture.

[213] Another aspect of the present invention is to provide the method as defined above comprising inspecting presence of roe in fish and marine invertebrates

Another aspect of the present invention is to provide the method as defined above comprising evaluating quantity of injected water in meat.

Still another aspect of the present invention is to provide the method as defined above comprising determining infection, rotting or presence of free radicals in analyzed objects.

A last aspect of the present invention is to provide the method as defined above comprising determining freezing level of examined product.

CLAIMS

1. An industrial quality and process control (QPC) system adapted to analyze adjacent lines of goods (3) said QPC comprising at least one packed array of MRI/NMR devices, said packed array comprising a plurality of i adjacently positioned MRI/NMR devices installed side by side with virtually zero gap between the magnets; said array characterized by dimensions of x, y, and z, where i is an integer not less than 2, and x, y, and z are integers not less than 0; wherein each of said MRI/NMR devices provides magnetic shielding from the other MRI/NMR devices and wherein each MRI/NMR device comprises a magnet, a gradient coil, and an RF coil such that said QPC system comprises in total not less than i independent magnets, i independent gradient coils, and i independent RF coils; further wherein the analysis of said lines of goods is performed simultaneously and independently by each of said MRI/NMR devices.

2. The QPC system according to claim 1, wherein the shape of the stack is polygonal, circular or any combination thereof.

3. The QPC system according to claim 1, additionally comprising computerized means (10A) adapted for time sharing of at least one of the group of means consisting of gradient power supplying means (10B); RF transmitting and/or amplifying means (10C); RF receiving means (10D); digital signal processing means (10E); and any combination thereof.

4. The QPC system according to claim 1, wherein at least a portion of the goods are fed into the MRI/NMR devices by means of a conveyor belt.

5. The QPC according to claim 1, wherein the analyzed goods (3) are selected from the group consisting of agricultural products, cosmetics, chemicals, powders, enveloped items, medicaments, industrial goods, metalware, and any other continuous or discrete members.

6. A method for analyzing a multiple adjacent lines of objects (3) simultaneously, , comprising steps of:
   a. obtaining at least one QPC according to claim 1;
   b. feeding said goods (3) into said MRI/NMR, each line is directed towards a single device;

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c. analyzing said goods (3) by said MRI/NMR; and,

d. evacuating said goods (3) from the MRI/NMR.

7. The QPC system according to claim 1, wherein at least a portion of the goods are fed into the MRI/NMR devices by means of tunnels, conduits, or pipes.

8. The QPC system according to claim 1, wherein said QPC system is operated either continuously or batchwise.

9. The QPC system according to claim 1, wherein the magnets of the MRI/NMR devices are passively shielded by RF and/or magnetic shielding.

10. The QPC system according to claim 1, wherein the magnets of the MRI/NMR devices are actively shielded by RF and/or magnetic shielding.

11. The QPC system according to claim 1, wherein the analyzed goods are chosen from the group consisting of solid matter and liquid matter.

12. The method according to claim 11, further comprising an additional step of feeding said goods into said MRI/NMR devices by means of a plurality of conveyor belts.

13. The method according to claim 11, further comprising an additional step of feeding said goods into said MRI/NMR devices by means of a plurality of tunnels, conduits, or pipes.

14. The method according to claim 11, wherein at least one of said steps of feeding and analyzing is performed in a manner chosen from the group consisting of continuously and batchwise.

15. The method according to claim 11, additionally comprising a step of passively shielding the magnets of said MRI/NMR devices by RF and/or magnetic shielding means.

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16. The method according to claim 11, additionally comprising a step of actively shielding the magnets of said MRI/ NMR devices by RF and/or magnetic shielding means.

17. The method according to claim 11, additionally comprising a step of time sharing of at least one of the group of means consisting of gradient power supplying means; RF transmitting and/or amplifying means; RF receiving means; digital signal processing means; and any combination thereof.

18. The QPC system according to claim 1, additionally comprising feeding means adapted for feeding goods in a form chosen from the group consisting of solid, liquid, gaseous, and any combination thereof.

19. The QPC system according to claim 1, adapted for sorting avian eggs, wherein said sorting comprises sorting said eggs according to at least one criterion chosen from the group consisting of (a) the gender of the embryo within said eggs; (b) fertility of said eggs; and (c) size of said eggs and especially sorting the gender of embryo; selectively eliminating fertilized eggs from product line; or evacuating eggs characterized with improper size or physiological condition or any combination thereof.

20. The QPC system according to claim 1, wherein said goods are chosen from the group consisting of fruits, nonfruit agricultural products, and agricultural raw materials, and further wherein said analysis is chosen from the group consisting of (a) determining the presence of seeds; (b) locating a hollow core within a piece of fruit; (c) determining whether or not said goods are overripe; (d) analyzing for mold damage; (e) analyzing for damage due to freezing; (f) determining the sugar level; (g) determining the water level; (h) determining the acidity; and (i) any combination thereof.

21. An industrial quality and process control (QPC) system adapted to analyze adjacent lines of goods, said QPC comprising a plurality of i MRI/NMR devices installed side by side with virtually zero gap between the magnets; wherein each of said MRI/NMR devices provides magnetic shielding from the other MRI/NMR devices; and wherein each MRI/ NMR device includes a magnet, a gradient coil and an RF coil such that said QPC system includes no less than i independent magnets, i independent gradient coils, and i independent RP coils; and further wherein each MRI/NMR device receives goods

from at least one of said adjacent lines of goods and is adapted to analyze said goods and outputs of said goods wherein said analysis is performed independently of the other MRI/NMR devices.

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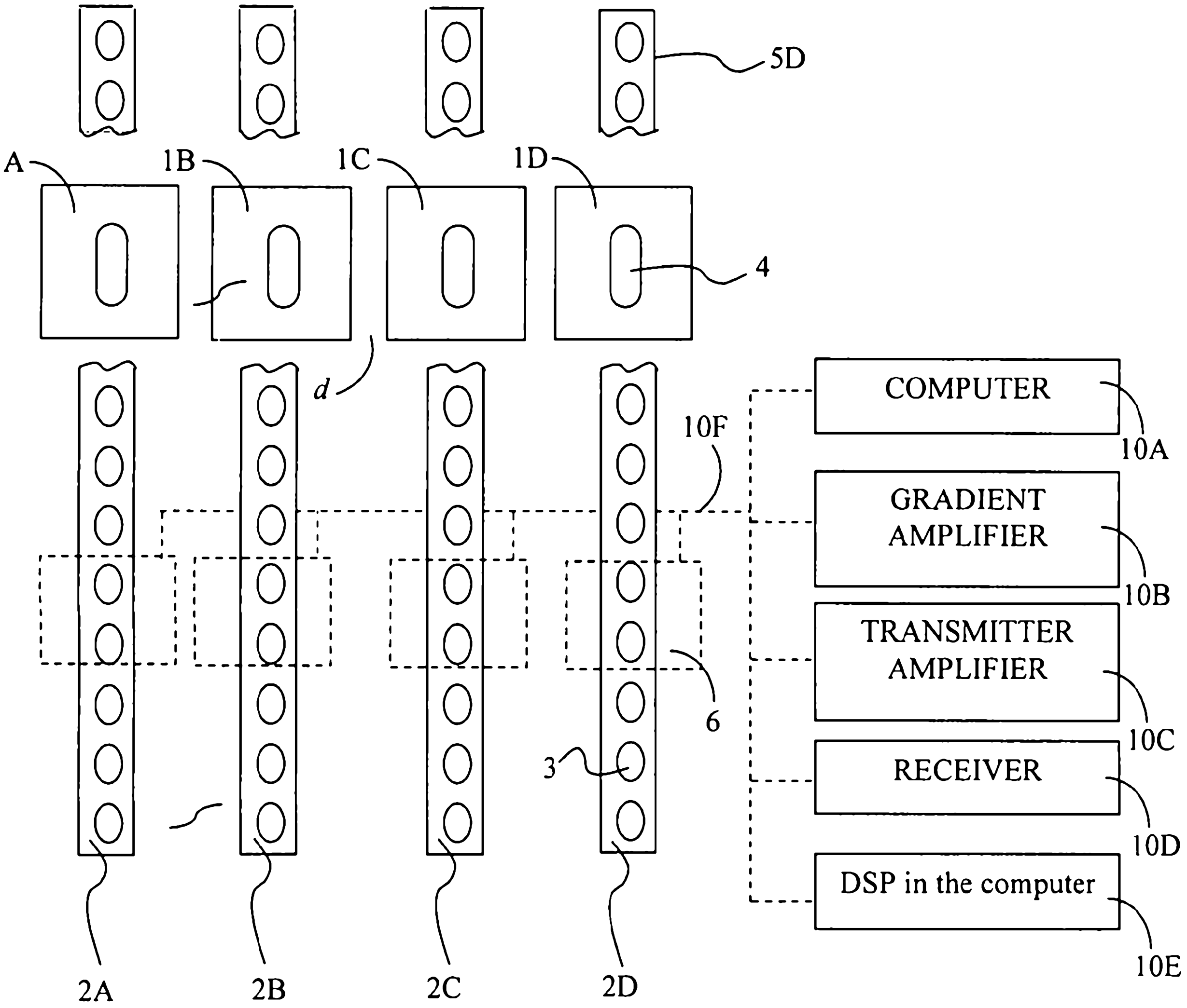

Fig. 1

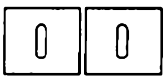

Fig. 2A

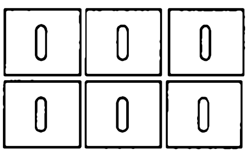

Fig. 2B

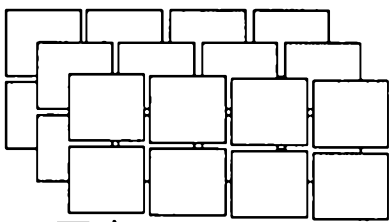

Fig. 2C

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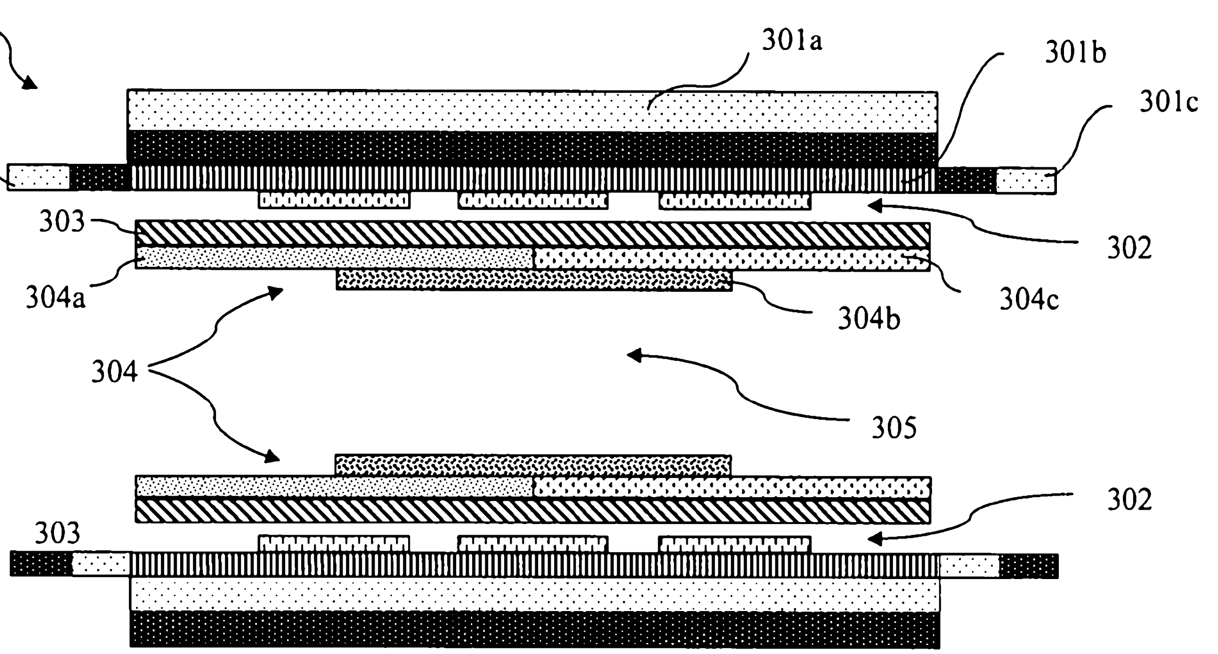

Fig. 3a

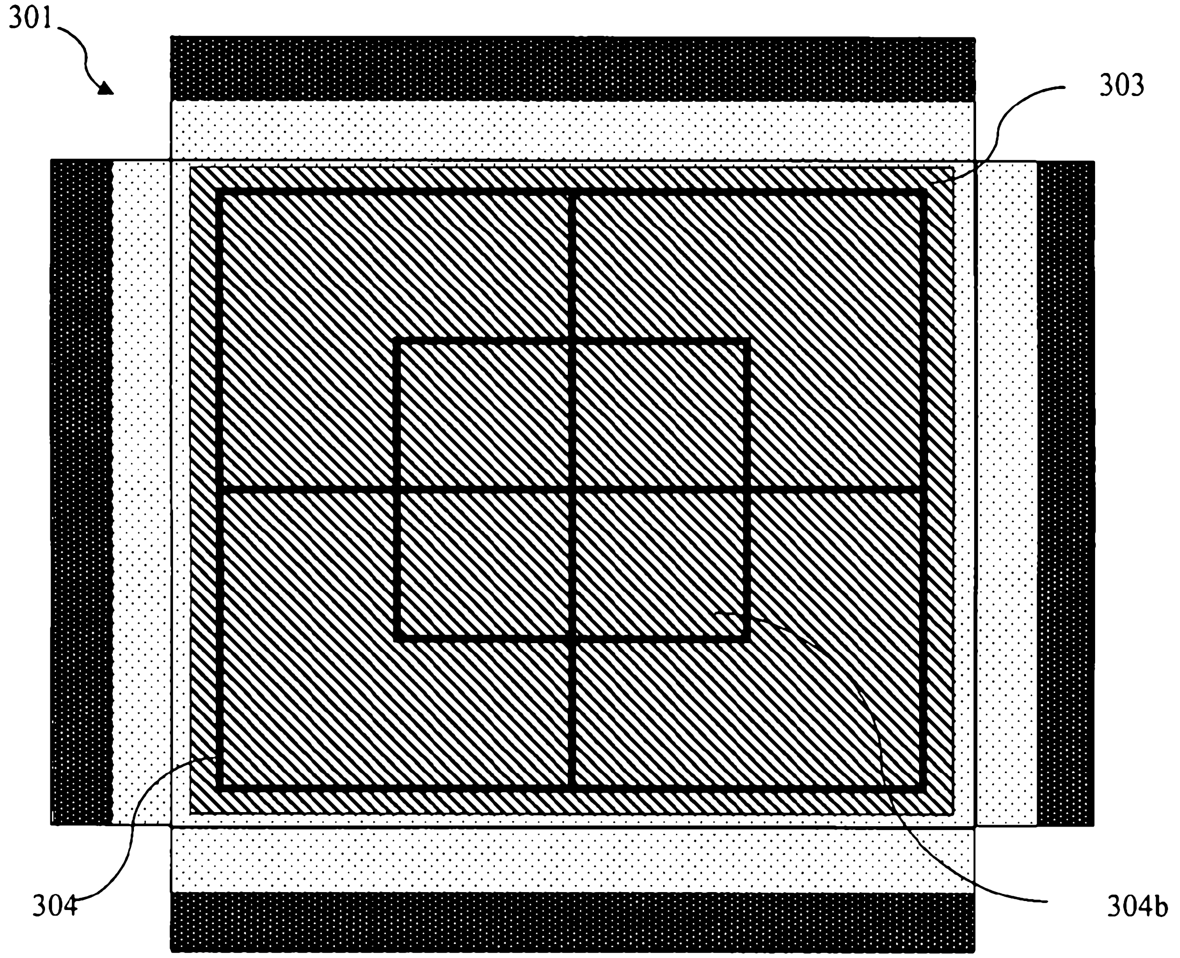

Fig. 3b

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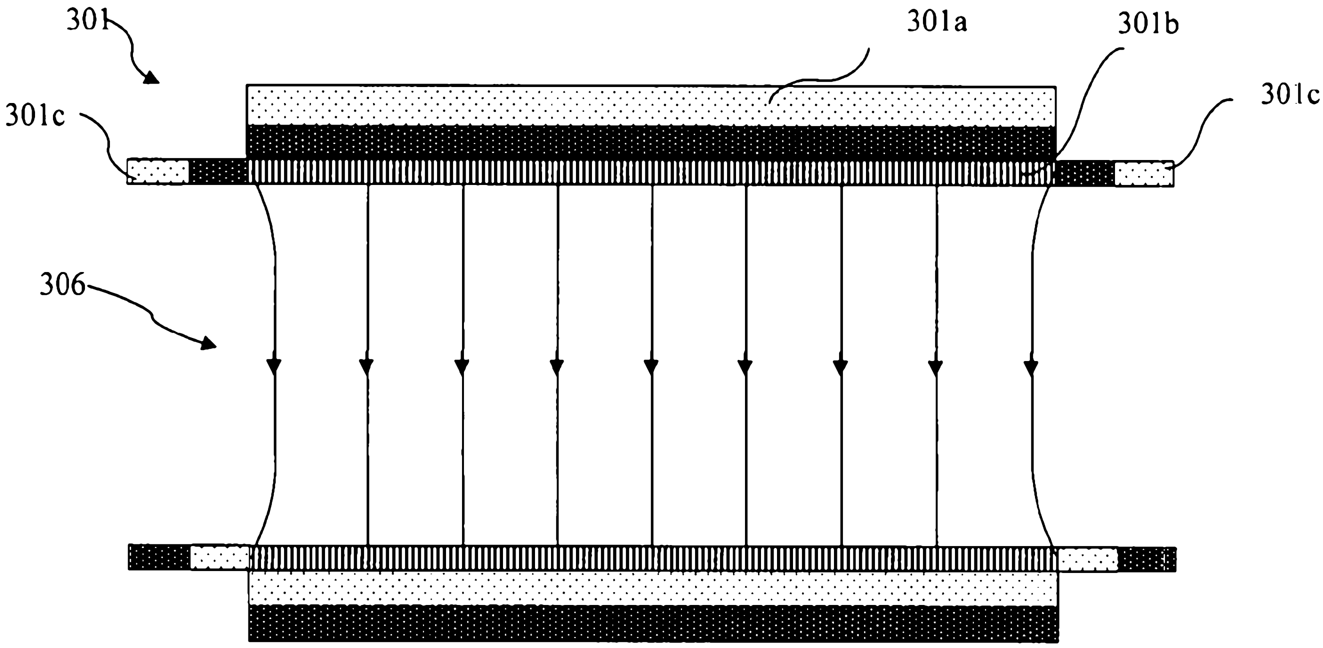


Fig. 4a

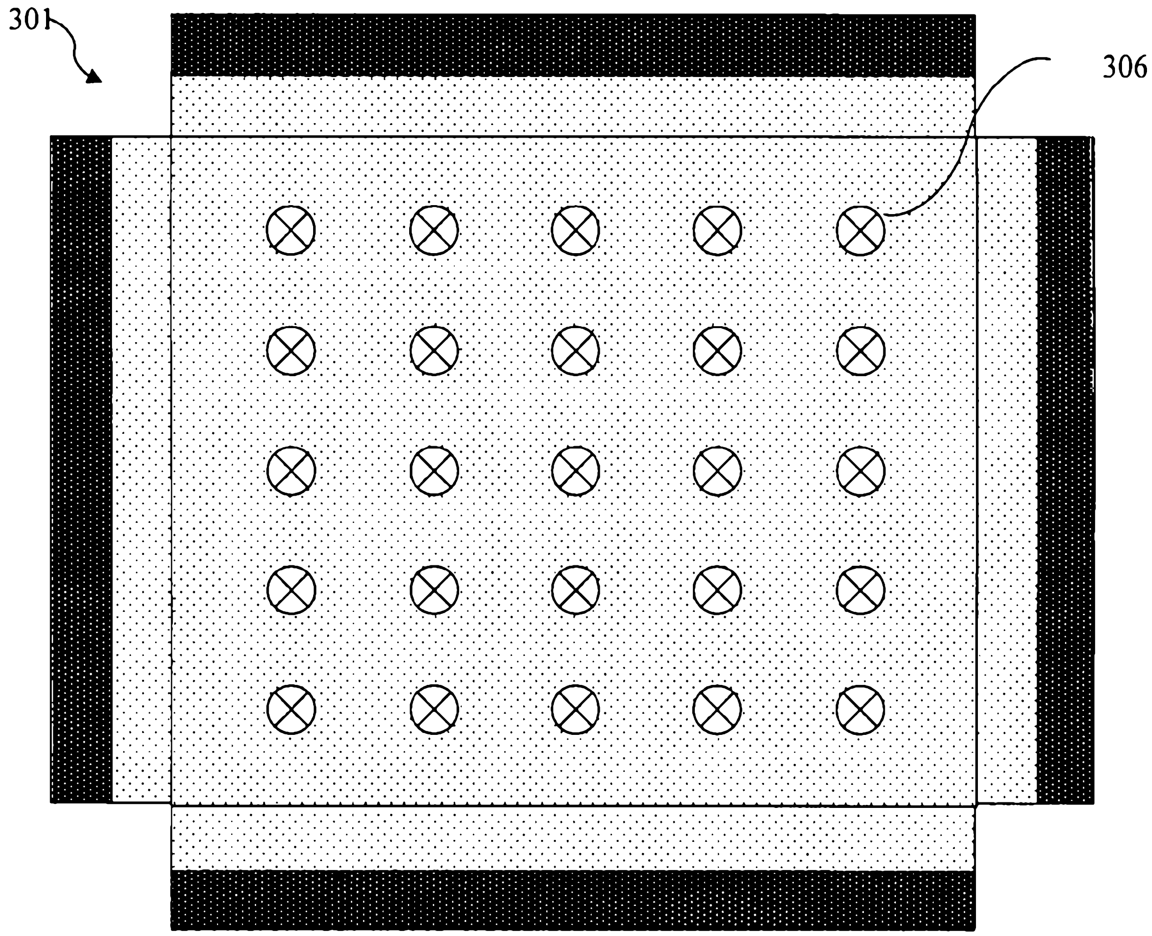
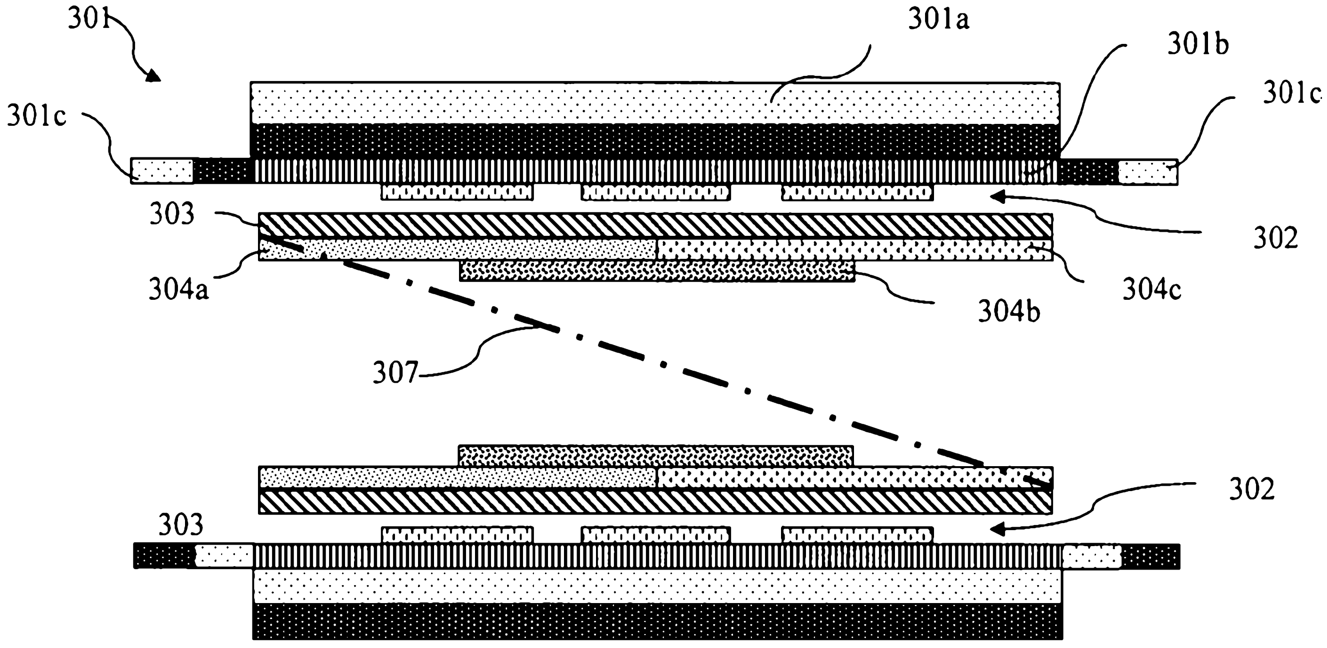


Fig. 4b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307
302
303

Fig. 5

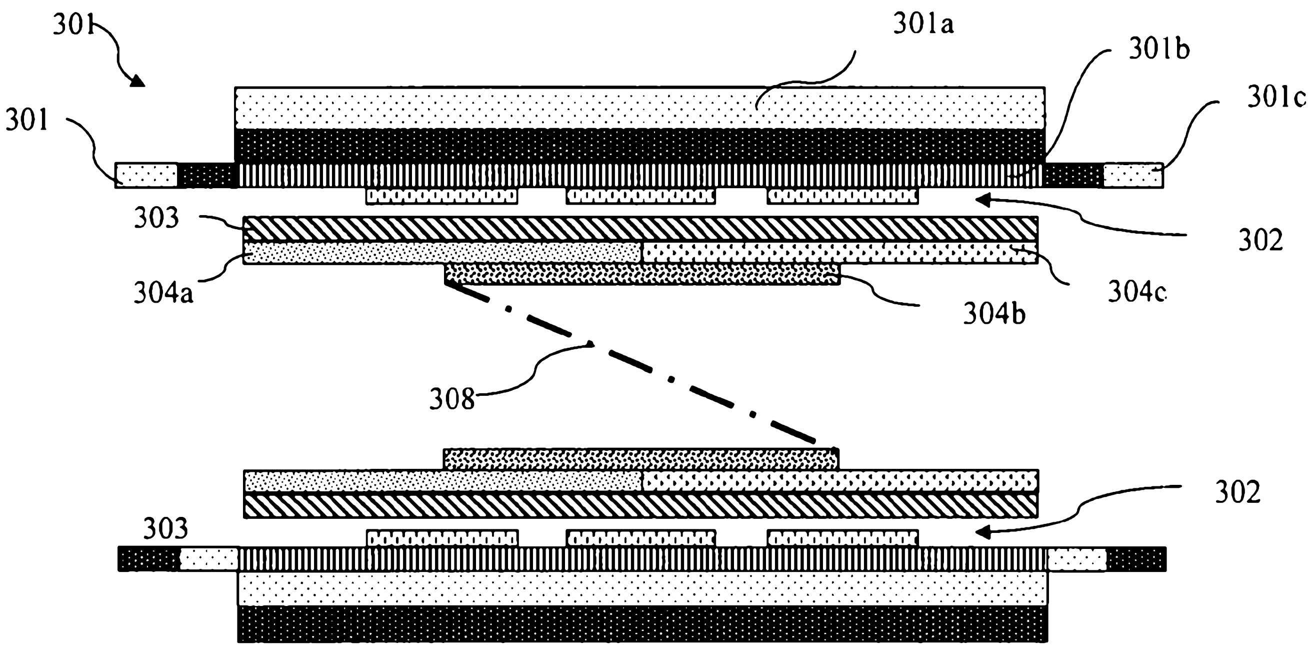
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Fig. 6

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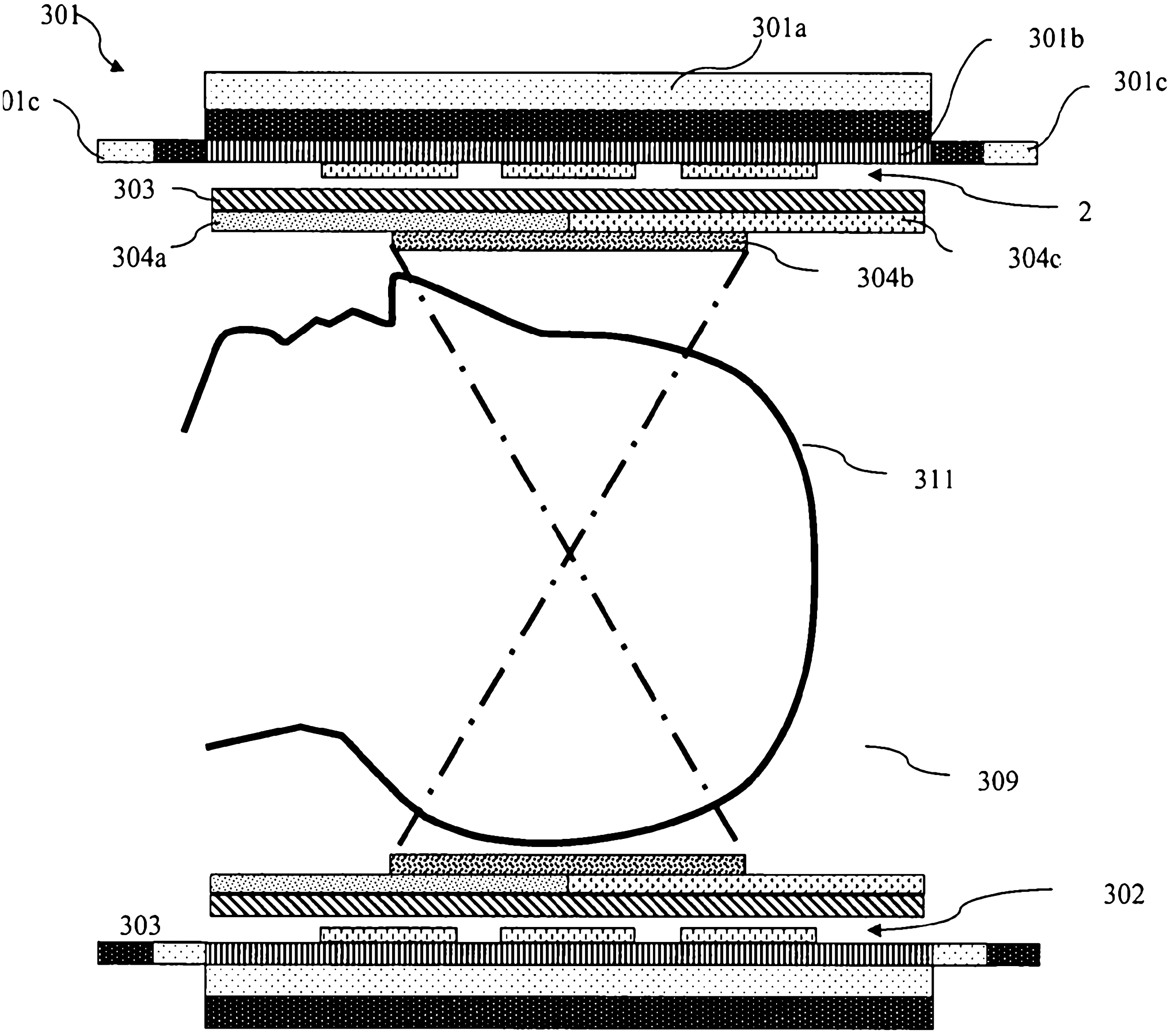

Fig. 7

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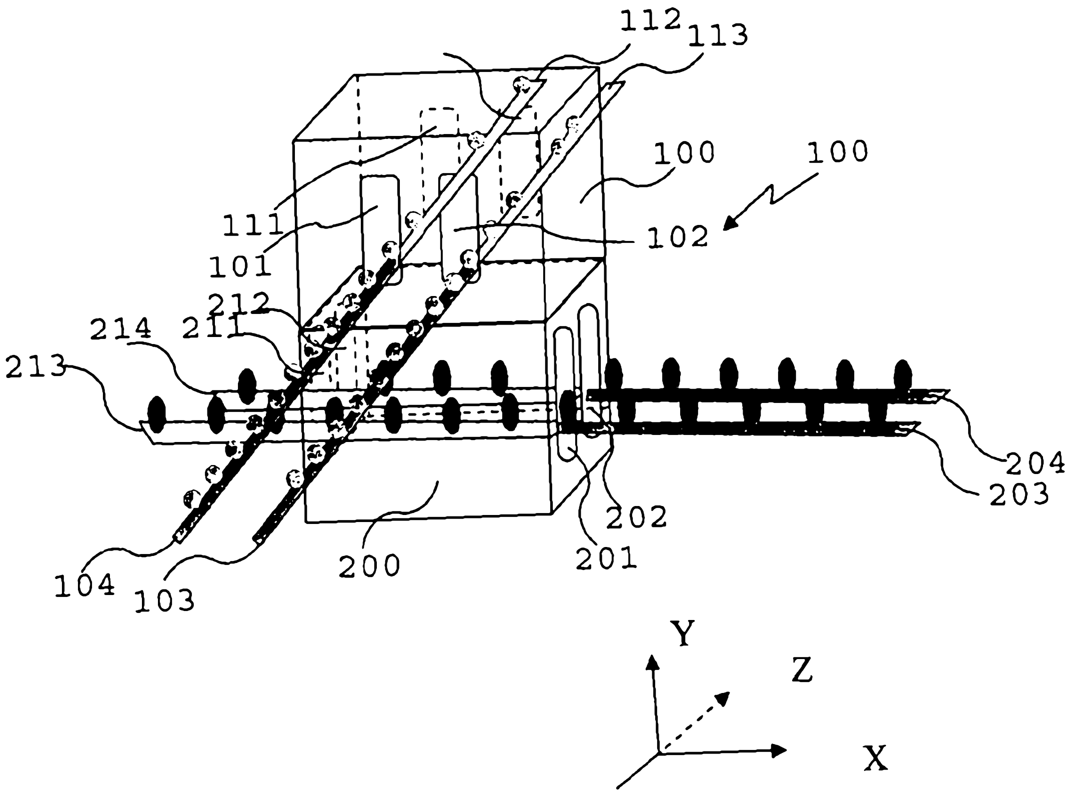

Fig. 8

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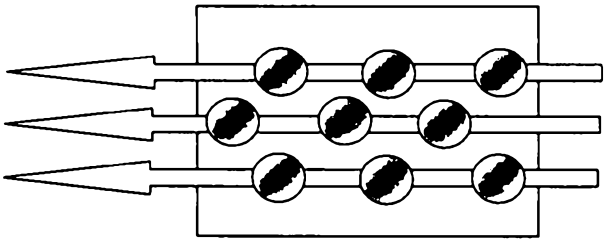

Fig. 9B

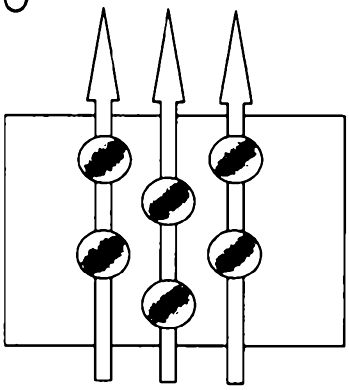

Fig. 9A

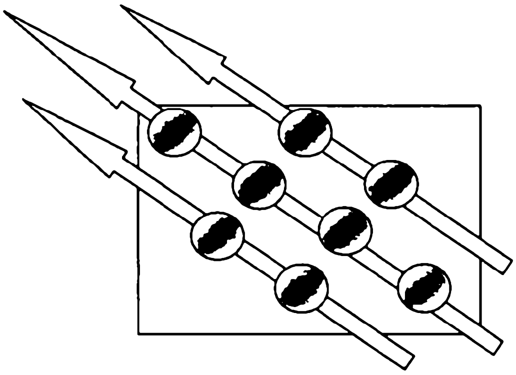

Fig. 9C

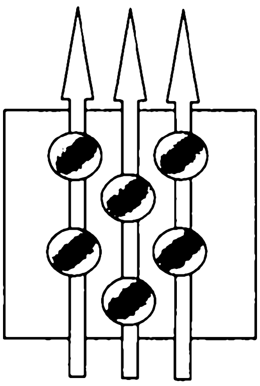

Fig. 9E

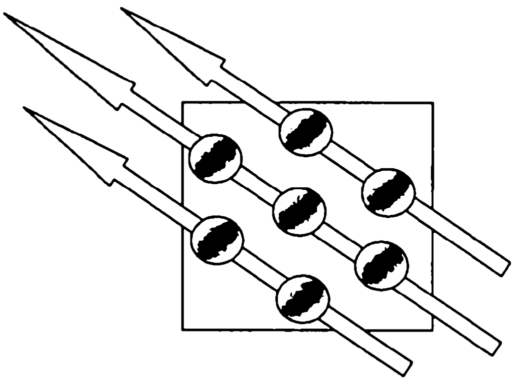

Fig. 9D

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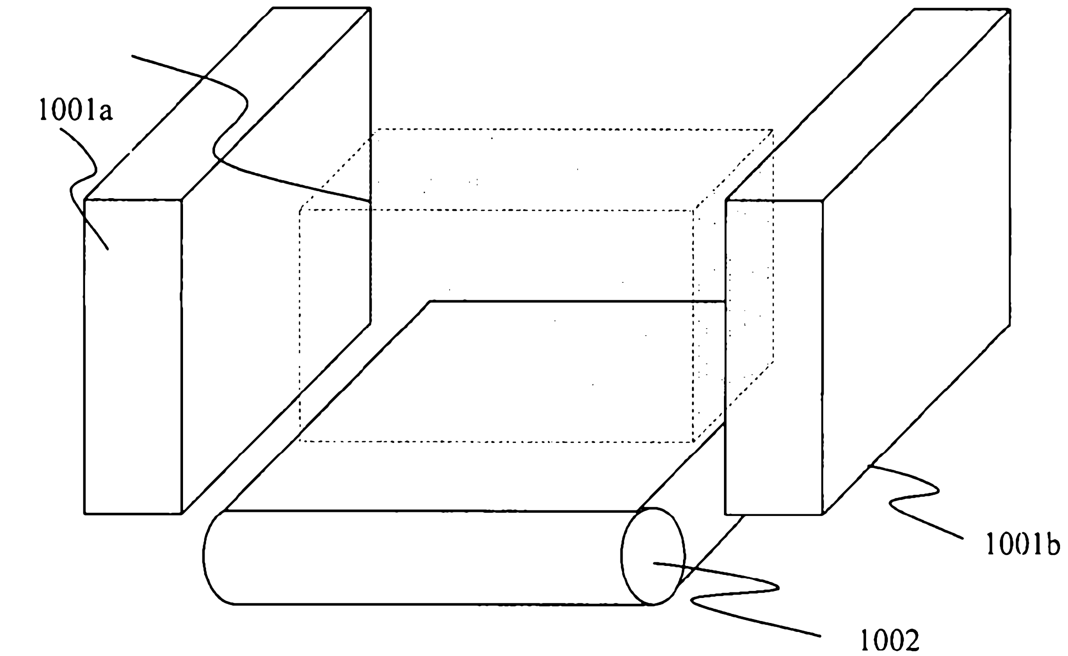

Fig. 10

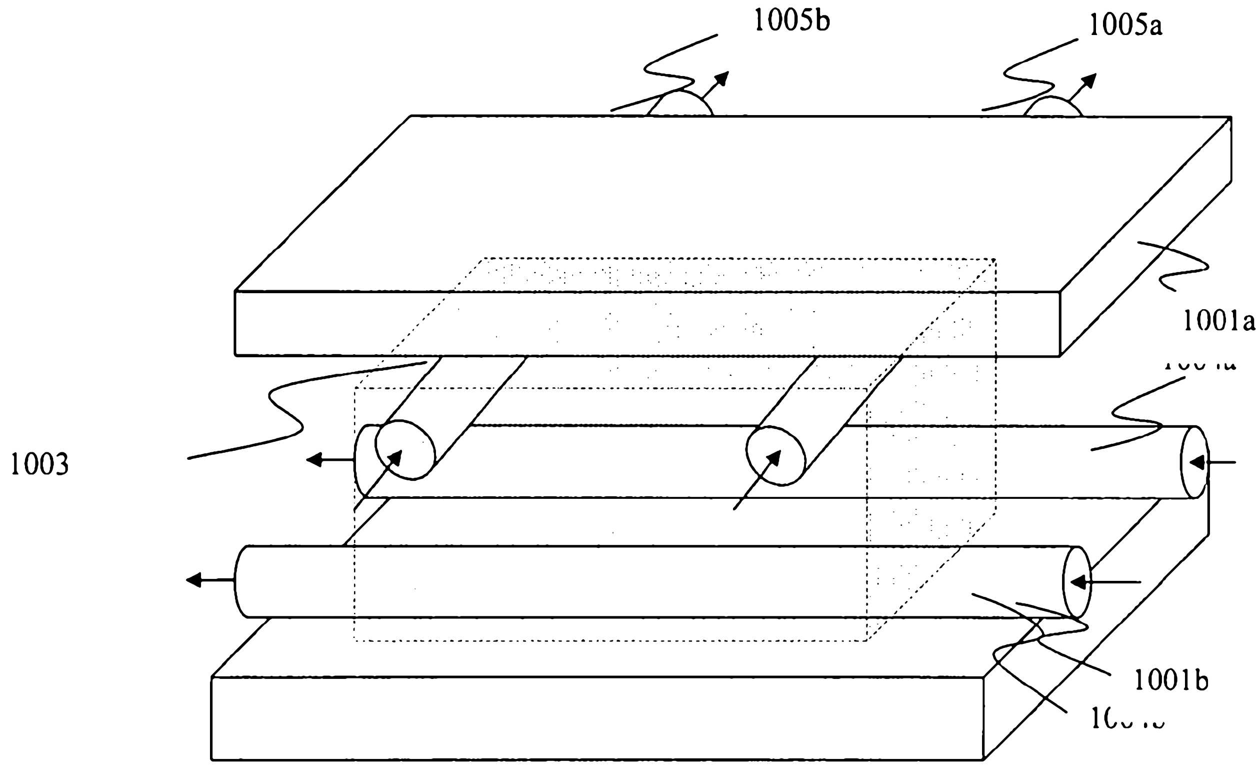

Fig. 11

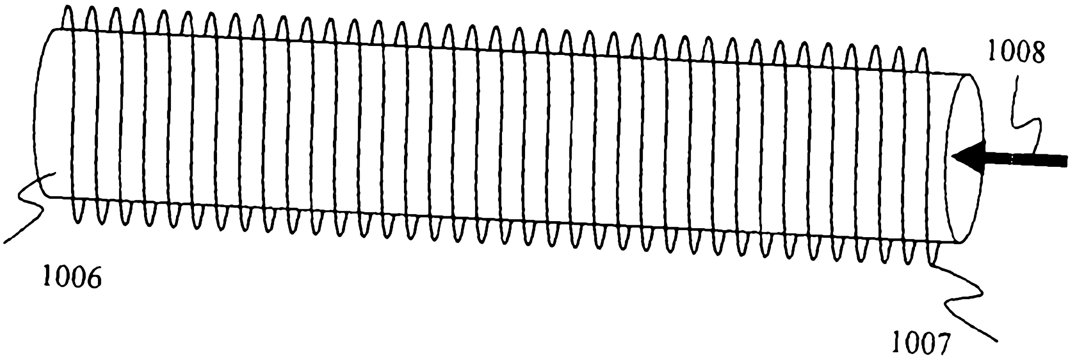

Fig. 12

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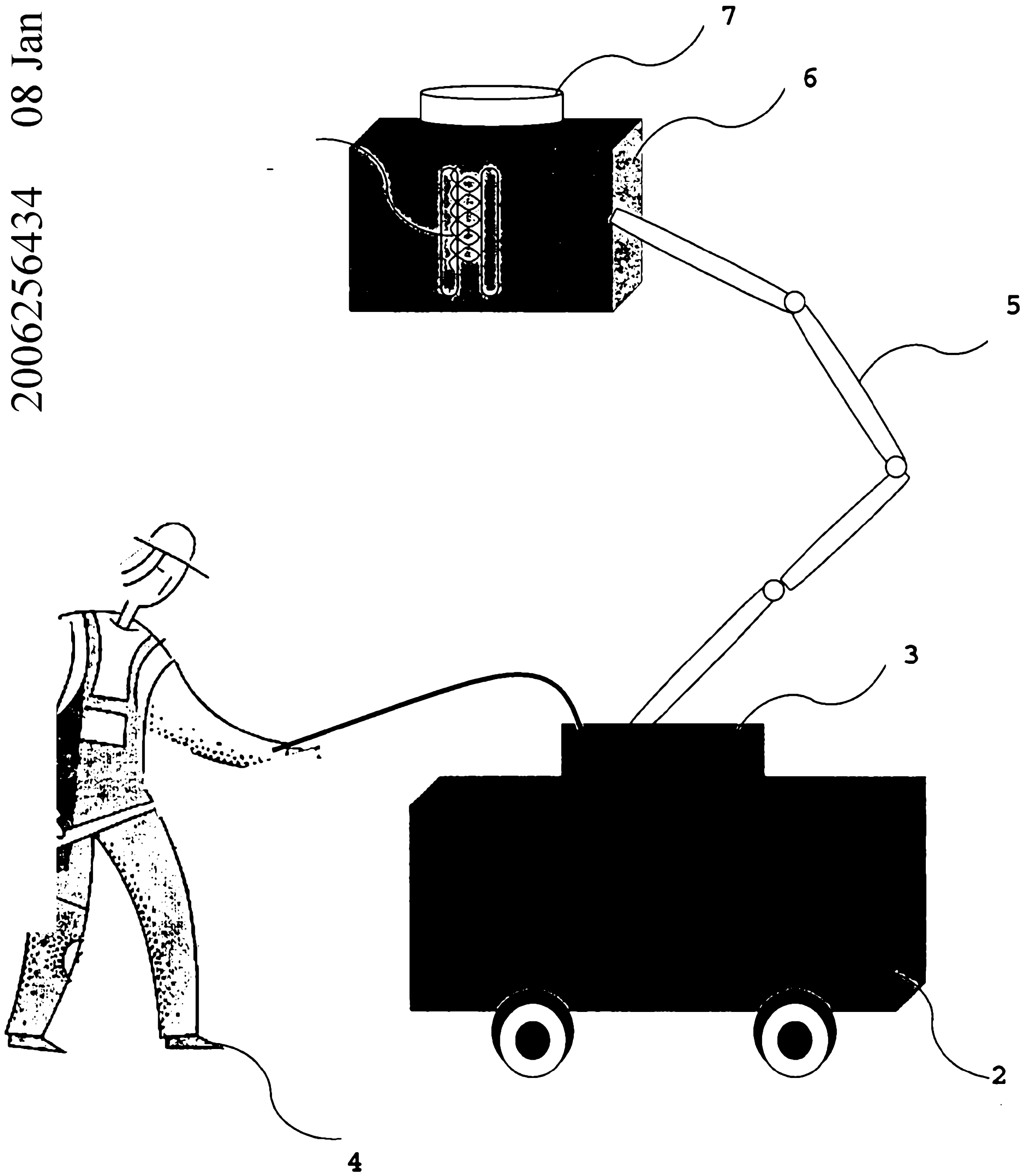

Fig. 13