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(54) **Title:** METHOD AND APPARATUS FOR INK JET PRINTING

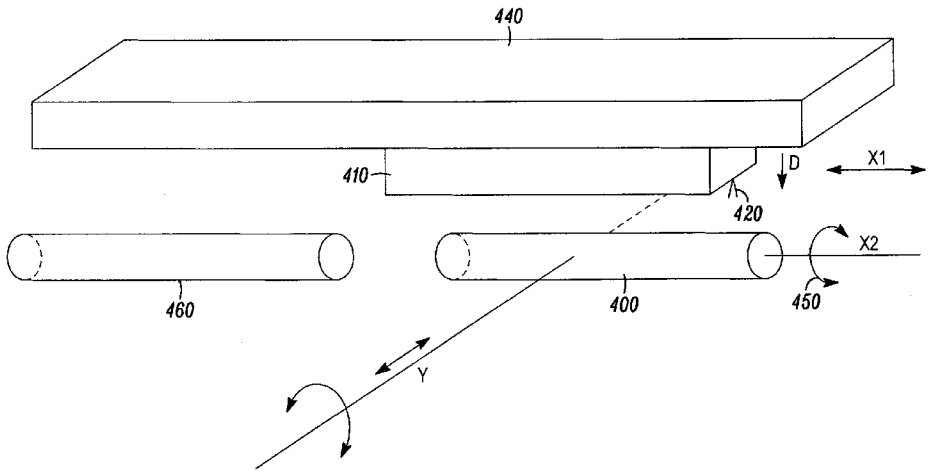


FIG. 4

(57) **Abstract:** Apparatus and methods are provided for ink jet printing onto three dimensional objects. An ink jet printing head (410, 910) is adapted to release jets of ink (420) in a first direction D. Means (440) are provided for translating the ink jet printing head along a first axis X1, first axis X1 being perpendicular to the first direction D. Means (1010, 1030) are provided for rotating a three dimensional object (400, 900) about a second axis X2, second axis X2 being parallel to first axis X1. A method of ink jet printing comprises translating the ink jet printing head along first axis X1, releasing jets of ink (520, 920) in first direction D, and rotating the three dimensional object about the second axis X2. The invention solves problems associated with printing images onto three dimensional objects accurately, repeatably and/or rapidly.

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Method and Apparatus for Ink Jet Printing

Field of the Invention

The invention relates to the field of ink jet printing. The invention is applicable to printing on three dimensional objects, such as cylindrical or spherical objects.

Background of Invention

It is known for manufacturers to:

(i) Stick images onto objects, for example with adhesive. This known technique relies on creating a physical copy of the image, e.g. on a plastic foil.

(ii) Print images onto cylindrical or spherical objects. The copy of the image may first be made on a mesh, which is then used as a mask. Ink or paint is forced through the mesh onto the object. For an image that comprises more than one colour, each colour must be applied using a different mask, in a separate printing step.

In these prior art methods, inaccuracy is introduced by the process of copying an image. If a foil is created, then a durable bond must be created between the foil and the object. If a mask is used, then there is the difficulty of aligning different masks accurately for the different colours. Each ink may need to be prepared separately, by mixing various ingredients. A variety of chemicals must be used in the processes that are used to create masks. These chemicals need to be stored, and disposed of, appropriately. The electromechanical nature of the printing process provides an upper limit to the rate of throughput of objects that are being subjected to the mask printing process. The object must be moved towards and away from the mask in order for the printing step to take place, and this

movement can only be achieved with finite acceleration and deceleration.

Finally, problems can arise due to the shape of the object onto which an image is to be printed. Images can sometimes only be printed onto some parts of objects. If the cylindrical object is, for example, a pen, then it is likely to have a clip for attachment to clothing. The clip makes access to part of the pen impossible, for some prior art methods. Although pens are generally cylindrical in shape, they may also show a significant taper along their length, which may also present problems for accurate reproduction of the image.

Tapered objects also present problems for prior art techniques that rely on sticking a copy of the image, e.g. a foil, onto the object. A two dimensional foil will not wrap easily around a tapered object.

If the cylindrical or spherical object has texture, such as the dimples on a golf ball, this will present further problems for some prior art approaches.

Ink jet printing is a technique that is conventionally used to print large, flat images, usually on paper. Examples of images that can be created by ink jet printing are large colour posters and advertising images, e.g. of A4 page size or larger. These techniques involve holding the paper, onto which the ink jet printer is to print, under the ink jet printing head.

The inventors have seen writing on electrical cable that appears to have been produced by ink jet printing. However, the inventors are not aware of any details of how such ink

jet printing has been implemented. It might, for example, have been achieved by printing using a conventional ink jet printer whilst the cable insulation was still flat, and then forming the insulation into a cylinder. The ink jet printing might have been implemented on a layer of material that was then wrapped around the cable insulation. Alternatively, the cable might have been compressed during the printing process, in order to present a quasi-flat surface.

The inventors are aware of an oral disclosure, i.e. industry rumours, that at least one major manufacturer has attempted to devise a way of ink jet printing onto cylindrical objects, but that this attempt was unsuccessful. The inventors are therefore unaware of any enabling disclosure, which would permit ink jet printing on 3-dimensional objects, such as cylindrical or spherical objects.

Summary of Invention

In accordance with a first aspect of the invention, there is provided an ink jet printer in accordance with claim 1.
In accordance with a second aspect of the invention, there is provided a method of ink jet printing in accordance with claim 10.
In accordance with a third aspect of the invention, there is provided a three dimensional object in accordance with claim 19.
Further aspects of the invention relate to a use of an ink jet printer in accordance with claim 20.

The appended dependent claims provide details of further features of embodiments of the invention.

Embodiments of the invention involve ink jet printing onto three dimensional objects, for example generally cylindrical or spherical objects. However, in the context of embodiments of the invention, it is envisaged that these terms should be interpreted broadly. The term 'three dimensional object', in the context of the description and claims is meant to encompass a wide variety of non-planar objects, with varying structure, dimensions and surface texture. For example, it is within the contemplation of the invention that the ink jet printer may print onto objects with surface texture, such as dimples or concave regions. The term cylindrical may also include geometrical shapes that are generally cylindrical, such as 'cigar shaped' objects, and objects of circular cross section that taper in one direction. The term spherical may also encompass broadly spherical objects with non-uniform radius of curvature, e.g. ovoid objects, and objects with areas of spherical cross-section, such as the top of a conical section of a sphere. It is also envisaged that both cylindrical and spherical objects may have irregularities, such as steps in their surface or regions that are raised or lowered with respect to the radius of curvature of the remainder of the object.

Embodiments of the invention may provide numerous advantages over the known prior art. Embodiments of the invention may avoid the difficulties associated with creating masks or foils. In particular, embodiments of the invention may avoid the need for various chemicals that are used to create printing masks.

In comparison with prior art arrangements, embodiments of the invention may allow one or more of the following:
(i) More accurate printing;

(ii) Printing on parts of cylindrical and spherical objects that could not be reached by prior art arrangements;
(iii) A greater rate of throughput of objects;
(iv) A reduced set-up time.

Brief Description of the Drawings

Figure 1 shows a prior art apparatus for contact printing onto cylindrical objects.
Figure 2 shows a flowchart for a prior art method of contact printing onto cylindrical objects.
Figure 3 shows the general geometrical arrangement of the ink jet printer according to some embodiments of the invention, using the example of an object of cylindrical or spherical shape.
Figure 4 shows an embodiment of an ink jet printer in accordance with the invention.
Figure 5 shows an example of an ink jet printing head in accordance with embodiments of the invention.
Figures 6, 7 and 8 illustrate three possible configurations of single printing heads that can release several ink colours.
Figure 9 shows a further embodiment of the ink jet printer for printing on a three dimensional object.
Figure 10 shows a frame for mounting and rotating three dimensional objects.

Description of Embodiments of the Invention

Figure 1 shows a prior art apparatus for contact printing onto cylindrical objects. Cylindrical objects 100, 102 and 104 are propelled in the direction shown by arrow A.

Actuator arms 106 and 108 lift each cylindrical object upwards, in turn, as the cylindrical object reaches the location at which an image is to be printed. Cylindrical

object 110 is shown in the raised position, supported by actuator arms 106 and 108.

Vessel 118 contains liquid ink 114. Above vessel 118 is a wiper 116. When cylindrical object 110 is in the correct location for printing, wiper 116 wipes across the inside lower surface of vessel 118. This wiping action presses ink through the base of vessel 118.

The central portion 120 of the base of vessel 118 comprises a mesh mask, which allows ink to pass through at the correct locations for reproduction of the image on the surface of cylindrical object 110. At this point in time, central portion 120 contacts cylindrical object 110.

The liquid ink 114 shown in figure 1 is only of one colour. Here the term 'colour' includes the possibility of black or white ink. A printing station such as that shown in figure 1 must be provided for each colour.

Various mechanical means may be used to propel cylindrical objects 100, 102, 104 and 110. However, one possible arrangement is a conveyor belt 130, including driving wheels 132, 134, 136.

Figure 2 shows a flowchart for a prior art method of contact printing onto cylindrical objects. The method of figure 2 may be used with the apparatus of figure 1, and for the purposes of simplicity will only be described with reference to figure 1.

Following the start of the method at 202, the mesh 120 carrying the image to be printed is added to frame 118, see step 204. The image to be copied is then added to mesh

120, see step 206. This copying step may itself involve chemical etching, and the expenditure of tens of minutes or hours of working time by a skilled technician.

At step 208, ink 114 is added to frame 118. Step 210 summarizes the action of conveyor belt 130 and actuator arms 106, 108 in moving cylindrical object 110 to the location at which the image is printed. In step 212, wiper 116 is moved across the ink 114. This action presses ink onto the mesh, and through to object 110.

Step 214 concerns a decision about the quality of the image produced on cylindrical object 110. A skilled operator may make this decision, based on experience. If the image quality is unacceptable, then the method proceeds to step 216. At step 216, one or more corrective or maintenance action(s) is undertaken. The method then returns to step 210, where another cylindrical object will have an image printed on it, to replace the object which had a substandard image. If the image quality is acceptable, then the method proceeds to step 218.

Step 218 involves a decision about whether or not there are more objects to print. If there are more objects to print, then the method returns to step 210. If there are no more objects to print, then the process ends at step 220.

Figure 3 shows the general geometrical arrangement of the ink jet printer, according to embodiments of the invention, for printing an image onto a three dimensional object 300. Three dimensional object 300 of figure 3 may be, for example, of cylindrical or spherical shape.

The embodiment of the invention shown in figure 3 comprises ink jet printing head 310. Ink jet printing head 310 is adapted to release jets of ink 320 in a first direction D, as illustrated in figure 3.

Three dimensional object 300 can be rotated, as shown by the arrow towards the lower edge of figure 3. Three dimensional object 300 is arranged with an axis through its centre, 330, perpendicular to direction D. The means for rotating three dimensional object 300 are adapted to rotate three dimensional object 300 about central axis 330.

With this arrangement, the three dimensional object 300 can be rotated so that different portions of its surface are presented to the jets of ink 320 released from ink jet printing head 310. An image can therefore be built up on three dimensional object 300. High speed and quality can be ensured by arranging for computer control of the rotation of three dimensional object 300.

The ink jet printer may be further adapted, whereby ink jet printing head 310 releases coloured jets of ink 320. With such an arrangement, a coloured image can be built up on object 300 without needing the object to be moved to the location of a different printing station for printing each colour. This overcomes the problem of those prior art arrangements that use print masks, which require movement of the cylindrical object to a different location for each coloured mask.

The means for rotating three dimensional object 300 may be adapted to rotate three dimensional object 300 reversibly, as illustrated by the arrow at the lower edge of figure 3. This may speed up the printing process, enabling a shorter

printing time. Where a series of objects is to be printed, this may allow a greater rate of throughput of objects.

In use of the arrangement of figure 3, jets of ink 320 are released onto object 300 in a first direction D, from ink jet printing head 310. Three dimensional object 300 is rotated about its central axis 330. Central axis 330 is perpendicular to the first direction D.

Figure 4 shows an ink jet printer for printing on a three dimensional object 400, in accordance with embodiments of the invention.

Ink jet printing head 410 is mounted on support bar 440. Ink jet printing head 410 has an array of sources of ink adapted to release jets of ink 420 in a first direction D. The sources of ink are shown in detail in figures 5-8. In the arrangement of figure 4, the sources of ink are located on the surface of ink jet printing head 410 that faces downwards, and that face is not visible in the projection shown in figure 4.

Support bar 440 allows movement of ink jet printing head 410 along first axis X1. First axis X1 is perpendicular to first direction D. The arrangement of figure 4 allows printing head 410 to release ink onto any point along the length of three dimensional object 400.

In the embodiment of figure 4, the three dimensional object onto which an image is to be printed is a cylindrical object 400. Cylindrical object 400 lies along second axis X2, which is parallel to first axis X1. Second axis X2 passes through the centre of cylindrical object 400.

Bidirectional arrow 450 in figure 4 indicates that cylindrical object 400 can be rotated about second axis X2.

In some embodiments of the invention, cylindrical object 400 may also be moved along third axis Y shown on figure 4.

Figure 4 shows a further cylindrical object 460. Cylindrical object 460 indicates one possible position where a further three dimensional object may wait, whilst an image is being reproduced on object 400. In an alternative arrangement, support bar 440 may allow ink jet printing head 410 to move along the whole length of cylindrical objects 400 and 460, allowing printing onto both objects during the same translation of ink jet printing head 410. This would allow an image to be printed onto cylindrical object 460 before the image on cylindrical object 400 had been completed.

With reference to figure 4, a method of ink jet printing an image onto a three dimensional object 400 comprises:
(i) translating ink jet printing head 410 along first axis X1, with ink jet printing head 410 releasing jets of ink 420 in first direction D from the array of sources of ink.
(ii) rotating the three dimensional object about second axis X2, and repeating step (i).

Considering the cylindrical object 400 shown in figure 4, an image can be reproduced accurately on a section of the circumference of cylindrical object 400 that may, for example, be of 5mm to 10 mm width. Once this has taken place, rotation of object 400 about axis X2 then allows another section of object 400 to be presented to printing head 410. In this way, the apparatus of figure 4 allows an

image to be built up in strips around object 400, possibly around the entire circumference.

The width of the section of cylindrical object 400 onto which an image can be created without rotating object 400 depends on the radius of curvature of object 400. The greater the radius of curvature of object 400, the greater the width of the section onto which an image can be reproduced accurately without a rotation step.

Figure 4 shows a third axis Y, which is perpendicular to first direction D and second axis X2. The ink jet printer of the invention may be adapted to translate cylindrical object 400 along third axis Y.

Translation of cylindrical object 400 along third axis Y offers the possibility of building up an image on cylindrical object 400 using further steps, in addition to steps (i) and (ii) discussed above. With the possibility of translation along third axis Y, an image can be built up on cylindrical object 400 using the following steps:

a) translating ink jet printing head 410 along first axis X1, the ink jet printing head releasing jets of ink 420 in first direction D from the array of sources of ink;

b) translating the cylindrical object 400 along third axis Y and repeating step (a);

c) rotating cylindrical object 400 about second axis X2, and repeating steps (a) and (b).

Although steps a) to c) above are described for cylindrical object 400, they provide a method that is of general applicability to a wide variety of three dimensional objects.

Translation of cylindrical object 400 along third axis Y allows object 400 to be presented to different areas of ink jet printing head 410. This allows different sub-groups of the sources of ink on ink jet printing head 410 to release jets of ink 420 in first direction D. This possibility is of advantage when different areas of ink jet printing head 410 carry out different functions, for example they release ink of different colours.

The embodiment of figure 4 achieves relative movement between ink jet printing head 410 and cylindrical object 400 by translation of ink jet printing head 410 along first axis X1. However, this relative movement could also be achieved by translating cylindrical object 400 along second axis X2. The decision between these two solutions for achieving relative movement may depend on several issues, which include the weight, bulk and fragility of cylindrical object 400. Further factors for consideration are whether the shape of cylindrical object 400 allows rapid mounting of the object within the ink jet printer and removal of the object, and whether successive objects can easily be mounted in precisely the same location within the ink jet printer.

Similarly, if the ink jet printer of figure 4 allows translation of cylindrical object 400 along third axis Y, this is to be understood as one technique for achieving relative movement. A mechanical equivalent to this would be an arrangement whereby printing head 410 is arranged to move along an axis parallel to third axis Y shown on figure 4.

Figure 5 shows an example of an ink jet printing head 510 that may be used in embodiments of the invention.

Figure 5 shows the surface of the printing head that releases ink, which corresponds to the underside of printing head 410 in the projection of figure 4. The projection shown in figure 5 corresponds to a view upwards, from the lower edge of the page, in figure 4.

Ink jet printing head 510 has first array 512 and second array 514 of sources of ink. First array 512 and second array 514 of sources of ink are adapted, in operation, to release ink in direction D shown in figure 4. Line K-K in figure 5 shows the boundary between first array 512 and second array 514 of sources of ink.

First array 512 and second array 514 of sources of ink shown in figure 5 may achieve various different functions. First array 512 may, for example, produce white ink, and second array 514 may produce magenta ink. Such 'two colour' printing heads are commercially available.

First array 512 and second array 514 of sources of ink are separately controllable, to release ink independently of each other. Individual sources of ink within each array may be separately controllable, so that only some of the sources of ink within each array release ink at any one time. One ink jet printing head used in the invention was able to provide up to 662 droplets of ink per second.

Most colour printing requires approximately eight different colours of ink. The term 'colour' here includes black and white as two of the eight colours.

There are various ways in which the ink jet printer according to embodiments of the invention can provide all eight of these colours. Two examples would be:

(i) The ink jet printer can be arranged to have four printing heads of the general design of printing head 510. These could be arranged to move together as one block, or individually, along support bar 440 in figure 4. Each printing head 510 would have sources of ink for two colours. The four printing heads 510 would together therefore be able to provide the full eight colours.

(ii) A single printing head could be adapted to release ink of all eight colours.

Figures 6, 7 and 8 illustrate three possible configurations of a single printing head that could release all eight ink colours.

The ink jet printing head 610 of figure 6 has eight arrays, i.e. sub-groups of ink sources, each array running the length of the printing head. Lines L-L show the boundaries between the arrays.

The printing head 710 of figure 7 has eight generally rectangular arrays of ink sources. Each array is half the length of printing head 710, and covers one quarter of the width of printing head 710. Lines M-M show the boundaries between the arrays. Each array shown in figure 7 comprises eight sources of ink, although in practice the number would be likely to be much higher.

Printing head 810 of figure 8 has eight arrays of ink sources, each of which runs the width of the printing head. Lines N-N show the boundaries between the arrays.

Figure 9 shows an embodiment of the ink jet printer for printing on a three dimensional object, in accordance with embodiments of the invention.

In Figure 9, ink jet printing head 910, support bar 940, ink jet 920, first axis X1, second axis X2, third axis Y and direction D correspond to those shown in Figure 4.

In the embodiment of figure 9, the three dimensional object onto which an image is to be printed is a spherical object 900. The ink jet printer comprises means for rotating spherical object 900 about second axis X2, as shown by arrow 950. In addition, the ink jet printer comprises means for rotating the spherical object about third axis Y, as shown by arrow 960. Both second axis X2 and third axis Y pass through the centre of spherical object 900.

The embodiment of figure 9 may in addition have means for translating the spherical object 900 along third axis Y.

Ink jet printing head 910 may correspond to any of the arrangements of figures 5-8.

The embodiment of figure 9 creates an image on spherical object 900 using method steps analogous to those explained above in connection with figure 4.

Rotation of spherical object 900 about second axis X2 or third axis Y leads to the presentation of different portions of the surface of spherical object 900 to printing head 910.

Translation of spherical object 900 along third axis Y in figure 9 allows the spherical object 900 to be located

under different portions of ink jet printing head 910. This movement is a relative movement between the printing head 910 and spherical object 900. An equivalent movement could be achieved by arranging for translation of printing head 910 along an axis parallel to the third axis Y.

Translation of printing head 910 along support bar 940 also allows the spherical object 900 to be located under different portions of ink jet printer head 910. Once again, this movement is a relative movement between the printing head 910 and spherical object 900. An equivalent movement could be achieved by arranging for translation of spherical object 900 along an axis parallel to first axis X1, such as second axis X2.

The ink jet printer according to embodiments of the invention may be used to print an image onto a wide variety of objects. Although not limited to the list below, the invention may be used to reproduce an image onto the following objects:

(i) An elongated object of generally cylindrical cross-section, such as that shown in figure 4.
(ii) A spherical object, such as that shown in figure 9.
(iii) An object with a stepped surface.
(iv) An irregularly shaped object.
(v) An ovoid object.
(vi) An object with concave surface indents, such as dimples.
(vii)An object with convex raised areas, such as bumps.
(viii) A pen.

The ink jet printer according to embodiments of the invention may employ a variety of possible mounts to hold one or more three dimensional objects for printing. Figure

10 shows a frame 1010 for mounting cylindrical objects 1000, 1002, 1004, 1006, and providing rotation.

Frame 1010 comprises circular cups 1020, 1022, 1024, 1026 for grasping one end of each cylindrical object. Each circular cup is made from resilient material, such as rubber, into which each cylindrical object can be removably inserted. The other end of each three dimensional object is mounted in a freely pivotable mounting, of which a wide variety would be available to the skilled person.

Frame 1010 is connected to means for rotating the cylindrical object, such as stepper motor 1030. Stepper motor 1030 is connected within frame 1010 to circular cups 1020, 1022, 1024, 1026, which transfer rotational force to the cylindrical objects 1000, 1002, 1004, 1006 within them. Stepper motor and circular cups 1020, 1022, 1024, 1026 provide means for rotating the cylindrical objects 1000, 1002, 1004, 1006 about second axis X2 shown in figures 4 and 9.

Stepper motor 1030 and circular cups 1020, 1022, 1024, 1026 may provide reversible rotation of cylindrical objects 1000, 1002, 1004, 1006 about second axis X2.

Movement along third axis Y shown in figures 4 and 9 may be achieved by moving the entire frame 1010 along third axis Y. Alternatively, frame 1010 may be arranged to move just one of cylindrical objects 1000, 1002, 1004 and 1006 along third axis Y, whilst that cylindrical object remains within frame 1010, and frame 1010 is stationary. An individual actuator, not shown in figure 10, would achieve this. Two or three objects could be moved, in place of just one.

Frame 1010 may contain additional pivots, not shown, to allow rotation of the objects within it about third axis Y shown in figures 4 and 9. This allows the movement of spherical objects, such as that illustrated in figure 9, in the directions shown by arrow 960 in figure 9.

Stepper motor 1030 may be arranged to cause rotation about third axis Y, or this may be achieved using a separate actuator, not shown in figure 10. The means for rotating three dimensional objects about the third axis Y may be adapted to provide reversible rotation. The method for printing according to embodiments of the invention described above may therefore further comprise rotating the said three dimensional object about the third axis Y, as illustrated in figure 9.

Although stepper motor 1030 acts on all four cylindrical objects 1000, 1002, 1004, 1006 shown in Figure 10, alternative arrangements are possible. In particular, stepper motor may not act on all the objects within it simultaneously. Stepper motor 1030 may only act on one of the cylindrical objects at a time, for example cylindrical object 1004. When that cylindrical object is close to the ink jet printing head, and an image is being reproduced on cylindrical object 1004, cylindrical object 1004 can be rotated whilst the other objects 1000, 1002, 1006 remain stationary.

In order to build up an image, the ink jet printing head may pass two or more times along first axis X1 before the step of translating or rotating the three dimensional object. Ink released during the second and any subsequent passes may provide additional colours in the image and/or greater image resolution.

The method for printing according to embodiments of the invention may further comprise the image to be printed being divided into sub-sections, each sub-section either being of smaller area than the image and/or only containing a subset of the colours of the image. In this case, each time that the ink jet printing head 410, 910 passes along the first axis X1, jets of ink 420, 920 are released for only one sub-section of the image.

The method for printing according to embodiments of the invention may allow translation of the three dimensional object 300, 400, 900 in the first direction D. Such movement would, for example, be particularly useful for image re-production on a three dimensional object that has steps in its surface. Here a step is a region of raised or lowered height, relative to the remainder of the object. An actuator would achieve this movement. Although not shown in figure 10, a suitable actuator would be arranged to move one or more of cylindrical objects 1000, 1002, 1004, 1006 in figure 10 in first direction D, as required.

The method for printing according to embodiments of the invention may comprise reversible rotation of the three dimensional object, either about second axis X2 or third axis Y. Reversible rotation allows for more rapid re-orientation of the three dimensional object. It may also allow additional options for dividing up the image to be reproduced into subsections.

Embodiments of the invention may offer one or more significant advantages over known prior art arrangements. These may include one or more of the following:

(i) Embodiments of the invention may avoid the disadvantages of painting through masks, including the inaccuracies introduced by copying an image onto a mask, and the need to handle, store and dispose of chemicals.

(ii) Embodiments of the invention may require less time to set up an image. An image needs only to be converted electronically into the correct format, in contrast to the time needed for the various mechanical steps for setting up a mask. This may contribute to a greater rate of throughput of objects.

(iii) Embodiments of the invention may permit printing on parts of cylindrical and spherical objects that could not be reached by prior art arrangements. This may include the portions of a cylindrical or spherical object lying close to major steps or changes in surface height.

(iv) Embodiments of the invention may obviate the need for the object to be moved to different locations for printing with different colours.

(v) The control of the rotation of the object can be implemented digitally. A digital stepper motor can be used, under computer control, to provide rotation of the three dimensional object to any required degree of accuracy. Control of the jets of ink can also be controlled digitally, providing more accurately timed release of ink than prior art arrangements that relied on forcing ink through a mask.

(vi) The arrangement of embodiments of the invention is robust. Embodiments of the invention do not require direct physical contact between the ink jet printing head and the three dimensional object 300, 400, 900.

(vii) The same ink jet printing head can print on objects with a variety of shapes.

(viii) The masks of prior art arrangements tend to wear out after ink has been forced through them onto perhaps 1000-

5000 objects. Each new mask would be likely to differ slightly from previous masks. Embodiments of the invention may effectively allow the same image to be printed onto an indefinite numbers of objects, identically, provided that the ink jet head is maintained and cleaned adequately.

It will be appreciated that, for clarity purposes, the above description has described embodiments of the invention with reference to different functional units. Hence, references to specific functional units are only to be seen as references to suitable means for providing the described functionality, rather than indicative of a strict logical or physical structure or organization.

Aspects of the invention may be implemented in any suitable form including hardware, software, firmware or any combination of these. Aspects of the invention may optionally be implemented, at least partly, as computer software running on one or more data processors and/or digital signal processors. Thus, the elements and objects of an embodiment of the invention may be physically, functionally and logically implemented in any suitable way. Indeed, the functionality may be implemented in a single unit, in a plurality of units or as part of other functional units.

Although the invention has been described in connection with some embodiments, it is not intended to be limited to the specific form set forth herein. Rather, the scope of the present invention is limited only by the claims. Additionally, although a feature may appear to be described in connection with particular embodiments, one skilled in the art would recognize that various features of the

described embodiments may be combined in accordance with embodiments of the invention.

Additionally, although individual features may be included in different claims, these may possibly be advantageously combined, and the inclusion in different claims does not imply that a combination of features is not feasible and/or advantageous. Also, the inclusion of a feature in one category of claims does not imply a limitation to this category, but rather the feature may be equally applicable to other claim categories, as appropriate.

The order of individual steps in a method claim does not imply that the steps must be performed in this order. Rather, the steps may be performed in any suitable order. In addition, singular references do not exclude a plurality. Thus, references to 'a', 'an', 'first', 'second', etc. do not preclude a plurality.

Claims

1. An ink jet printer for printing on a three dimensional object, comprising:

an ink jet printing head (410, 910) the ink jet printing head having an array of sources of ink (512, 514) adapted to release jets of ink (520, 920) in a first direction (D);

means (440, 940) for translating the ink jet printing head (410, 910) along a first axis (X1), the first axis (X1) being perpendicular to the first direction (D); and

means (1010, 1030) for rotating a three dimensional object (400, 900) about a second axis (X2), the second axis (X2) being parallel to the first axis (X1).

2. An ink jet printer in accordance with claim 1, further comprising:
means (1010, 1030) for translating the three dimensional object along a third axis (Y), the third axis (Y) being perpendicular to the first direction (D) and the second axis (X2).

3. An ink jet printer in accordance with claim 1 or claim 2, further comprising:
means (1010, 1030) for rotating the three dimensional object (900) about a third axis (Y), the third axis (Y) being substantially perpendicular to the first direction (D) and the second axis (X2).

4. An ink jet printer in accordance with any previous claim, further comprising:

means for translating the three dimensional object (400, 900) in the first direction (D).

5. An ink jet printer in accordance with any previous claim, further comprising:
a frame (1010) having mounting means (1020, 1022, 1024, 1026) adapted to hold at least two of the three dimensional objects (1002, 1004, 1006, 1008).

6. The ink jet printer of claim 5, wherein the frame (1010) comprises:
a rotatable holder (1020, 1022, 1024, 1026) for each three dimensional object (1000, 1002, 1004, 1006); and
a motor (1030);
the rotatable holders (1020, 1022, 1024, 1026) and motor (1030) providing the means for rotating the three dimensional objects about the second axis (X2).

7. An ink jet printer in accordance with any previous claim, wherein the ink jet printing head (410, 910) comprises two or more arrays of sources of ink (512, 514), each array of sources of ink (512, 514) being:
(i) separably controllable to release ink; and
(ii) providing ink of only one colour.

8. An ink jet printer in accordance with any previous claim, wherein:
the means (1010, 1030) for rotating the three dimensional object about the second axis (X2) is adapted to provide reversible rotation.

9. An ink jet printer in accordance with any of claims 3 to 8, wherein:

the means (1010, 1030) for rotating the three dimensional object about the third axis (Y), is adapted to provide reversible rotation.

10. A method of ink jet printing an image onto a three dimensional object (400, 900), comprising:

(i) translating an ink jet printing head (410, 910) along a first axis (X1), the ink jet printing head (410, 910) releasing ink in a first direction (D) from an array of sources of ink (512, 514), the first direction (D) being perpendicular to the first axis (X1);

(ii) rotating a three dimensional object about a second axis (X2), the second axis (X2) being parallel to the first axis (X1), and repeating step (i).

11. A method in accordance with claim 10, further comprising:
after step (i) and before step (ii), translating the three dimensional object (400, 900) along a third axis (Y), the third axis (Y) being perpendicular both to first direction (D) and to second axis (X2), and repeating step (i).

12. A method in accordance with claim 11, further comprising:
after step (ii), repeating both step (i) and the step of translating the three dimensional object along third axis (Y).

13. A method in accordance with claim 10, further comprising:

rotating the three dimensional object (400, 900) about a third axis (Y), the third axis (Y) being perpendicular to the first direction (D) and the second axis (X2).

14. A method in accordance with any of claims 10 to 13, wherein:
the step of translating the ink jet printing head (410, 910) along the first axis (X1) comprises the ink jet printing head (410, 910) passing at least two times along the first axis (X1),
whereby ink released during at least a second pass of the ink jet printing head (410, 910) provides at least one from the group of:
at least one additional colour in the image;
greater image resolution.

15. A method in accordance with claim 14, wherein the image to be printed is divided into sub-sections, each sub-section being at least one of the group of:
a smaller area than the image;
only containing a subset of the colours of the image;
whereby, each time that the ink jet printing head (410, 910) passes along the first axis (X1), jets of ink (520, 920) are released for only one sub-section of the image.

16. A method in accordance with any of claims 10 to 15, further comprising:
translating the three dimensional object (400, 900) in the first direction (D).

17. A method in accordance with any of claims 10 to 16, further comprising:
reversibly rotating the three dimensional object (400, 900) about the second axis (X2).

18. A method in accordance with any of claims 11 to 17, further comprising:
reversibly rotating the three dimensional object (900) about the third axis (Y).

19. A three dimensional object bearing an image printed in accordance with the method of any of claims 10-18.

20. Use of an ink jet printer in accordance with any of claims 1 to 9 for printing an image onto at least one of the group of:
(i) an elongated object of generally cylindrical cross-section (400);
(ii) a spherical object (900);
(iii) an object with a stepped surface;
(iv) an irregularly shaped object;
(v) an ovoid object;
(vi) an object with concave surface indents;
(vii) an object with convex raised areas;
(viii) a pen.

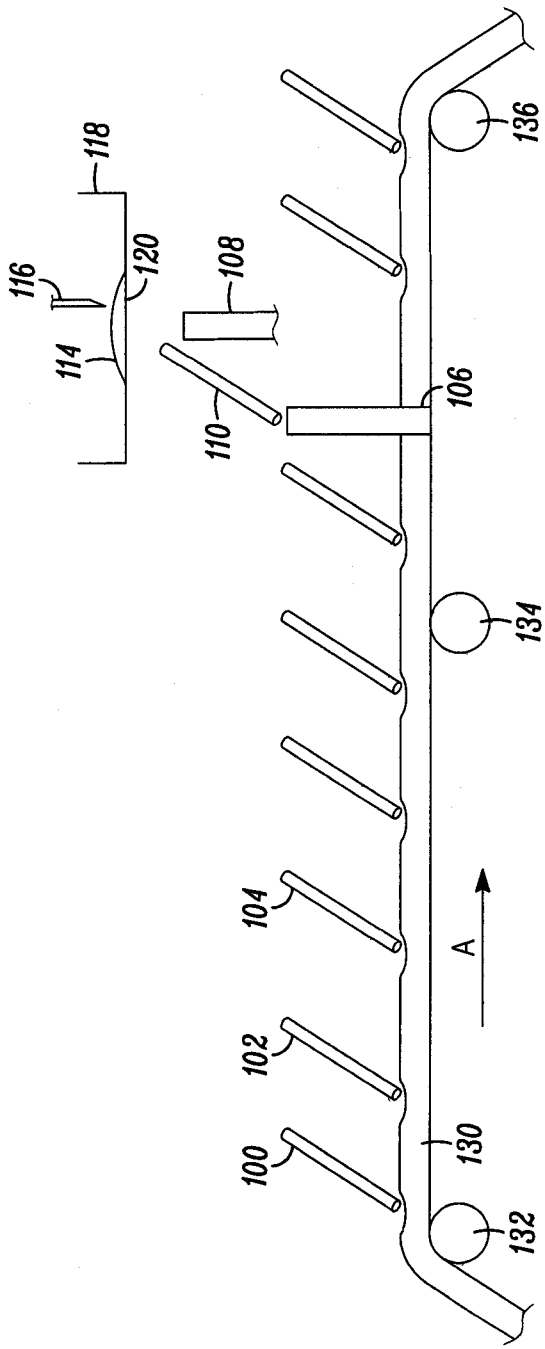


FIG. 1

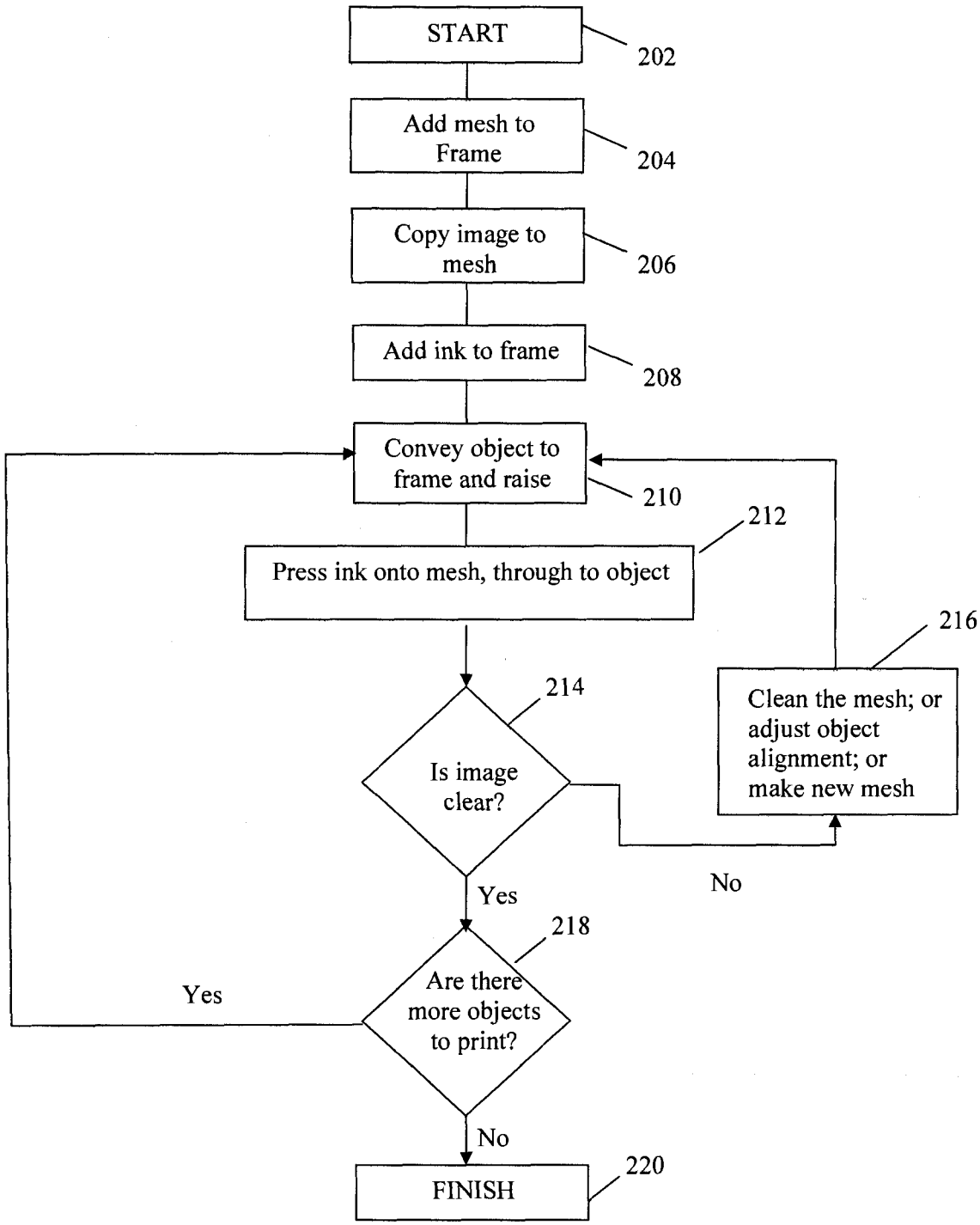

START
202
Add mesh to Frame
204
Copy image to mesh
206
Add ink to frame
208
Convey object to frame and raise
210
212
Press ink onto mesh, through to object
214
Is image clear?
No
216
Clean the mesh; or adjust object alignment; or make new mesh
Yes
218
Are there more objects to print?
Yes
No
220
FINISH

FIG.2

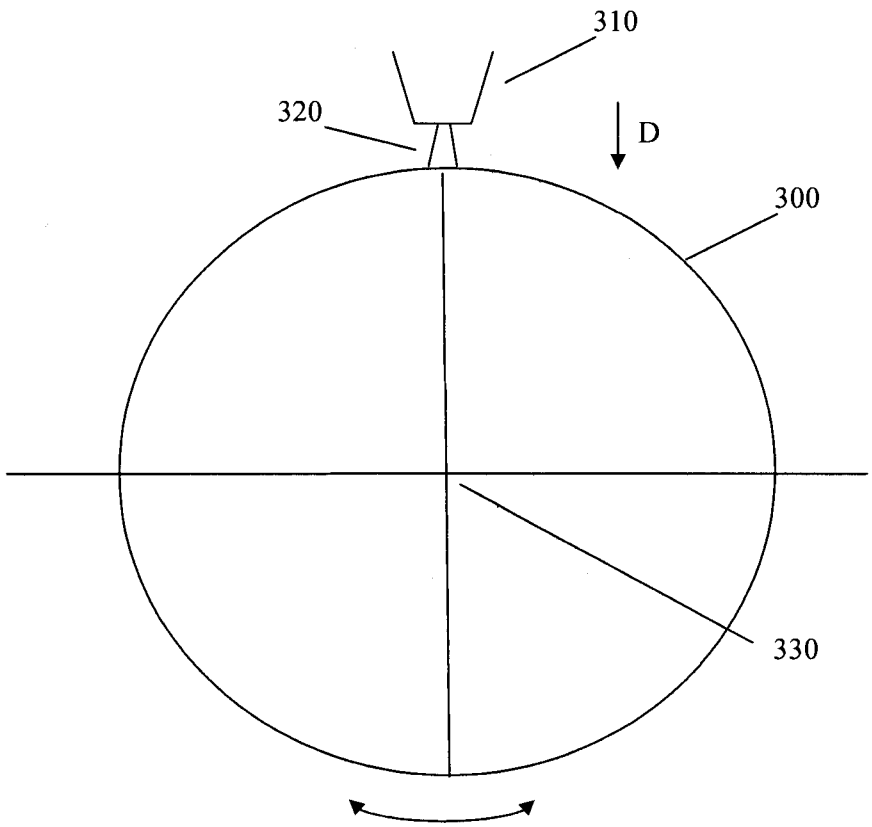


FIG.3

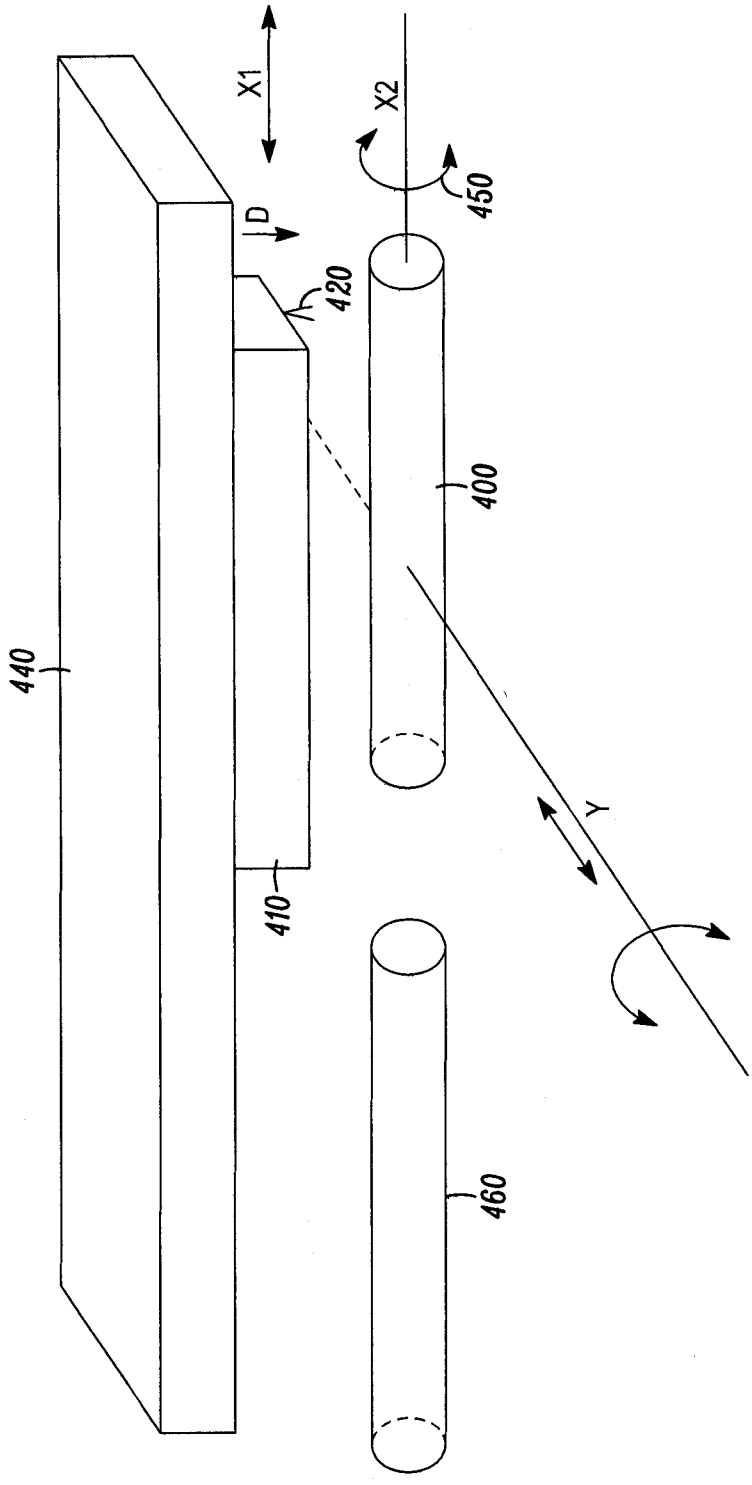


FIG. 4

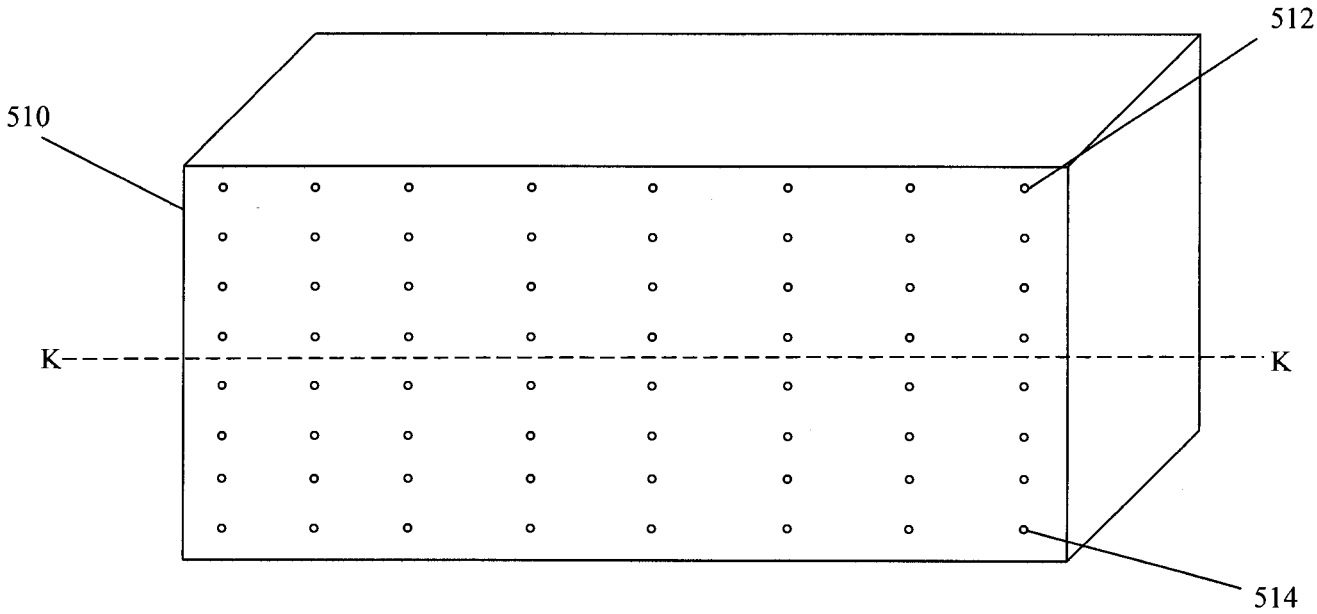


FIG.5

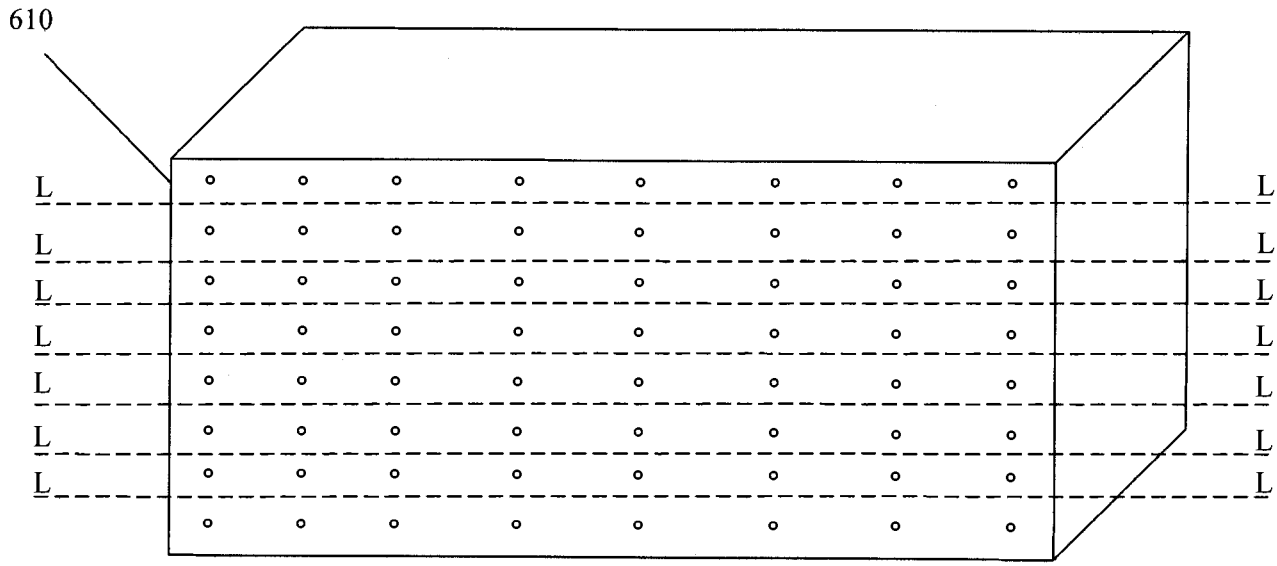


FIG.6

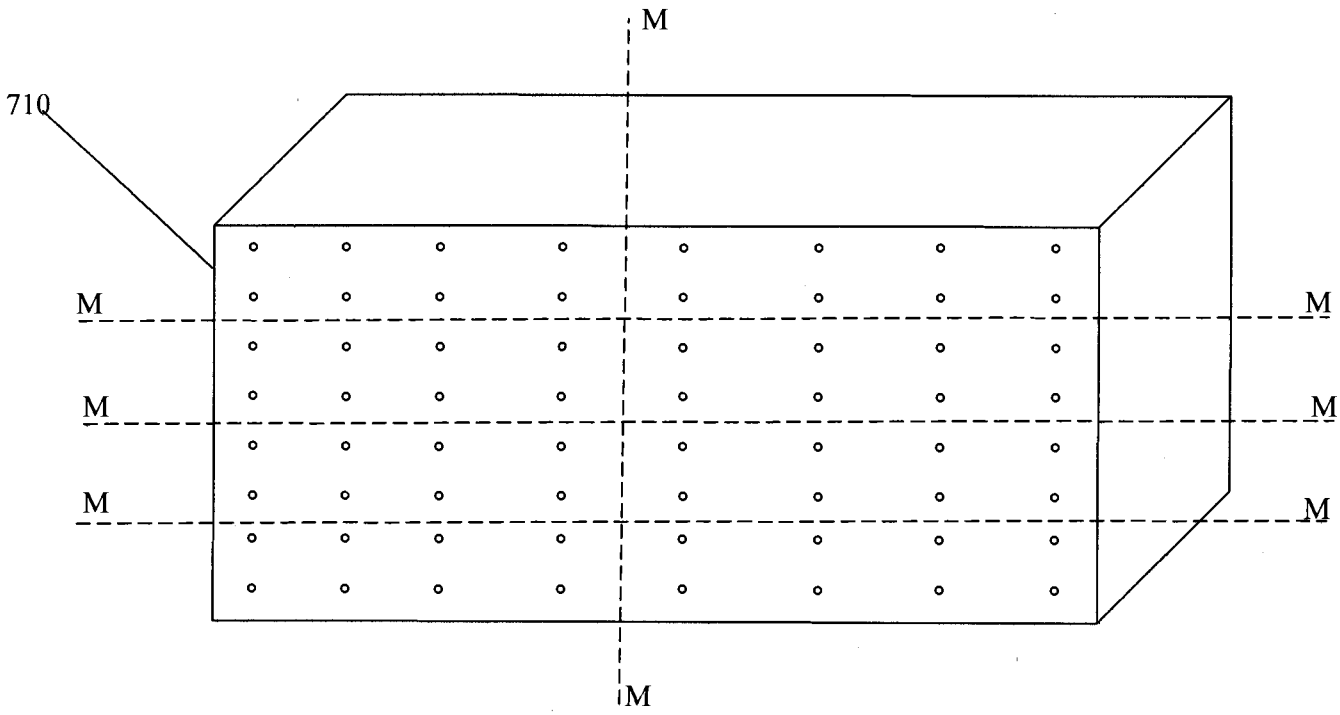


FIG.7

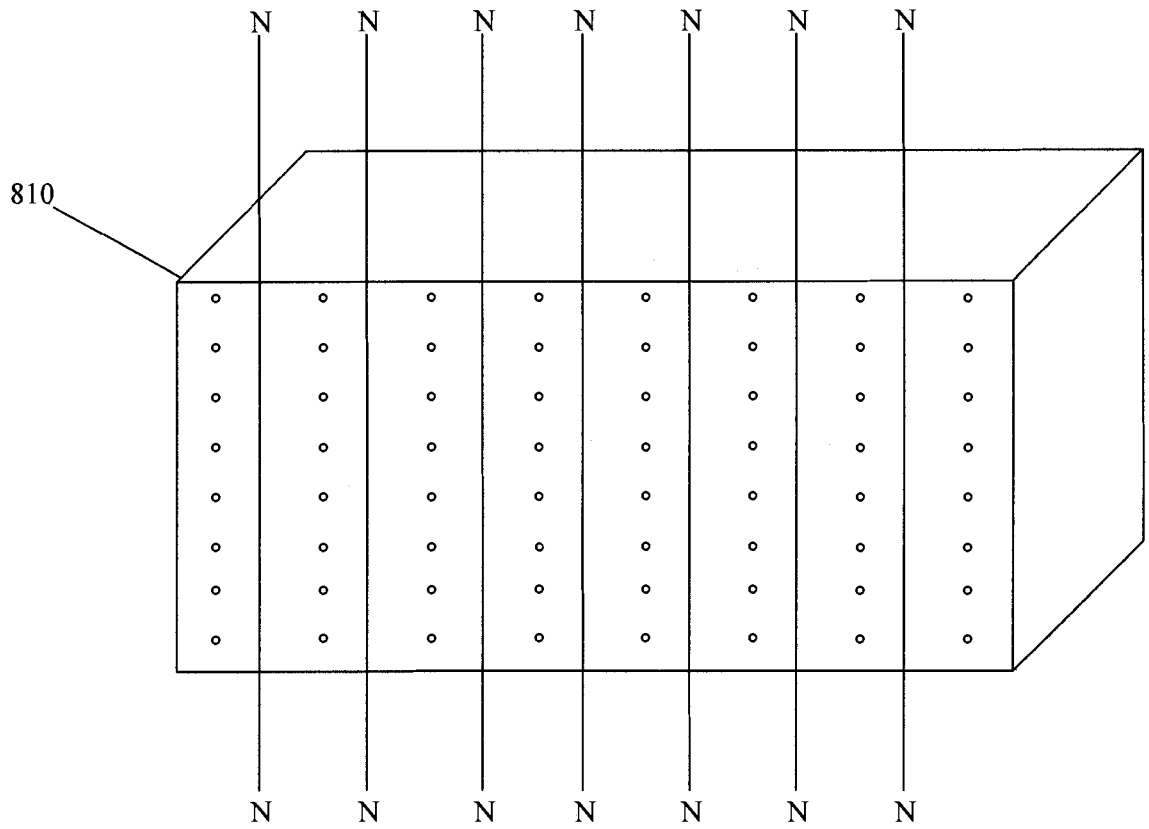


FIG.8

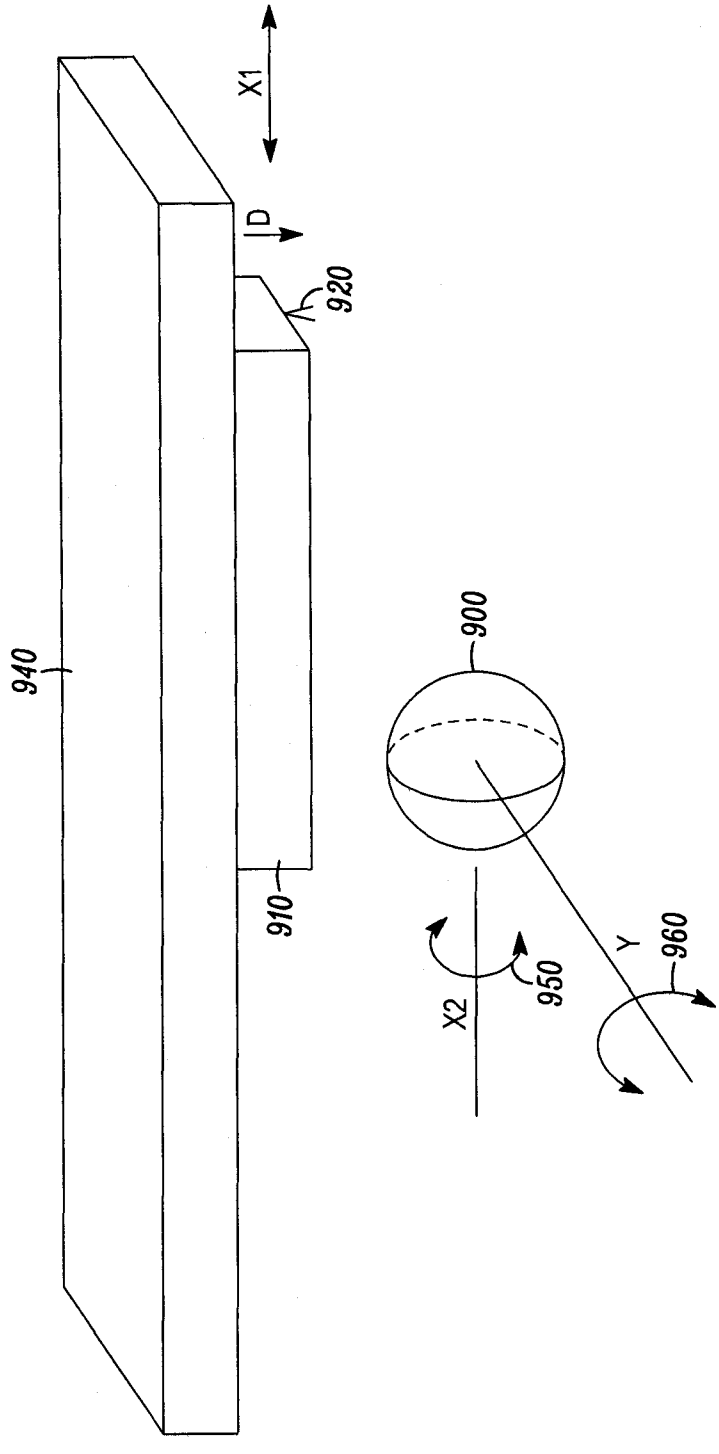


FIG. 9

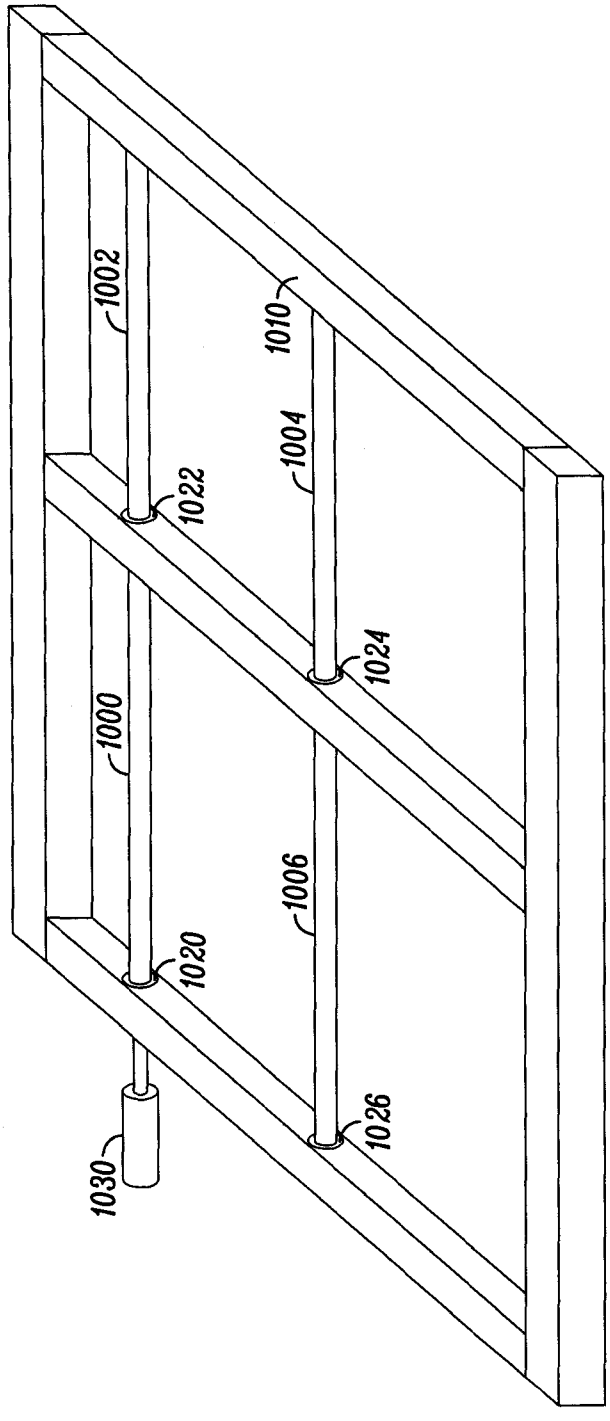


FIG. 10

INTERNATIONAL SEARCH REPORT

International application No
PCT/EP2008/055287

A. CLASSIFICATION OF SUBJECT MATTER
INV. B41J3/407

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

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
B41J

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

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)
EPO-Internal, WPI Data

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	JP 2007 001164 A (MIMAKI ENG KK) 11 January 2007 (2007-01-11) abstract the whole document	1-20
X	US 2001/019340 A1 (KUBO NAOKI [JP] ET AL) 6 September 2001 (2001-09-06) figures 14-16 paragraph [0175] - paragraph [0198] paragraph [0258] - paragraph [0263]	1-20
X	JP 2001 205794 A (MASTER MIND KK) 31 July 2001 (2001-07-31) abstract	1,10,19, 20

-/--

[X] Further documents are listed in the continuation of Box C.

[X] See patent family annex.

* Special categories of cited documents :

"A" document defining the general state of the art which is not considered to be of particular relevance

"E" earlier document but published on or after the international filing date

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"O" document referring to an oral disclosure, use, exhibition or other means

"P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art.

"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
21 August 2008	01/09/2008

Name and mailing address of the ISA/	Authorized officer
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INTERNATIONAL SEARCH REPORT

International application No
PCT/EP2008/055287

C(Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	US 2005/285919 A1 (MARTINEZ RAUL JR [US] ET AL MARTINEZ RAUL [US] ET AL) 29 December 2005 (2005-12-29) paragraph [0003] paragraph [0084] - paragraph [0106] paragraph [0129] figure 3	1-20
X	US 2006/250464 A1 (SHEINMAN YEHOSHUA [IL]) 9 November 2006 (2006-11-09) the whole document	1,2,7,8, 10,11, 14,15, 17,19,20

INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No
PCT/EP2008/055287

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
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US 2001019340 A1	06-09-2001	NONE	
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US 2005285919 A1	29-12-2005	NONE	
US 2006250464 A1	09-11-2006	NONE	