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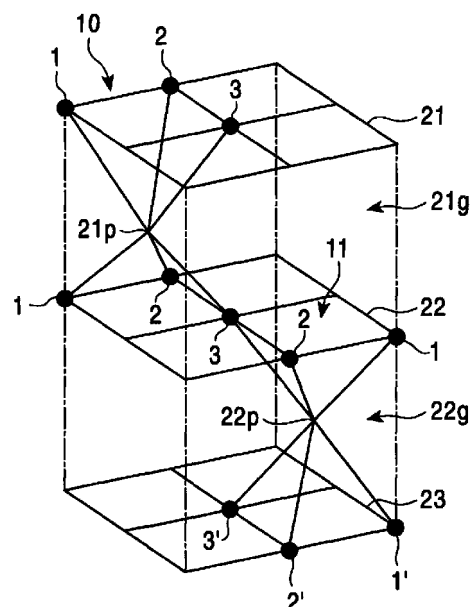
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(54) **Method and apparatus for weaving three-dimensional fibrous tissue and woven filter**

(57) Due to their dense structures, conventional three-dimensional tissues are suitable for applications as reinforcing members but not for applications such as filters. According to the present invention, a three-dimensional fibrous tissue is woven by setting four adjacent partitions in a carrier movement space 10, shifting the carrier movement space 10 in a row and a column directions of the space by one partition to set a next carrier movement space 11, and alternately performing a rotation operation in the carrier movement space 10, 11. In addition, a filter is woven by forming woven layers 21g, 22g in a longitudinal direction of fibers at a fixed interval and adhering or welding the fibers at nodes 21p, 22p in the woven layers.

FIG. 4



EP 1 045 056 A2

Description

Field of the Invention

[0001] The present invention relates to a method for weaving a three-dimensional fibrous tissue, the structure of a weaving device, and a three-dimensional fibrous filter formed using the present weaving method and device.

Background of the Invention

[0002] A method and device has been well known which forms fibers into a three-dimensional tissue by connecting fibers to carriers arranged in a matrix form and moving the carriers in a row and a column directions of the matrix. When such a method is used for forming a three-dimensional tissue, fibers are beaten in their union portions during weaving using a comb- or bar-shaped reed, thereby forming a tissue with a high weaving density.

[0003] Due to its dense structure, however, the three-dimensional tissue formed according to the prior art is suitable for applications such as reinforcing members for plastics or metal, but not for other applications such as filters that require a large number of spaces in the tissue and that require a liquid or gas to pass there-through.

Summary of the Invention

[0004] The problem to be solved by the present invention has been described, and means for solving it will be explained below. The present invention provides a method for weaving a three-dimensional fibrous tissue by moving carriers arranged in a matrix form, in a row and a column directions of the matrix, wherein weaving is carried out by setting four adjacent partitions in a space within which the carriers are moved and rotating the carriers using this carrier space as a rotation unit.

[0005] In addition, weaving is carried out by shifting the carrier movement space in the row and column directions by one partition to set a next carrier movement space and alternately performing the rotation operation in the carrier movement space and the next carrier movement space.

[0006] Further, a filter is woven based on the method by forming woven layers in a longitudinal direction of fibers at fixed intervals and adhering or welding together yarns crossing one another in the woven layers.

[0007] In addition, the present invention constructs a device for weaving three-dimensional fibrous tissue comprising a carrier drive section for moving carriers arranged in a matrix form, in a row and a column directions of the matrix, the carriers each having a bobbin loaded thereon, a block drive section for similarly moving blocks arranged in a matrix form, in a row and a col-

umn directions of the matrix, and a device for lifting a woven three-dimensional fibrous tissue.

Brief Description of the Drawing

[0008]

Figure 1 is a matrix diagram showing an arrangement of carriers.

Figure 2 is a matrix diagram showing how the carriers are rotatively moved during a first-layer operation.

Figure 3 is a matrix diagram showing how the carriers are rotatively moved during a second-layer operation.

Figure 4 is a solid figure showing fibers subjected to the first- and second-layer operations.

Figure 5 is a solid figure showing fibers obtained by performing the first- and second-layer operations on a matrix having a plurality of spaces in which the carriers are moved.

Figure 6 is a typical drawing of a weaving device.

Figure 7 is a side sectional view of a carrier and a bobbin.

Figure 8 is a bottom perspective view of the carrier. Figure 9 is a perspective view showing how blocks are fitted together.

Figure 10 is a perspective view showing a slide construction of the blocks.

Figure 11 is a matrix diagram of a carrier drive section and a block drive section.

Figure 12 is a sectional view of a tissue, including laser oscillators.

Detailed Description of the Preferred Embodiments

[0009] First, a basic operation associated with a method for weaving a three-dimensional tissue according to the present invention will be described with reference to Figures 1 to 5.

[0010] In Figures 1 to 3, carriers 1, 2, 3 each having a bobbin are placed on a matrix arranged in two-dimensional directions and including three rows and three columns. It is assumed that a fiber is drawn out front a bobbin on each of the carriers 1, 2, 3 in a direction of the drawing away from the reader and that an end portion of the fiber is fixed in position on a matrix of the same arrangement. First, attention is paid to the three carriers 1, 2, 3 within a carrier movement space 10 enclosed by an alternate long and short dash line. The carrier movement space 10 is comprised of four adjacent partitions including three partitions each having a corresponding one of the three carriers 1, 2, 3 and one empty partition. In the matrix, the rows and columns can independently be moved. First, columns L1, L3 are moved downward. Then, the matrix becomes as shown in Figure 24. (Figure 2 shows only the carriers 1, 2, 3 within the carrier movement space 10).

[0011] In this case, the columns move in a vertical direction by one block per movement, whereas the rows move in a lateral direction by one block per movement.

[0012] Next, rows C1, C3 are moved leftward. Then, the matrix becomes as shown in Figure 2B. Further, column L2 is moved upward. Then, the matrix becomes as shown in Figure 2C.

[0013] Due to the above operations, the carriers 1, 2, 3 within the carrier movement space 10 each have been moved counterclockwise around a rotational center 10a by one block relative to the state shown in Figure 1, as shown in the matrix in Figure 2C.

[0014] Next, row C2 is moved rightward, columns L1, L3 are moved downward, and rows C1, C3 are moved leftward, in this order. These operations result in the matrix shown in Figure 2D. That is, the carriers 1, 2, 3 each have further been moved counterclockwise around the rotational center 10a by one block relative to the state shown in Figure 2C.

[0015] Subsequently, column L2 is moved upward, row C2 is moved rightward, and columns L1, L3 are moved downward, in this order. These operations result in the matrix shown in Figure 2E. That is, the carriers 1, 2, 3 each have further been moved counterclockwise around the rotational center 10a by one block relative to the state shown in Figure 2D.

[0016] Finally, rows C1, C3 are moved leftward, column L2 is moved upward, and row C2 is moved rightward, in this order. These operations result in the matrix shown in Figure 2F. That is, the carriers 1, 2, 3 each have further been moved counterclockwise around the rotational center 10a by one block relative to the state shown in Figure 2E. That is, the above 12 row and column operations have caused the carriers 1, 2, 3 within the carrier movement space 10 to rotate once around the rotational center 10a relative to the state shown in Figure 1. The above operations are collectively referred to as a "first-layer operation".

[0017] Next, attention is paid to the three carriers 1, 2, 3 within a next carrier movement space 11 enclosed by the alternate long and short dash line in Figure 1. The next carrier movement space 11 also comprised of three partitions each having a corresponding one of the three carriers 1, 2, 3 and one empty partition, and is obtained by shifting the carrier movement space 10 rightward along the row direction by one partition and downward along the column direction by one block. First, columns L1, L3 are moved upward, and rows C1, C3 are moved rightward, and column L2 is moved downward, in this order. These operations result in the matrix shown in Figure 3A. That is, the carriers 1, 2, 3 within the carrier movement space 11 each have been moved counterclockwise around a rotational center 11a by one block relative to the state shown in Figure 1.

[0018] Next, row C2 is moved leftward, columns L1, L3 are moved upward, and rows C1, C3 are moved rightward, in this order. These operations result in the matrix shown in Figure 3B. That is, the carriers 1, 2, 3

each have further been moved counterclockwise around the rotational center 11a by one block relative to the state shown in Figure 3A.

[0019] Next, column L2 is moved downward, row C2 is moved leftward, and columns L1, L3 are moved upward, in this order. These operations result in the matrix shown in Figure 3C. That is, the carriers 1, 2, 3 each have further been moved counterclockwise around the rotational center 11a by one block relative to the state shown in Figure 3B. Finally, rows C1, C3 are moved rightward, column L2 is moved downward, and row C2 is moved leftward, in this order. As a result, the carriers 1, 2, 3 within the next carrier movement space 11 each have been rotated once counterclockwise around the rotational center 11a relative to the state shown in Figure 1, resulting in the matrix shown in Figure 3D. The above operations are collectively referred to as a "second-layer operation".

[0020] The second-layer operation is performed after the fibers have been drawn out in the direction away from the reader by a specified amount, following the first-layer operation. After the second-layer operation has been finished, the fibers are further drawn out in the same direction by a specified amount to repeat the first-layer operation.

[0021] Effects of continuously performing the first- and second-layer operations described above will be explained. In this case, the matrix including three rows and three columns is substituted by a lattice, and nodes in this lattice are assumed to be the carriers 1, 2, 3, as shown in Figure 4.

[0022] This figure sequentially shows an initial lattice 21, a first-layer lattice 22, and a second-layer lattice 23 from top to bottom. The initial lattice 21 shows the carriers 1, 2, 3 on a matrix to which end portions of the fibers drawn out from the carriers 1, 2, 3 in Figure 1 in the direction away from the reader are fixed. The first-layer lattice 22 shows the carriers 1, 2, 3 after the completion of the first-layer operation, while the second-layer lattice 23 shows the carriers 1, 2, 3 after the completion of the second-layer operation.

[0023] The positions at which the carriers 1, 2, 3 on the initial lattice 21 are arranged correspond to the positions at which the carriers 1, 2, 3 on the first-layer lattice 22 are arranged, the positions at which carriers 1, 2, 3 on the first-layer lattice 22 are arranged correspond to the positions at which the carriers 1, 2, 3 on the second-layer lattice 23 are arranged.

[0024] In an initial state, the fibers joining the carriers 1, 2, 3 on the initial lattice 21 with the carriers 1, 2, 3 on the first-layer lattice 22 are disposed to extend generally in parallel, while the fibers joining the carriers 1, 2, 3 on the first-layer lattice 22 with the carriers 1, 2, 3 on the second-layer lattice 23 are disposed to extend generally in parallel.

[0025] First, in the first-layer lattice 22, the above first-layer operation is performed in the carrier movement space 10 with the carriers 1, 2, 3 to rotate the car-

riers 1, 2, 3 counterclockwise once. At this point, since the rotation operation is not performed for the initial lattice 21, the fibers between the initial lattice 21 and the first-layer lattice 22 cross one another to form a node 21p. Then, a first-layer woven layer 21g is formed between the initial lattice 21 and the first-layer lattice 22.

[0026] Next, in the second-layer lattice 23, the above second-layer operation is performed in the carrier movement space 11 with the carriers 1, 2, 3 to rotate the carriers 1, 2, 3 counterclockwise once. At this point, since the rotation operation is not performed for the first lattice 22, the fibers between the first-layer lattice 22 and the second-layer lattice 23 cross one another to form a node 22p. Then, a second-layer woven layer 22g is formed between the first-layer lattice 22 and the second-layer lattice 23.

[0027] These operations form the fibers joining the carriers 1, 2, 3 in one layer with the carriers 1, 2, 3 in another, into the laminated tissues 21g, 22g, thereby forming a solid structure. The above embodiment has been described in conjunction with the one carrier movement space 10 existing in the initial lattice 21. However, even if the size of the initial lattice 21 is increased so that a plurality of carrier movement spaces 10 can spread two-dimensionally therein, similar operations enable the solid structure to be formed by rotating the carriers 1, 2, 3. Figure 5 shows an embodiment in which the initial lattice 21 includes four carrier movement spaces 10.

[0028] A method for weaving a three-dimensional fibrous tissue according to the present invention will be described to which the above first- and second-layer operations are applied. Figure 6 is a typical drawing showing the entire construction of a weaving device. The weaving device is comprised of a carrier drive section 5, a block drive section 6, a lifting device 7, and other components.

[0029] The carrier drive section 5 has carriers 51 arranged in a matrix form and each having a bobbin 50 loaded thereon. As shown in Figures 7 and 8, the carrier 51 has a cross-shaped slide groove 51a formed in its bottom surface. The slide groove 51a is formed to have a generally T-shaped cross section so that a pin 5b fixed to a support plate 5a of the carrier drive section 5 can be fitted therein. This construction enables each carrier 51 to be moved on the support plate 5a in a row and a column direction of the matrix while keeping the bobbin 50 integrally loaded thereon.

[0030] On the other hand, the block drive section 6 has blocks 61 also arranged in a matrix form and each having a through-hole 61a for a fiber 8. As shown in Figure 9, the blocks 61, 61, ... are each shaped generally like a rectangular parallelepiped and each have a slide groove 62a formed in a side portion thereof corresponding to the row direction and a projection 62b fitted in the slide groove 62a in the adjacent block. Likewise, the blocks 61, 61, ... each have a slide groove 63a formed in a side portion thereof corresponding to the column

direction and a projection 63b fitted in the slide groove 63a in the adjacent block. The blocks 61, 61, ... are assembled together by fitting the projection 62b of one block in the slide groove 62a of the adjacent block and fitting the projection 63b of one block in slide groove 63a of the adjacent block. The blocks 61, 61, ... constructed in this manner are arranged in the matrix form so that the blocks 61, 61, ... in the row or column direction can be integrally moved.

[0031] As shown in Figure 10, the blocks 61, 61, ... in the row direction have slide plates 64, 65 disposed at an end portion thereof. The slide plates 64, 65 are alternately arranged in the column direction, and the plurality of slide plates 64, 64, ... (Figure 10 shows two slide plates 64, 64) share a drive plate 64a fixedly installed thereon. In addition, the drive plate 64a has a rack 64b disposed thereon in the row direction and which meshes with a pinion 64d of a pulse motor 64c to convert rotative driving by the pulse motor 64c into reciprocating motion of the slide plates 64, 64, ...

[0032] Likewise, the plurality of slide plates 65, 65, ... share a drive plate 65a fixedly installed thereon. In addition, the drive plate 65a has a rack 65b disposed thereon in the row direction and which meshes with a pinion 65d of a pulse motor 65c to convert rotative driving by the pulse motor 65c into reciprocating motion of the slide plates 65, 65, ...

[0033] With the above construction, by driving the pulse motors 64c, 65c, the slide plates 64, 65 can be slidably moved to correspondingly move the blocks 61, 61, ... of the block drive section 6 every other row (for example, only the even- or odd-number rows). The blocks 61, 61, ... in the column direction also have the slide plates, the drive plates, and the pulse motors (not shown in the drawings) disposed thereon to enable the blocks 61, 61, ... to be moved every other column.

[0034] In the above construction, the carriers 51 arranged in the carrier drive section 5 and the blocks 61 arranged in the block drive section 6 are both arranged in a matrix form as shown in Figure 11. Depending on the shape of a three-dimensional fibrous tissue to be formed, fibers supplied from the bobbins 50 on the required carriers 51 are allowed to penetrate the through-holes 61a in the corresponding blocks 61 and are then connected to a terminal plate 70 of the lifting device 7. The matrix configuration of the block drive section 6 is not necessarily the same as that of the carrier drive section 5, and the matrix requires only a minimum number of rows and columns required to move the carriers 51 appropriately.

[0035] A method for generating a three-dimensional fibrous tissue in the weaving device constructed as described above will be described below. First, fibers are extended from the bobbins 50 on the required carriers 51, subsequently allowed to penetrate the through-holes 61a in the corresponding blocks 61, and then connected to the terminal plate 70 at corresponding positions. In this case, the bobbins 50 for supplying fibers

can be selected as appropriate depending on the shape of a tissue to be formed, but are continuously arranged in each of the above carrier movement spaces 10 in the row and column directions. That is, the carrier drive section 5 has a plurality of carrier movement spaces 10 disposed therein and extending in the row and column directions.

[0036] Then, the lifting device 7 is used to move the terminal plate 70 in a direction away from the block drive section 6, while the carrier drive section 5 and the block drive section 6 simultaneously perform the above first-layer operation. That is, the block drive section 6 simultaneously performs the first-layer operation in the plurality of carrier movement spaces 10 by using the above slide drive mechanism to move the blocks every other row and column in the row and column directions. At this point, the carrier drive section 5 carries out slidable movement in synchronism with the slidable movement by the block drive section 6 because the carrier drive section 5 is similarly constructed (not shown in the drawings) to move the blocks every other row and column in the row and column directions. These operations form as many nodes 21p, 21p, ... as the carrier movement spaces 10 in the fibers between the block drive section 6 and the terminal plate 70, thereby forming the first-layer woven layer 21g. At this point, due to the synchronous movement of the carrier drive section 5 and the block drive section 6, no node is formed between these sections.

[0037] Subsequently, the lifting device 7 is used to move the terminal plate 70, while the carrier drive section 5 and the block drive section 6 simultaneously perform the second-layer operation. Then, the second-layer woven layer 22g, which follows the first-layer woven layer 21g formed by means of the first-layer operation; is formed between the block drive section 6 and the terminal plate 70. Subsequently, the above first- and second-layer operations are repeated to sequentially and repeatedly form the first-layer woven layer 21g and the second-layer woven layer 22g between the block drive section 6 and the terminal plate 70. In this manner, a three-dimensional fibrous tissue is formed.

[0038] Once the first-layer woven layer 21g and the nodes 21p, 21p, ... have been formed, the fibers are joined together at the nodes 21p by means of adhesion or welding. To join the fibers together at the nodes, two laser oscillators 9, 9 are used to irradiate the nodes with laser beams. As shown in Figure 12, the laser oscillators 9, 9 are arranged so as to be moved by feed motors 91, 91 in a row and a column directions of a tissue to be formed and to rotatively move within a plane including the cross section of the tissue. Thus, the irradiation directions of the two laser oscillators 9, 9 are controlled to join the fibers together at the nodes 21p, 21p, ... Thereby, only target nodes 21p are irradiated with laser beams to avoid the adverse effects of the beams on the other fibers and nodes.

[0039] In addition, the output of each of the two

laser oscillators 9, 9 can be controlled depending on the distance between this laser oscillator 9, 9 and a node, and output control is carried out based on the total output of the two laser oscillators 9, 9, thereby achieving an efficient joining step without the use of extra energy. Further, the output control is configured to correspond to various materials of fibers such as stainless wires, copper wires, nickel wires, nylon yarns, and polyester fibers.

[0040] In addition, metallic fibers can be coated with a solder powder, a flux, etc. beforehand. Chemical fibers can be deposited using a paste material, and nylon or the like can be deposited using a formic acid.

[0041] After the second-layer woven layer 22g has been formed following the joining operation for the nodes 21p in the first-layer woven layer 21g, a similar joining step is executed for the nodes 22p to sequentially form tissues. In addition, although the above junction step is carried out for the nodes formed inside the cross section of the tissue, an outer frame may be disposed on an outer-most layer of the tissue so as to join by means of adhesion or welding with that part of the outer-most layer which is contained in this outer frame portion, thereby enabling the external shape of the tissue formed to be maintained to omit joining for each node.

[0042] In addition, if joining for each node is carried out by means of welding, spot welding can efficiently be used.

[0043] Due to spaces formed among the fibers, the three-dimensional fibrous tissue formed using the above operations can be used as a filter for various applications. In addition, due to its large surface area, the three-dimensional fibrous tissue can be used as a catalyst showing efficient effects when the fibers constituting the three-dimensional fibrous tissue are formed of a member with a catalytic effect.

[0044] In addition, by controlling the speed at which the terminal plate 70 is moved by the lifting device 7 as well as the slidable-movement speed on the block drive section 5, the assently angle of the tissue can freely be varied. Consequently, the level of the filtering capability, one of the characteristics of the filter, can be controlled to adjust the intensity of the filter.

[0045] In addition, if the first- or second-layer operation shifts to the next-layer operation when the carriers 1, 2, 3 (Figures 1 to 3) have rotated, for example, by 180 degrees around the rotational center 10a or 11a (when the state shown in Figure 1 has shifted to the state shown in Figure 2D or 3B), the fiber orientation of the three-dimensional fibrous tissue to be formed can be varied. If the carriers are moved through 90 degrees at a time, this timing with which the operation shifts to the next-layer operation may arbitrarily be selected from 90, 270, and 360 degrees and more.

[0046] In addition, by disposing a resin immersion step and a resin molding step between the terminal plate 70 and the block drive section 6, the tissue formed

may directly be used as a composite or a component without altering its shape. Accordingly, the three-dimensional fibrous tissue can be provided with a plurality of functions or formed into a very light structure or a honeycomb structure.

[0047] In addition, as described above, the positions and number of the bobbins 50 on the carrier drive section 5 from which the fibers are supplied can arbitrarily be selected within the range of the carrier movement space 10, so that three-dimensional fibrous tissues (or filters) of various shapes or densities can be formed. Thus, the present method is configured to provide a higher degree of freedom than the conventional methods for weaving a tissue.

[0048] Due to the above construction, the present invention has the following effects.

[0049] The present invention provides a method for weaving a three-dimensional fibrous tissue by moving carriers arranged in a matrix form, in a row and a column directions of the matrix, wherein weaving is carried out by setting four adjacent partitions in a space within which the carriers are moved and rotating the carriers within this carrier space. Consequently, a weaving base of the three-dimensional fibrous tissue can be formed by means of the simple rotation of the carriers involving a small movement range.

[0050] In addition, weaving is carried out by shifting the carrier movement space in the row and column directions of the matrix by one partition to set a next carrier movement space and alternately performing the rotation operation in the first carrier movement space and the next carrier movement space. The three-dimensional fibrous tissue can be formed by means of the repetition of the simple independent block operations, thereby facilitating control.

[0051] Further, a filter is woven by a method as in Claim 1 or 2 forming woven layers in a longitudinal direction of fibers at fixed intervals and adhering or welding together yarns crossing one another in the woven layers. As a result, spaces are formed in the woven layers, resulting in a construction providing sufficient filter functions.

[0052] In addition, the present invention provides a device for weaving three-dimensional fibrous tissue comprising a carrier drive section for moving carriers arranged in a matrix form, in a row and a column directions of the matrix, the carriers each having a bobbin loaded thereon; a block drive section for similarly moving blocks arranged in a matrix form, in a row and a column direction of the matrix; and a device for lifting a woven three-dimensional fibrous tissue. As a result, the fibers are prevented from crossing one another between the carrier drive section and the block drive section, thereby simplifying control. In addition, by controlling the movement speed of the lifting device and the slide-movement on the block drive section, the assembly angle of the tissue can arbitrarily be varied.

Claims

1. A method for weaving a three-dimensional fibrous tissue by moving carriers arranged in a matrix form, in a row and a column directions of the matrix, characterized in that weaving is carried out by setting four adjacent partitions in a space within which the carriers are moved and rotating the carriers using this carrier space as a rotation unit.
2. A method for weaving a three-dimensional fibrous tissue characterized in that weaving is carried out by shifting said carrier movement space in the row and column directions by one partition to set a next carrier movement space and alternately performing said rotation operation in the first carrier movement space and the next carrier movement space.
3. A filter woven by a method as in Claim 1 or 2 characterized in that the filter is obtained by forming woven layers in a longitudinal direction of fibers at fixed intervals and adhering or welding together yarns crossing one another in the woven layers.
4. A device for weaving a three-dimensional fibrous tissue comprising a carrier drive section for moving carriers arranged in a matrix form, in a row and a column directions of the matrix, the carriers each having a bobbin loaded thereon; a block drive section for similarly moving blocks arranged in a matrix form, in a row and a column direction of the matrix; and a device for lifting a woven three-dimensional fibrous tissue.

FIG. 1

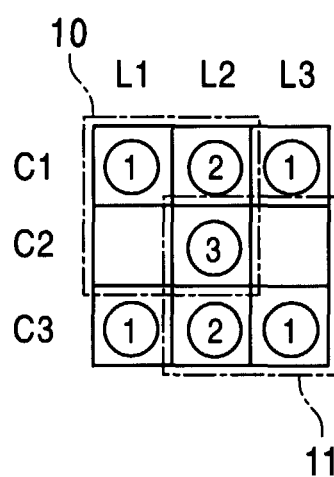


FIG. 2A

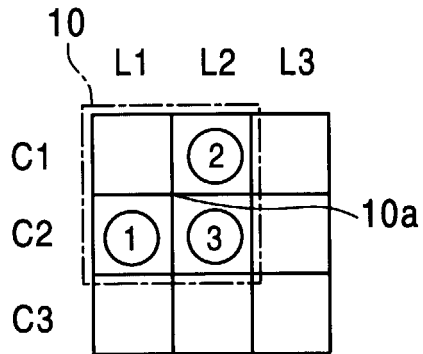


FIG. 2B

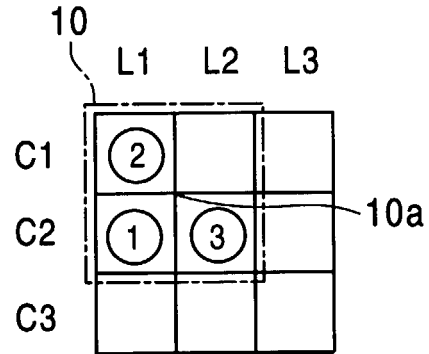


FIG. 2C

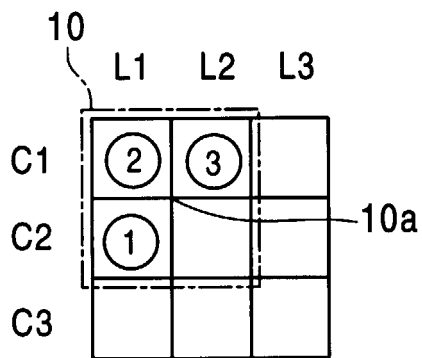


FIG. 2D

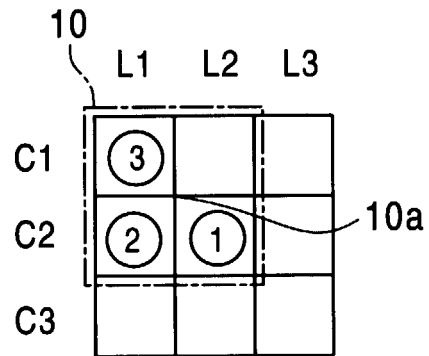


FIG. 2E

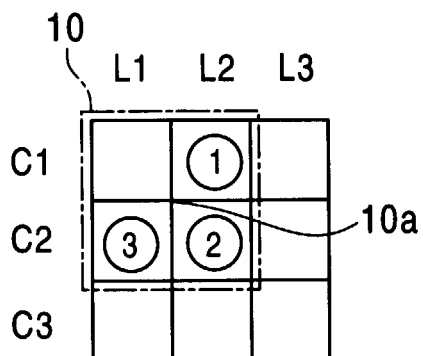


FIG. 2F

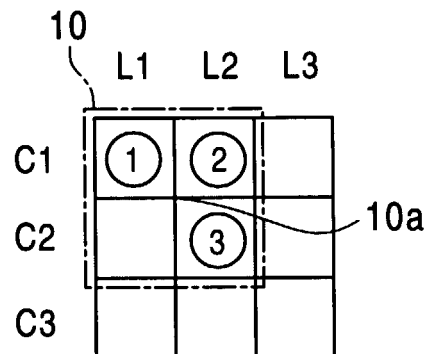


FIG. 3A

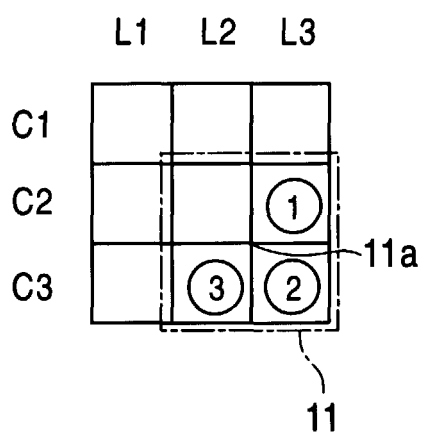


FIG. 3B

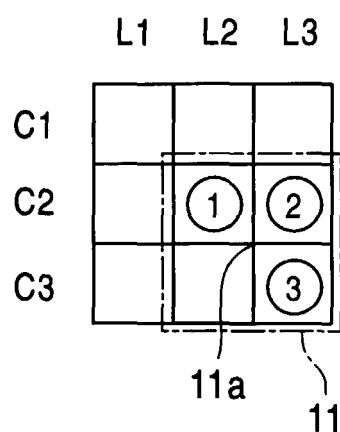


FIG. 3C

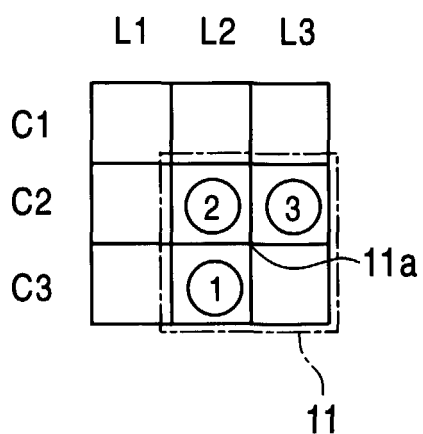


FIG. 3D

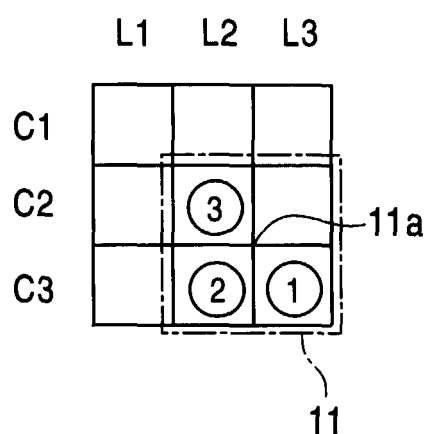


FIG. 4

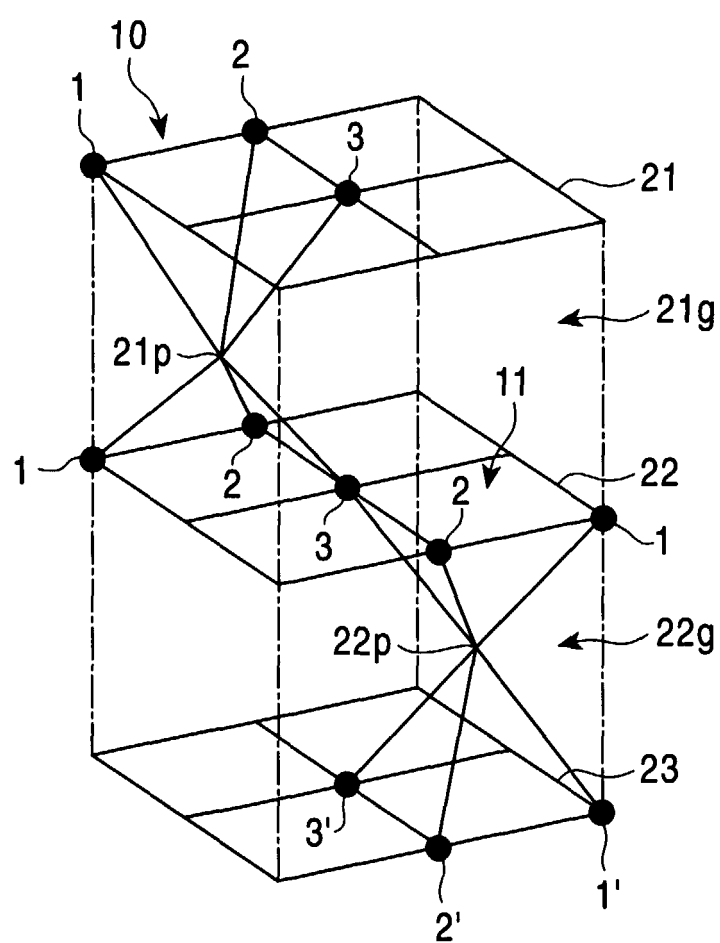


FIG. 5

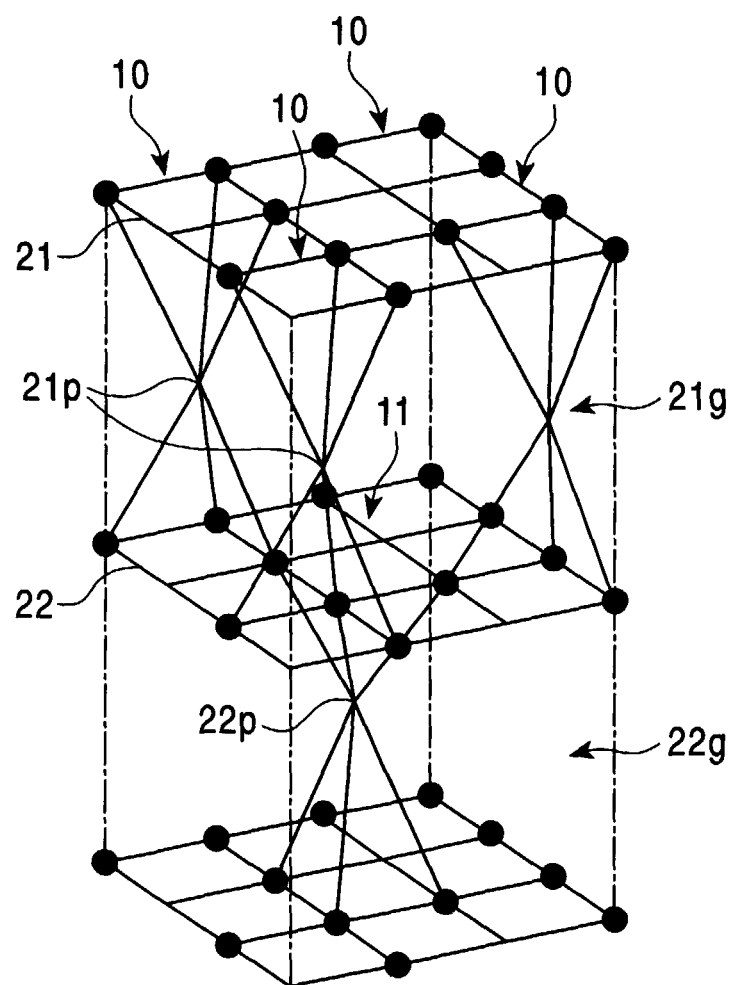


FIG. 6

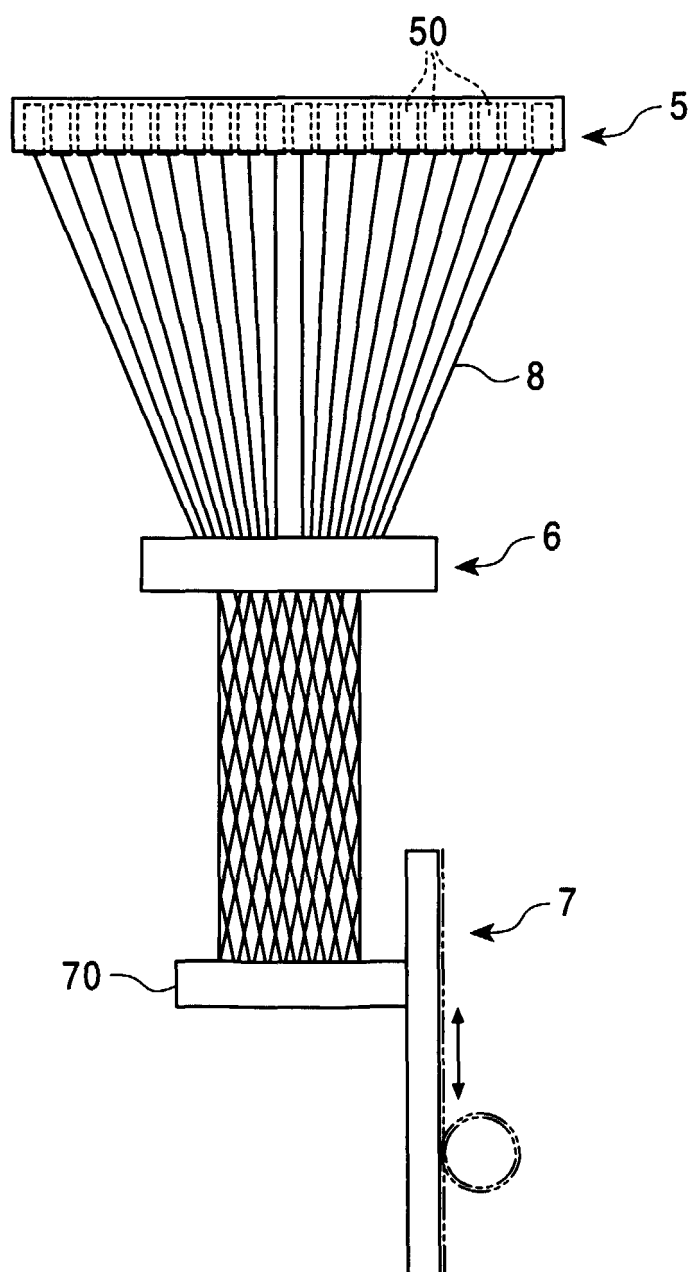


FIG. 7

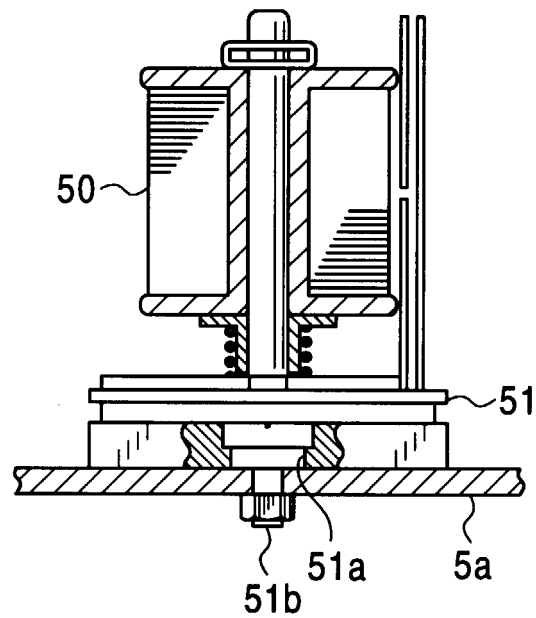


FIG. 8

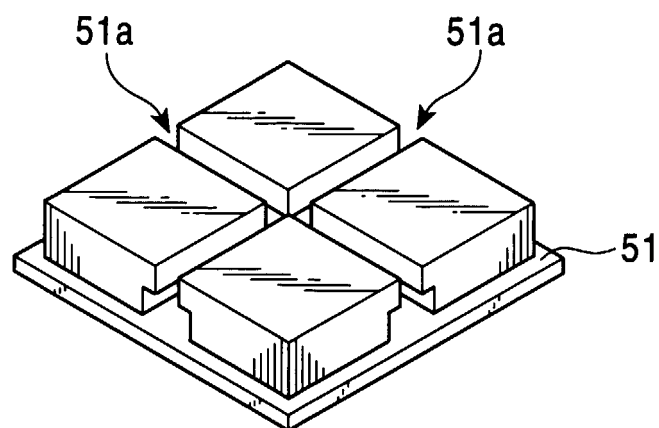


FIG. 9

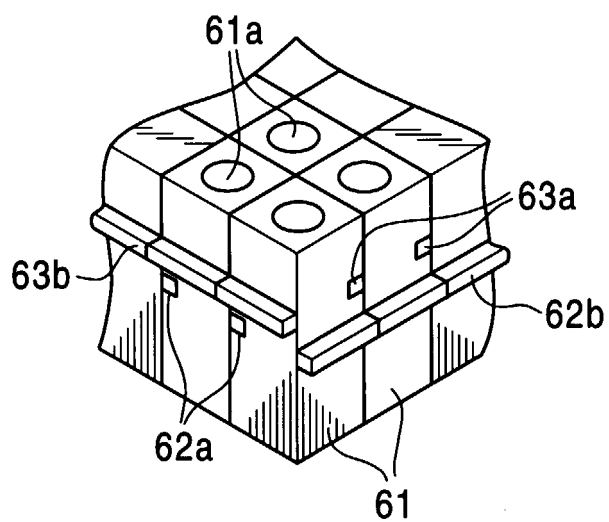


FIG. 10

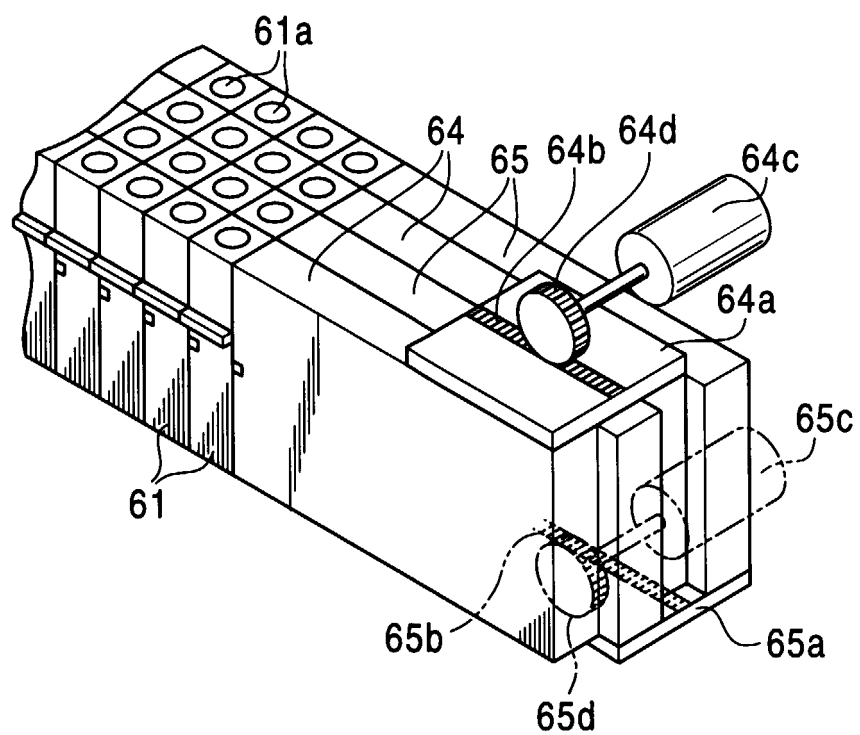


FIG. 11

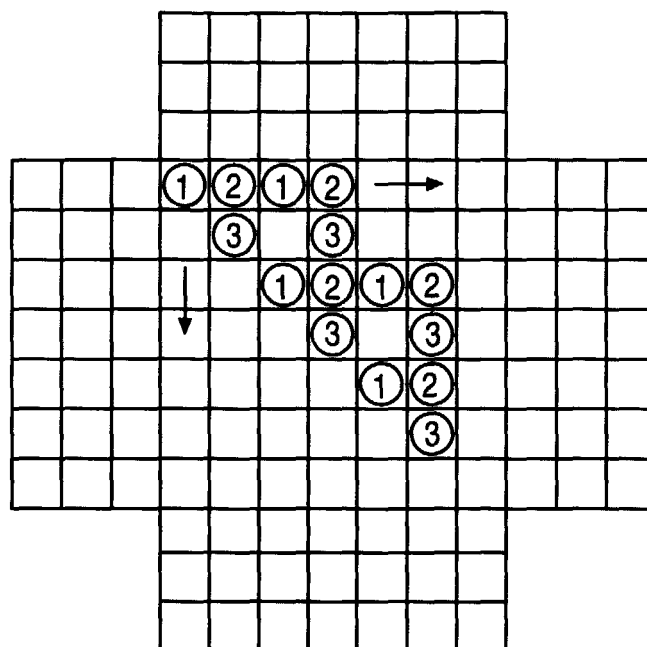


FIG. 12

