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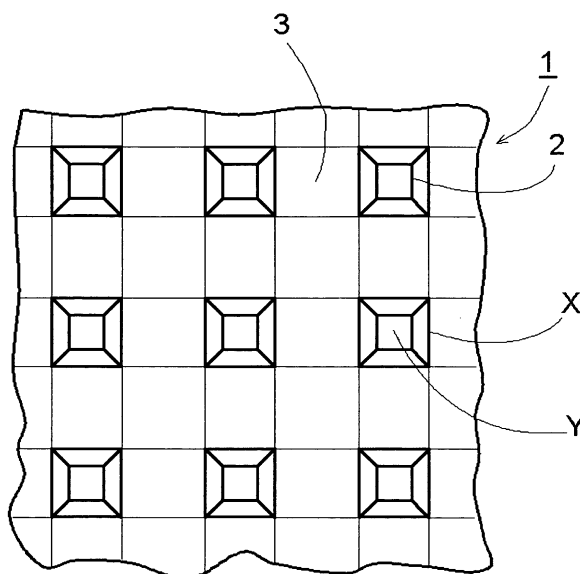
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(54) **TOOL WITH SINTERED BODY POLISHING SURFACE AND METHOD OF MANUFACTURING THE SAME**

(57) An efficiently processible polishing tool, particularly used for a CMP pad conditioner, capable solving problems in a fixing strength for fixing abrasive grains to a base plate and problems in nonuniform polished surface and a method of effectively manufacturing the polishing tool. The polishing tool (1) comprises a polishing

part formed of a super abrasive grain sintered body sintered integrally with the lining material of a cemented carbide. The polishing part comprises a plurality of polishing units (2) with top parts. The top parts are positioned on an approximately same plane. The polishing units (2) are formed by forming a linear groove (3) group in the polishing part.

Fig. 6



Description

[Technical Field]

[0001] The present invention relates to a tool having an abrasive part of sintered superabrasive and a method for the manufacture of the same. More particularly, the invention relates to an abrasive tool for the conditioning of chemical-mechanical polishing (CMP) pads, which are commonly composed of hard urethane. The tool also can be effectively used for processing various semiconductor materials to achieve an efficient and high planarity performance. This invention further relates to an effective method for the manufacture of such tool.

[Technical Background]

[0002] In recent years as technology advances in multi-layer wiring for the production of super LSI devices, CMP has been used as an effective technique for planarizing interlayer insulation films and wafers of metal such as silicon. For the CMP technique polishing pads are employed, which is commonly made of hard urethane foam and which needs to be frequently conditioned on the surface in order to secure a high degree of planarity and wafer polishing rate.

[0003] Pad conditioning has been conventionally practiced with a tool in which diamond particles are fixed to a base plate by electrodeposition. Electrodeposition conditioning tools are known, that comprise such a rotating abrasive tool, for example, that the circular surface of tool has a hollow central region with no abrasive particles thereon. There are further outer circular regions: in the first, next to the central region, smaller superabrasive particles are fixed by electrodeposition on several spaced rows of projections that are in the shape of partial sphere, and in the second, superabrasive particles are electrodeposited with metal on several ring-formed projections (Patent Document 1). Since the superabrasive particles are fixed to the base plate only with nickel metal deposit that physically rests over, their retention is not always enough to give an acceptable tool life, with some particles becoming loosened during a process.

[0004] Another abrasive tool is known whose abrasive material layer comprises particles of diamonds or the like, which are resin-bonded to the rotating circular top flat surface of the tool; the layer is sectioned with radial and concentric slits (Patent Document 2).

However, since such resin bonding does not always produce an adequate retention of the abrasive particles, the tools can achieve rather an insufficient life in some applications. Electrodeposition bonding technique cannot always achieve a sufficient tool life, either.

[0005] Further a dresser is known that comprises a thin film of polycrystalline diamond deposited by chemical vapor deposition on the projections of a base metal working surface (Patent Document 3).

It is apparently difficult, however, to form a diamond thin film by this technique following adequately the irregular surface of the base metal with patterned small indentations and projections, in order to produce sufficient retention of the film or to obtain a tool with a precision high enough to meet the needs, which are more and more demanding.

[0006] As described above, conventional abrasive tools, or pad conditioners, can only have a deposit of abrasive particles with the tops or upper ends not in a uniform but varying level because of the fluctuating particle sizes that those individual particles employed on the base plate (base metal) have. Such feature causes a problem that a part alone of particles that is most protruding from the base plate (base metal) comes to be used in the conditioning process, and the partial excessive loading may cause a severe damage to the particles, eventually even leading to a premature termination of the tool life.

[0007] It may be desired, for elimination of the downtime and costs for pad conditioning, the planarization of silicon or like metal wafers be practiced with a tool wherein particles of diamond or other superabrasive are fixed to the surface of a base plate of rigid metal, in the place of the polishing pad of urethane foam and loose abrasive particles that are conventionally used. That assumes that a high precision uniformity be provided and maintained for the surface of layer of abrasive particles, which are deposited on the base metal plate to provide cutting edges. Such tasks have not been fully solved heretofore, however.

Patent Document 1: JP, A, 2002-337050

Patent Document 2: JP, A, 2004-291184

Patent Document 3: JP, A, 10-071559

[Disclosure of the Invention]

[Tasks to be solved by the Invention]

[0008] One of the objects of the present invention is to provide an abrasive tool capable of efficient processing and an effective method for the manufacture of such tool, wherein the above described problems have been eliminated that

are related to the both retention of abrasive particles to the base plate and the precision of polished surfaces. This invention, in particular, is to provide such tool to be effectively adaptable as CMP pad conditioner that enables an efficient production of high precision surfaces on semiconductor wafers or the like.

5 [Means for Solving the Problems]

[0009] The inventor has found, as a result of devoted and concentrated efforts for a solution to the above described problems, that they could be solved by composing the abrasive part of a plurality of abrasive units of sintered superabrasive particles that are in specific arrangement, and further efforts have lead to this invention.

10 According to the invention is provided an abrasive tool comprising an abrasive part that comprises a layer of sintered superabrasive particles, wherein said abrasive part comprises a plurality of abrasive units that have upper ends arranged on an equal level.

Also provided is such tool, wherein the abrasive part is composed of a layer of sintered superabrasive particles that are joined integrally to a backing of cemented carbide, and said abrasive units are arranged in said abrasive part along
15 groups of linear grooves.

Further provided is such tool, wherein the upper ends of abrasive units have sharpened edges.

Further provided is such tool, wherein the abrasive units are in a shape of truncated or non-truncated pyramid.

[0010] According to the invention also provided is such an abrasive tool, wherein the abrasive units are in a shape of truncated rectangular pyramid that have at least one of the top edges sharpened.

20 Further provided is such abrasive tool, wherein the abrasive units are in a shape of truncated or non-truncated triangular pyramid.

Further provided is such abrasive tool, wherein the abrasive units are in a shape of truncated triangular pyramid that have at least one of the top edges sharpened.

Further provided is such abrasive tool, wherein the abrasive units comprise a linear ridge on the top thereof.

25 Further provided is such abrasive tool, wherein the abrasive units are in a shape of rectangular or triangular pyramid arranged at a pitch of 200 μm or more but not exceeding 1,500 μm .

Further provided is such abrasive tool, wherein the abrasive units are in a shape of non-truncated rectangular or triangular pyramid and has a height of 30 μm or more but not exceeding 200 μm .

Further provided is such abrasive tool, wherein the superabrasive is diamond.

30 Further provided is such abrasive tool, wherein the diamond particles have a nominal particle size of 40 to 60 μm or less.

Further provided is such abrasive tool, wherein the layer of sintered superabrasive particles has a thickness of 0.1 mm or more.

Further provided is such abrasive tool, wherein said abrasive tool is in a circular or annular shape.

[0011] Further provided is such abrasive tool, wherein the abrasive part is in a circular or annular shape.

35 Further provided is such abrasive tool, wherein the abrasive part has an outer diameter of 90 mm or more.

Further provided is such abrasive tool, wherein the abrasive part has a height of 1 mm or less over a bottom of the grooves.

Further provided is such abrasive tool, wherein the abrasive part consists of 2 or 4 equally divided segments that are in a shape of sector with an identical central angle.

40 Further provided is such abrasive tool, wherein said segments each comprise two groups of grooves, a first group is parallel to a radial border of the segment and a second group is arranged to cross perpendicularly to said first group.

Further provided is such abrasive tool, wherein the abrasive part consists of 3 or 6 equally divided segments that are in a shape of sector with an identical central angle.

45 Further provided is such abrasive tool, wherein said segments each comprise three groups of grooves, and a first group of which is arranged parallel to a radial border of the segment and second and third groups are arranged to cross said first group at an angle of 60° and 120°, respectively.

Further provided is such abrasive tool, wherein the grooves are formed by wire electrical discharge machining (W-EDM).

Further provided is such abrasive tool, wherein said abrasive tool is a CMP pad conditioner.

50 **[0012]** According to the invention there is provided a method for the manufacture of an abrasive tool having an abrasive part that comprises a layer of sintered superabrasive particles, wherein said abrasive part comprises a plurality of abrasive units that have upper ends arranged on an equal level, comprising:

1) providing a sintered composite that comprises sintered superabrasive particles that are as a whole joined to a backing material of cemented carbide,

2) leveling said composite surface, and

55 3) cutting in said composite surface to form groups of linear grooves and an array of abrasive units along said grooves.

Also provided is such method, comprising:

- 1) providing a sintered composite composed of a layer of sintered superabrasive particles that are joined integrally to a backing of cemented carbide,
- 2) cutting said composite to yield a segment in a shape of sector,
- 3) collecting a plurality of segments, which are identical in geometry to the one obtained in 2) with an equal central angle,
- 4) arranging said segments closely to each other, so as to form a composite surface in entire circular or annular shape, fixing said segments to a base plate on a flat surface thereof, and
- 5) cutting in said segments to produce an array of abrasive units on said composite, whereby group of grooves are formed parallel to a radial border of each segment as obtained in 4).

Further provided is such method as described above, wherein the abrasive part, as worn with abrasive units having decreased heights, is cut in along said grooves by wire-EDM.

[Effects of the Invention]

[0013] With an abrasive part comprising sintered superabrasive particles, the abrasive tool of the present invention is advantageous to those conventional techniques, in that a substantially increased retention of superabrasive particles is secured and that thus the risky popping out of superabrasive particles is minimized due to the sintering process, which is conducted in a condition of combined ultrahigh pressure and high temperature where diamond is the thermodynamically stable phase of carbon, while the bond metal is molten. A higher retention can be achieved especially in the case where diamond is employed for the superabrasive, since the diamond particles are firmly joined with each other as a result of partly dissolution by the metal on the surface of the diamond.

[0014] Moreover, while it is often difficult to obtain an entire large diameter abrasive part, complete with an adequate overall soundness, this can be realized by the present invention, which can provide such a large area of abrasive part without a significant deformation at a high degree of precision, wherein a superabrasive particle sintered body is manufactured from a plurality of partial abrasive parts, because abrasive parts of a large diameter are made by cutting fan-shaped partial abrasive parts of a large diameter from a superabrasive particle sintered body of a small diameter in which unevenness of sintering does not occur and by combining a plurality of said partial abrasive parts.

[0015] With the abrasive part of the invention, when the abrasive units have worn out and diminished in the work operation, abrasive units and grooves can be reconstructed several times, readily by wire-EDM, for example, (along each of the grooves), since the abrasive units are formed on the abrasive part that comprises an adequately thick surface layer of sintered superabrasive particles.

[0016] Further in the invention, since the abrasive units are cut out of a compact or block of sintered superabrasive or, typically, diamond particles by means of wire EDM or like electric discharge machining process, they can be formed freely and as desired and thus a higher degree of tool precision can be readily achieved in the formation of triangular or rectangular pyramids, with the technique of the invention than with conventional art, in the level of upper ends and groove bottoms of the abrasive units.

In particular, when used as CMP pad conditioner, the abrasive tool of the invention is very effective for an efficient production of a high precision surface of semiconductor metals.

[Brief Description of the Drawings]

[0017]

Fig. 1 shows an explanatory view (plan) of an abrasive tool (Example 1) according to one embodiment of the present invention.

Fig. 2 is an explanatory view (plan) showing an abrasive tool (Example 2) according to another embodiment of the invention.

Fig. 3 is an explanatory view (plan) showing an abrasive tool according to still another embodiment of the invention.

Fig. 4 is an explanatory view (plan) showing an abrasive tool according to still another embodiment of the invention.

Fig. 5 is a detailed view of a part in Fig. 4.

Fig. 6 is a detailed view of a part in Fig. 1.

Fig. 7 shows an explanatory view (plan) of a construction example for the abrasive units of the abrasive tool according to the invention.

Fig. 8 shows an explanatory view in section as taken along A-A in Fig. 7.

Fig. 9 shows an explanatory view (plan) of another construction example for the abrasive units of the abrasive tool according to the invention.

Fig. 10 shows an explanatory view in section as taken B-B in Fig. 9.

Fig. 11 shows a schematic illustration of a wire electric discharge machining process applicable to the method for the manufacture of the abrasive tool according to an embodiment of the invention.

Fig. 12 shows an explanatory view (plan) of an abrasive tool according to another embodiment of the invention.

Fig. 13 shows an explanatory view (plan) of an abrasive tool according to another embodiment of the invention.

5 Fig. 14 shows an explanatory view (plan) of an abrasive tool according to another embodiment of the invention.

Fig. 15 shows an explanatory view (plan) of an abrasive tool according to another embodiment of the invention.

Fig. 16 shows an explanatory view (plan) of an abrasive tool according to another embodiment of the invention.

Fig. 17 shows an explanatory view (plan) of an abrasive tool according to another embodiment of the invention.

10 [Explanation of the Numerals]

[0018]

	1	Abrasive tool
15	2	Abrasive unit
	3	Groove
	4	Abrasive tool
	5	Abrasive unit
	6	Groove
20	7	Abrasive tool
	8	Abrasive unit
	9	Groove
	10	Abrasive part
	12	Group of parallel grooves in a first direction
25	13, 14	Side face of a (truncated) pyramid
	16	Group of parallel grooves in a second direction
	17, 18	Sloping side face of a pyramid
	19	(Truncated) rectangular pyramid-shaped abrasive unit
	22	Group of parallel grooves in a first direction
30	23, 24	Sloping side face of a triangular pyramid
	25	Abrasive part
	27	Group of parallel grooves in a second direction
	28, 29	Sloping side face
	31	Group of parallel grooves in a third direction
35	32, 33	Sloping side face
	34	Triangular pyramid-shaped abrasive unit
	41	Wire for electric discharge machining
	42	Abrasive part
	43, 44	Abrasive unit
40	51	Abrasive part
	52	Circular base plate
	53	Linear groove group
	55	Second group of grooves
	58	Sloping peripheral part
45	61	Abrasive part
	62	Circular base plate
	63	Linear groove group
	65	Second group of grooves
	66	Third group of grooves
50	68	Sloping peripheral part
	69	Sloping peripheral part
	71	Abrasive part
	72	Circular base plate
	73	Linear groove group
55	74	Border
	75	Second group of grooves
	81	Abrasive part
	82	Circular base plate

	83	Linear groove group
	84	Border
	85	Second group of grooves
	91	Abrasive part
5	92	Circular base plate
	93	Linear groove group
	94	Border
	95	Second group of grooves
	96	Third group of grooves
10	101	Abrasive part
	102	Circular base plate
	103	Linear groove group
	104	Border
	105	Second group of grooves
15	106	Third group of grooves

[Best Mode for Carrying out the Invention]

[0019] The present invention uses as a material compacts of sintered particles of superabrasive, such as diamond and c-BN (cubic boron nitride), which can be prepared by an established technique, whereby superabrasive particles are processed in a combined condition of ultra-high pressure and high temperature. Since products as recovered from the process may suffer a significant deformation, which has to be preliminarily removed to produce a roughly flat surface by mold electric discharge machining, for example. Then created are abrasive units, which are to come into direct contact with works, by stepwise forming the grooves and side faces of projections, following the mode of the invention specifically described herein.

Such preliminary flattening may be saved with some commercially available compacts as having a ready flat surface. For the formation of such grooves various techniques are available, including wire-EDM, mold-EDM, other precision EDM techniques and laser machining; wire EDM is preferred, though, especially for producing a sharp pointed top of abrasive units.

Wire EDM processes are usually program operated, whereby an electrode wire is driven along over a work surface of sintered superabrasive particles to cause electric discharge between the wire and certain ingredient of the work, thus removing the material.

[0020] In the abrasive tool of the present invention, such units can be created, for example, by cutting in several crossing groups of grooves, hereinafter also referred as "groups of separation /sectioning grooves", on a surface, either circular or annular with a central hole, of a compact of sintered superabrasive particles, to provide a sectioned abrasive surface. Alternatively they can be formed by EDM using a mold electrode that has a correspondingly patterned mold surface.

Groups of linear grooves are conveniently available to be formed either on the surface of sintered superabrasive particles or the electrode surface.

[0021] Such groups of separation sectioning grooves can be arranged in various ways. They can be formed on a circular compact, for example, in two (Fig. 1) or three (Fig. 2) groups of parallel linear [grooves] that cross each other at 90° or 60°; respectively; and extend from a peripheral point in one side of the circle on the outer circumference to a corresponding point on the opposite side at regular intervals. In those cases rectangular and triangular abrasive units are created, respectively.

The abrasive units may also have a shape with a linear ridge or the like on the top (Fig. 3 shows an abrasive unit with ridges running from one end to the other of the abrasive part; in Figs. 4 and 5, the base part of each abrasive unit has a rectangular shape). The ridges are formed essentially parallel to the longer sides in the case of rectangular based abrasive unit, as the EDM electrode wire is driven straight and creates in a pass each groove and adjacent sloping sides. Further, it is preferred for the use as a CMP conditioner, while not necessary for other uses, that an identical pitch be set for the both lines and rows in the arrangement of rectangular pyramid abrasive units.

[0022] In the examples described above, it is necessary that each abrasive unit should have an upper end adequately small, while adjacent abrasive units be sufficiently spaced from each other, so that they can work effectively in the abrasive processes. Fig. 6, which shows schematically, as an example, a detailed view of a part of the abrasive tool 1 shown in Fig. 1, reveals some area at the top of abrasive units. The proportion of such area (Y) to the base area (Y) of abrasive unit 2, can be determined by subtracting the total sectional area of all the adjacent grooves 3 from the radial sectional area of the whole layer of sintered superabrasive particles; proportions of 50 % or less and, in particular, 2 to 25 % have been found to yield good results.

Further the abrasive unit should preferably have a top angle of 30° to 120° and in particular 60° to 90°, and, to be more

specific, 70° to 80°, approximately.

[0023] The depth of the grooves (or the height of the abrasive units over the groove bottom) should be no less than 0.1 mm but not in excess of 1 mm; particularly appropriate is a depth no less than 0.15 mm but not in excess of 0.3 mm. Grooves too shallow are not effective for the elimination of debris from the work, frequently causing an excessively increased polishing resistance. Grooves formed too deep causes, on the contrary, can lead to abrasive units with insufficient strength in addition to a necessary increased depth of layer of sintered superabrasive particles.

[0024] While it may be convenient that the abrasive units be formed in a prism with a linear or a triangular, rectangular or more angular top, the lateral faces be vertical to the base plate, and the horizontal cross-sections be uniform throughout the height, the free cutting quality of the tool can be improved by providing at least one lateral face and, especially the one on the leading side of the rotation, inclined backward in relation to a plane parallel to the axis.

As for the shape of the abrasive units, truncated pyramids, such as rectangular and triangular ones, are favorable for sloping lateral faces around, and pointed top, non-truncated pyramids are even further favorable for the better cutting ability.

Further better performance can be achieved in free-cutting quality with an arrangement of abrasive units in the shape of prism or pyramid, by grinding with a specialized tool one or more, rectangular or triangular, side faces in different directions, in order to sharpen the edge or point at the top.

In particular, such sharpening process is practiced for one side of the polygonal (typically, triangular or rectangular) top of an abrasive unit in the shape of polygonal prism or truncated pyramid with a polygonal top face; a good free cutting quality can be achieved with abrasive units in rectangular or triangular pyramid, without such sharpening.

[0025] The abrasive part of the present invention is prepared with an outer diameter of 90 mm, with the layer of sintered superabrasive particles having a thickness no less than 0.1 mm but not in excess of 1 mm. For the layer of sintered superabrasive particles, compacts of polycrystalline diamond (PCD) and polycrystalline cubic boron nitride (PCBN) are available, which have on one side a backing block of carbide alloy, that is a tungsten carbide based composite, or another VIa metal carbide, of the periodical table, based composite. The compact is adhered on the backing face to the base plate of a tool; the opposite face is to be provided with the grooves for the used as an abrasive part.

[0026] Such compacts are available typically in disk shape, as a product of a process on a uniaxial hydrostatic press under ultrahigh pressure and high temperature conditions. In case a compact of intended diameter is not available, if the flatness requirement is not very close, the tool of the invention may be realized by preparing the abrasive part in several segments, which are then assembled into one.

[0027] For the construction of an abrasive part with several segments, it is appropriate to form a groove along the boundary lines, for achieving an arrangement of abrasive units in a distribution as uniform as possible over the whole surface of the abrasive part. Here a good arrangement without disorder of abrasive units can be obtained, except for some part close to the periphery, with an abrasive part divided into two or four segments, by forming two groups of parallel grooves, crossing each other at 90° and thus abrasive units in the shape of rectangular pyramid, either truncated or non-truncated.

In the case of the abrasive part composed of three or six segments, on the other hand, a similar good arrangement can be obtained, by cutting in three groups of regularly spaced parallel grooves that cross each other at 120° and also three lateral faces to create an array of abrasive units in the shape of truncated or non-truncated triangular pyramid.

[0028] In short, in the case of rectangular pyramid, linear grooves are first formed on the surface of the abrasive part by electric discharge, by feeding an EDM electrode wire along the surface of the abrasive part. Next, the wire is driven in the Z-axis direction relative to the surface of abrasive part, in order to pass along and cut the abrasive part to create a side face of the (truncated) rectangular pyramid adjacent to the groove. The operation is repeated to complete the groups of grooves.

[0029] In the invention, the top part of the pyramid comprises one or more diamond particles. So any pyramid in geometrical sense cannot be obtained because finest diamond particle has a definite volume. In the invention, however, we refer as not-truncated when the pyramid in question has a top diameter significantly small in relation to the base diameter. Obviously a truncated pyramid has a top larger in each direction than a corresponding pyramid.

[0030] For the production of (truncated) rectangular pyramid abrasive units, such as shown in Figs. 7 and 8, for example, first formed on the surface of an abrasive part 10 are a group of parallel grooves (one of which is representatively designated as 12, likewise applicable hereinafter) at a regular spacing in a first direction 11 and two side faces (representatively designated as 13 and 14, likewise applicable hereinafter) of rectangular pyramids. Then the abrasive part 10 is rotated, together with the base plate, by 90° about the axis of the annulus and, thereafter, another group of parallel grooves (one of which is representatively designated as 16, likewise applicable hereinafter) are formed in a second direction 15 similarly to the above, as well as the two other side faces (representatively designated as 17 and 18, likewise applicable hereinafter) of the pyramids. Thus provided are two groups of parallel grooves, which cross each other at a right angle, and (truncated) rectangular pyramid abrasive units 19, which are arranged along said grooves. The sectional view taken along A-A in Fig. 7 is shown in Fig. 5.

[0031] in the above description,

For the production of triangular pyramid abrasive units such as shown in Figs. 9 and 10, formed are a group of parallel grooves 22 in a first direction 21 and sloping faces 23, 24 of the pyramids adjacent to the grooves. Then, the abrasive part 20 is rotated by 120° about the central axis of abrasive part 25, and, in the same way, another group of parallel grooves 27 are formed at a regular interval in a second direction 26 and adjacent sloping side faces 28, 29 are formed by wire EDM (electric discharge machining).

Upon completion of the process, the abrasive part is rotated again by 120° and the same process is resumed to form another group of parallel grooves 31 in a third direction 30 to cross the other two at 120°, as well as side faces 32, 33 adjacent thereto of triangular pyramid abrasive units 34, thus accomplishing the arrangement of pyramids along the grooves.

[0032] For the abrasive units described above, it is appropriate that, either triangular or rectangular pyramid abrasive units have a protrusion height of no less than 30 μm but not in excess of 200 μm above the level of groove bottom. Protrusions too low may tend to cause a direct contact of the base of abrasive part with the work, such as CMP pad, resulting in inadequate conditioning performance.

Protrusions too high may cause, in contrast, to reduce the relative strength of the abrasive units, while an excessively thick layer becomes necessary for the sintered superabrasive particles.

On the other hand, the intervals, or a pitch, between adjacent grooves should not exceed 1500 μm, while the lower limit can be set, depending on the wire diameter to be employed for wire electric discharge machining, at something about 200 μm, for example.

[0033] The performance of the abrasive units depends on the particle size of the superabrasive particles contained in the top part of the (truncated) pyramid of abrasion unit. For the superabrasive of diamond particles, or the abrasive part being composed of sintered diamond (PCD), either 40 to 60 μm or less, 8 to 16 μm or less or, 0 to 2 μm can be used as an appropriate particle size for sintered diamond; among such sizes nominal sizes of or smaller than 8 to 16 μm or less are preferable, and 0 to 2 μm, in particular, has been found most appropriate.

[0034] A compact of sintered diamond particles to be used for the abrasive part of the present invention can be prepared by subjecting loose diamond particles to a combined condition of ultra-high pressure and high temperature where diamond is the thermodynamically stable phase, together with a block of cemented carbide for the backing material, and, as necessary, bonding metal such as cobalt. The abrasive part of the invention can be realized by cutting out a portion, which then is surface processed to create abrasive units, by precision EDM such as, typically, wire electric discharge machining. In the wire electric discharge machining, commonly, the electrode wire is struck against the surface of sintered diamond particles to initiate an electric discharge. The wire then is held close to maintain the discharge and moved horizontally along the surface of sintered diamond particles so as to carve a groove with a desired width and further side faces of abrasive units.

The groove can be also formed, as shown in Fig. 11, by driving the EDM electrode wire 41, after striking the work 42 of sintered diamond, not horizontally but in the direction designated with arrows in the drawing, thus forming a groove such that the tangential planes to the wire correspond to the sloping faces of opposed abrasive units 43, 44, and, then the side faces of the pyramids on each side of the groove, with the groove level taken as the reference plane. A thus constructed groove has a round bottom, showing an approximately arced cross section. Such designed abrasive unit is less susceptible to the stress concentration problem and has a higher strength (or longer service life) in abrasive processes than abrasive units with grooves having a flat bottom or angled corners.

[0035] The tool of the present invention can be realized in various shapes as illustrated in Figs. 12 to 17 by way of examples. For rather small tools, the abrasive part can be prepared in an entire continuous circular or annular form as illustrated in Figs. 12 and 13 by way of examples; however, as shown in Figs. 14 to 17 the abrasive part of the invention can be composed of several divided segments without any problem, so large annular abrasive parts with an outer diameter of 95 mm or more can also be easily obtained.

[0036] For an annular construction, it is preferable that the radial width be no less than 15 mm. The abrasive part can be also realized as a solid disk (without central hole) instead of an annular shape, especially when the design does not require a central hole. Moreover, as shown in Figs. 12 and 13, it is preferred to provide a sloping margin which is 1 mm or more wide as measured in the radial direction, on the outer diameter of a solid circular abrasion part, and both on the inner and outer diameter of annular abrasion part, for the prevention of any damage by accidental contact with the work of those margins with abrasive units.

[0037] For the construction of abrasive part with several divided segments, as illustrated by way of examples in Figs. 14 to 17, the disturbance or irregularity in abrasive unit arrangement and resulting effects on the work (CMP pad) caused by divide-and-assembled construction can be effectively either avoided or reduced to a minimum by providing a groove on and along each border. Here the number of division and shape of abrasive units available are related to each other: the rectangular pyramid design (Figs. 14 and 15) is available for the two (central angle of 180°) and four (central angle of 90°) segment composition, while triangular pyramid design (Figs. 16 and 17) is available for the three segment composition (central angle of 120°).

[0038] For the manufacture of a large diameter abrasive tool, segments of abrasive part are prepared by cutting out

from a compact of sintered particles of superabrasive (or diamond, preferably) large enough to give the intended size, and machined to the designed shape and dimensions. A plurality of such objects are collected and fixed with adhesive on a solid or annular, with a concentric circular hole at the center, circular surface of a rigid base plate of steel, in order to make such a large, solid circular or annular abrasive part.

Six, four, three or two sector shaped segments of sintered diamond particles of 60°, 90°, 120° and 180° central angle, respectively, are placed side by side on the radius (lateral joining). A 120° sector can be substituted for two 60° sectors. In this case the two 120 sectors should be arranged point-symmetrically relating to the center.

[0039] The segments of abrasive part 51, 61, 71, 81, 91, 101 are joined on the carbide backing side to the flat circular surface of the circular base plate 52, 62, 72, 82, 92, 102, respectively, so as to provide as a whole a circular or annular abrasive part.

[0040] The compact of sintered superabrasive particles is joined to the base plate, then subjected to wire electric discharge machining, in order to form on the surface of the compact one group 53, 63, 73, 83, 93, 103 of parallel linear grooves at regular intervals, whereby an electric discharge is taken place between the electrode wire and the compact of sintered superabrasive particles. Here, as the electrode wire is driven in parallel with the top or bottom face, to enter, via the preliminarily flattened surface, and cut in the layer of sintered superabrasive (typically a sintered diamond (PCD)) and or, in case of a thin layer of sintered superabrasive, further down to the cemented carbide layer.

[0041] Then, the electrode wire is driven in the direction of the thickness of the sintered superabrasive (Z-axis direction) and thus to cut out grooves. With a 360° continuous surface, either solid circular or annular, the first groove of a group, for either rectangular or triangular pyramid abrasive units, may be begun to form at any position. With a surface composed of several segments, however, each of the abrasive part segment borders 54, 64, 74, 84, 94, 104 has to be first provided with a groove formed along it. After that, the other grooves are formed in parallel on both sides thereof at a regular pitch over all the surface.

[0042] Upon the formation of a group of parallel grooves in one direction on the surface of the compact of sintered superabrasive particles, the compact is rotated about the central axis of the base plate, together with the base plate attached thereto by α being the angle of groove crossing. Then formed similarly to the above, a second group of parallel linear grooves 55, 65, 75, 85, 95, 105 at regular intervals, and sloping side faces adjacent to each groove. Here α is equal to 90° for 180° and 90° sectors, with the abrasive unit being in the shape of truncated or non-truncated pyramid. For a 120° or 60° sector on the other hand, the compact of sintered superabrasive is rotated by 60° (or 120°), a second group of parallel linear grooves are formed at the intervals similarly, as well as side faces adjacent to each groove; then rotating the compact by another 60° (or 120°) (by 240° relating to the first group of grooves) a third group of parallel linear grooves 56, 66, 76, 86, 96, 106 and adjacent side faces are further and likewise formed. For a continuous solid circle or annular material, α may be either 90° or 60°.

[0043] In the EDM operation described above, the grooves and pyramids, either triangular, rectangular, truncated or non-truncated, can be formed to have upper ends lying close to a level that is in parallel with the work bottom lying, by driving the electrode wire while holding a distance in the direction of thickness from the compact bottom.

[0044] In the present invention, it is not necessary that the triangular or rectangular pyramids of abrasive units be completely composed of sintered superabrasive particles; instead pyramids, either truncated or non-truncated, are also effective that are composed of sintered superabrasive down from the top to a depth (length) of around 60 μm , with the lower portion composed of carbide alloy.

Now, the invention will be described more specifically with examples.

[EXAMPLE 1]

[0045] An abrasive tool 1, having a structure schematically shown in Fig. 1, was prepared. A 90 mm diameter PCD block was used as a tool material, which had a 0.6 mm thick layer of sintered diamond joined with cemented carbide by simultaneous sintering.

The PCD block was subjected to an electric discharge machining (EDM) in order to flatten the surface of the sintered diamond layer and cut in a group of 560 μm wide parallel linear grooves 3 to form abrasive units with a square top of 260 μm sides. Here the area of the top part (not shown) of the abrasive units 2 corresponds to about 10 % the cross-section of the of sintered superabrasive layer, excluding the circumference (groove 3).

The edges of the top square were sharpened, and the tool was used as a CMP conditioner.

[EXAMPLE 2]

[0046] An annular abrasive tool 4, schematically shown in Fig. 2, was prepared. Four 90° sectors of sintered PcBN with an outer radius of 60 mm and an inner radius of 24 mm, were cut out by EDM, out of a PcBN block, which had a 0.6 mm thick layer of sintered c-BN joined with cemented carbide by simultaneous sintering, to be used as tool material. The sectors were stuck together to a base plate made of SUS stainless steel, so as to form as a whole a complete circle.

The surface of the sintered diamond layer was polished and flattened, and subjected to wire EDM to form a group of 560 μm wide parallel linear grooves 6 and abrasive units 5 having a square top with 350 μm sides. In this case, the area of the top of the abrasive units corresponded to 7 % of the total cross section of the sintered superabrasive particle layer.

The obtained tool was sharpened by the same technique as in Example 1, and used for polishing the surface of silicon wafers.

[EXAMPLE 3]

[0047] An abrasive tool, having a structure such that schematically shown in Fig. 12, was manufactured. As a material for the abrasive part a 100 mm diameter PCD compact was used, which was composed of 0.5 mm thick layer of sintered diamond particles with a nominal particle size of 40 to 60 μm that were integrated by simultaneous sintering with cemented carbide (WC - 8 % Co); the compact was fixed with an epoxy adhesive to a 108 mm diameter circular base plate of SUS 316 stainless steel.

Next, the surface of the PCD layer was flattened by die-sinking EDM; then 200 μm wide linear grooves were formed on the PCD layer to pass through the centre of the material by cutting in by wire electric discharge machining. Furthermore, grooves were formed to the required width, while the side faces of pyramids were cut out, by driving the wire towards the side faces or in a direction (Z-axis direction) parting from the base plate.

The above operation was repeated to form on the whole material face a group of parallel grooves at an 800 μm interval and roof-shaped projections with a top angle of 90°.

Then the whole was rotated by 90° about the central axis, and a second group of parallel grooves were formed to cross the first group of grooves at a right angle, by operating the wire electric discharge machining under the same conditions. At the same time, the side faces of the pyramids were cut out in the transversal direction, thus accomplishing the formation of a group of 200 μm high rectangular pyramids, as shown in Figs. 7 and 8,

[EXAMPLE 4]

[0048] The operations set forth in Example 3 were repeated to prepare an abrasive tool having rectangular pyramid abrasive units. A compact of PCD having a 100 mm outer diameter and 70 mm inner diameter was used for an abrasive part, which was composed of a 0.5 mm thick layer of sintered diamond particles of 0 to 2 μm nominal particle size, integrated with cemented carbide.

First, 140 μm wide a linear groove was formed on the flattened PCD layer surface to pass via the centre of the material by wire electric discharge machining. The EDM process was further operated to extend the groove to a designed width and to cut out side faces of the pyramids. The process was repeated to form a group of parallel grooves at 200 μm intervals and roof-shaped protrusions of top angle of 60° on and over the whole material face:

[0049] Next, the whole was rotated by 90° about the central axis and, then, the wire electric discharge machining process was operated again to form a second group of parallel grooves under the same conditions and, at the same time, to cut out another side faces to accomplish 200 μm high rectangular pyramids.

[EXAMPLE 5]

[0050] Various segments given below of abrasive part were used to manufacture the tools of respective construction. The diamond particles of the sintered diamond particles in each case had a nominal particle size of 20 to 30 μm . The wire EDM processes were substantially identical, except that, the tool material was rotated twice in the case of triangular abrasive units, by 60° each time, while only once by 90° in the case of rectangular pyramid abrasive units.

The process conditions and results are shown in the table below.

[0051]

[Table 1]

No.	Abrasive body (part)				abrasive unit	
	shape	outer radius mm	inner radius mm	groove interval (top interval*) μm	shape	height μm
1	180° sector	120	60	600	rectangular pyramid	80
2	120° sector	120	60	400	triangular pyramid	68

(continued)

No.	Abrasive body (part)				abrasive unit	
	shape	outer radius mm	inner radius mm	groove interval (top interval*) μm	shape	height μm
3	90° sector	120	60	1200	rectangular pyramid	160
4	60° sector	120	30	1000	triangular pyramid	138
* The top interval is applicable to triangular pyramids at run numbers 2 and 4.						

[0052] Each of the tools obtained was used as a CMP pad conditioner and achieved a good result.

[Industrial Applicability]

[0053] The abrasive tool of the present invention can be used for different types of abrasive tools; however, it is particularly preferred as disk-type rotating abrasive tool. While the tool is particularly adapted for the use as a CMP pad conditioner, but it is also suitable for directly polishing the wafer surfaces of semiconductor metal and the like. Additionally the tool can be applied for high precision machining of various work materials.

Claims

1. An abrasive tool comprising an abrasive part that comprises a layer of sintered superabrasive particles, wherein said abrasive part comprises a plurality of abrasive units that have upper ends arranged on an equal level.
2. The abrasive tool as claimed in claim 1, wherein said abrasive part is composed of a layer of sintered superabrasive particles that are joined integrally and to a backing of cemented carbide, and said abrasive units are arranged in said abrasive part along groups of linear grooves.
3. The abrasive tool as claimed in claim 1 or 2, wherein said upper ends have sharpened edges.
4. The abrasive tool as claimed in claim 1 or 2, wherein said abrasive units are in a shape of truncated or non-truncated rectangular pyramid.
5. The abrasive tool as claimed in claim 4, wherein said abrasive units are in a shape of truncated rectangular pyramid that has a sharpened edge on an upper end thereof.
6. The abrasive tool as claimed in claim 1 or 2, wherein said abrasive units are in a shape of truncated or non-truncated triangular pyramid.
7. The abrasive tool as claimed in claim 6, wherein said abrasive units are in a shape of truncated triangular pyramid that has a sharpened edge on an upper end thereof.
8. The abrasive tool as claimed in claim 1 or 2, wherein said abrasive units comprise a linear ridge on the top thereof.
9. The abrasive tool as claimed in any one of claims 1 to 7, wherein said abrasive units are in a shape of non-truncated, rectangular or triangular pyramid arranged at a pitch of 200 μm or more but not exceeding 1,500 μm .
10. The abrasive tool as claimed in claim 9, wherein said abrasive units are in a shape of non-truncated, rectangular or triangular pyramid and has a height of 30 μm or more but not exceeding 200 μm .
11. The abrasive tool as claimed in any one of claims 1 to 10, wherein the superabrasive is diamond.
12. The abrasive tool as claimed in claim 11, wherein said superabrasive being diamond has a nominal particle size of 40 to 60 μm or less.

13. The abrasive tool as claimed in any one of claims 1 to 12, wherein said sintered superabrasive has a layer thickness of 0.1 mm or more.
14. The abrasive tool as claimed in any one of claims 1 to 13, wherein said tool is in a circular or annular shape.
15. The abrasive tool as claimed in claim 14, wherein said abrasive part is in a circular or annular shape.
16. The abrasive tool as claimed in claim 15, wherein said abrasive part has an outer diameter of 90 mm or more.
17. The abrasive tool as claimed in any one of claims 2 to 16, wherein said abrasive part has a height of 1 mm or less over a bottom of the grooves.
18. The abrasive tool as claimed in any one of claims 14 to 17, wherein said abrasive part consists of 2 or 4 equally divided segments that are in a shape of sector with an identical central angle.
19. The abrasive tool as claimed in claim 18, wherein said segments each comprise two groups of grooves, a first group is parallel to a radial border of the segment and a second group is arranged to cross perpendicular to said first group.
20. The abrasive tool as claimed in any one of claims 14 to 17 wherein said abrasive part consists of 3 or 6 equally divided segments that are in a shape of sector with an identical central angle.
21. The abrasive tool as claimed in claim 20, wherein said segments each comprise three groups of grooves, a first group is arranged parallel to a radial border of the segment and second and third groups are arranged to cross said first group at an angle of 60 degrees and 120 degrees, respectively.
22. The abrasive tool as claimed in any one of claims 2 to 21, wherein said grooves are formed by wire electrical discharge machining (W-EDM).
23. The abrasive tool as claimed in any one of claims 1 to 22, wherein said abrasive tool is a CMP pad conditioner.
24. A method for the manufacture of an abrasive tool having an abrasive part that comprises a layer of sintered superabrasive particles, wherein said abrasive part comprises a plurality of abrasive units that have upper ends arranged on an equal level, comprising:
 - 1) providing a composite that comprises sintered superabrasive particles that are as a whole joined to a backing material of cemented carbide,
 - 2) leveling said composite surface, and
 - 3) cutting in said composite surface to form groups of linear grooves and an array of abrasive units along said grooves.
25. A method for the manufacture of an abrasive tool having an abrasive part that comprises a layer of sintered superabrasive particles, comprising:
 - 1) providing a sintered composite composed of a layer of sintered superabrasive particles that are joined integrally to a backing of cemented carbide,
 - 2) cutting said composite to yield a segment in a shape of sector,
 - 3) collecting a plurality of segments, which are identical in geometry to the one obtained in 2) with an equal central angle,
 - 4) arranging said segments closely to each other, so as to form a composite surface in entire circular or annular shape, fixing said segments to a base plate on a flat surface thereof, and
 - 5) cutting in said segments to produce an array of abrasive units on said composite, whereby group of grooves are formed parallel to a radial border of each segment as obtained in 4).
26. A method of regenerating an abrasive tool as claimed in any one of claims 1 to 23, wherein said abrasive part, as worn to have a decreased abrasive unit height, is cut in along said grooves by wire-EDM to regenerate the grooves and the upper ends of abrasive units.

Fig. 1

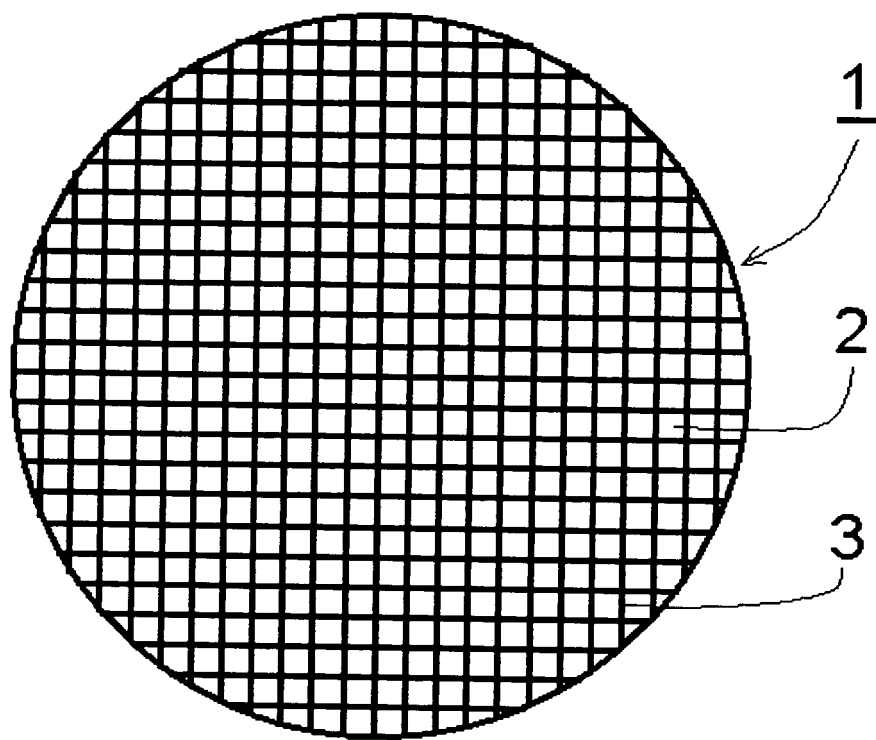


Fig. 2

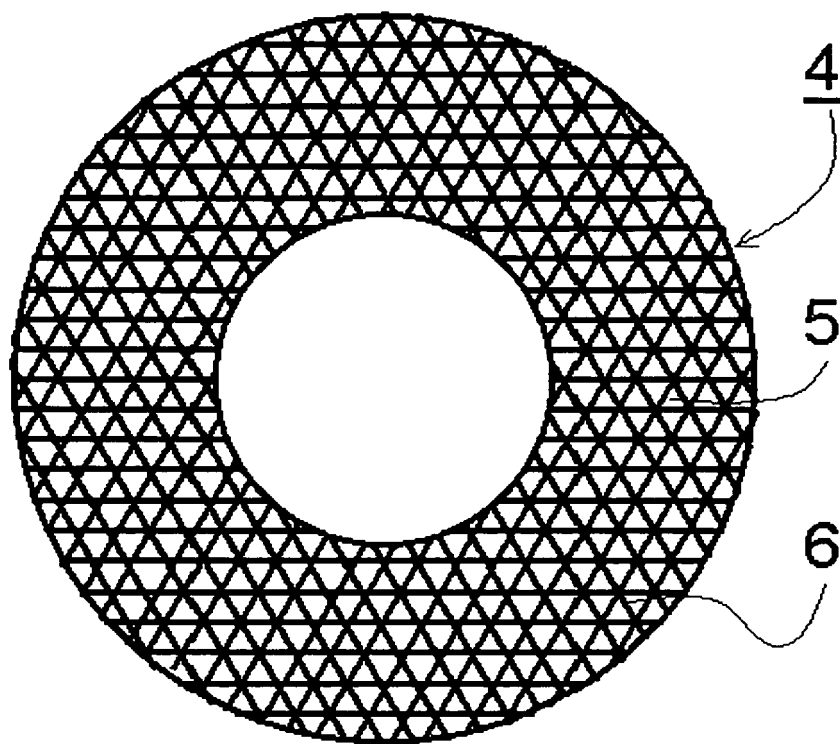


Fig. 3

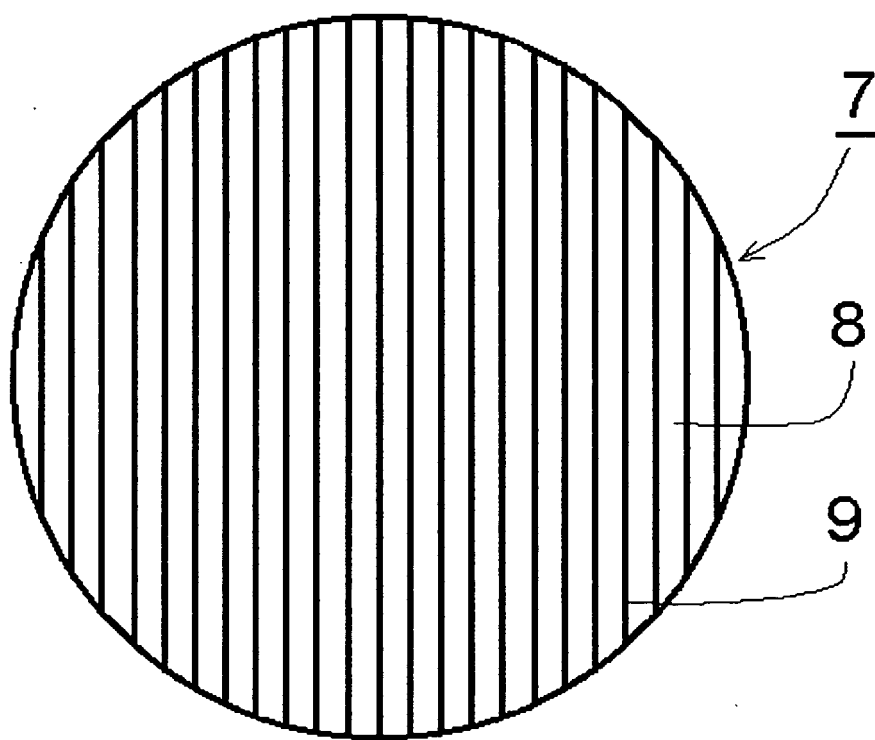


Fig. 4

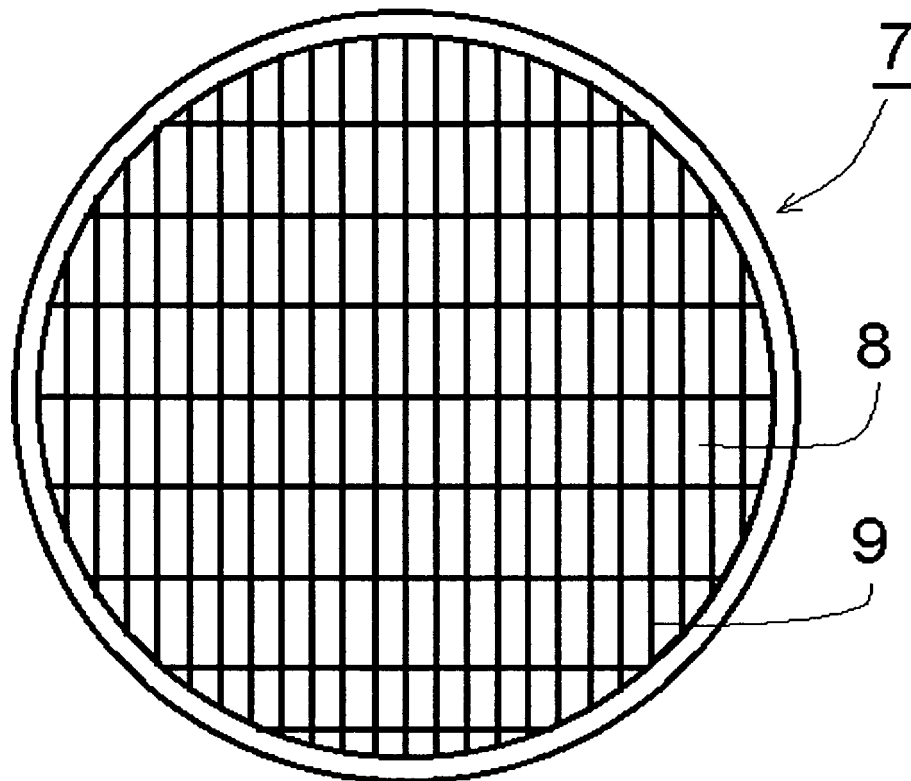


Fig. 5

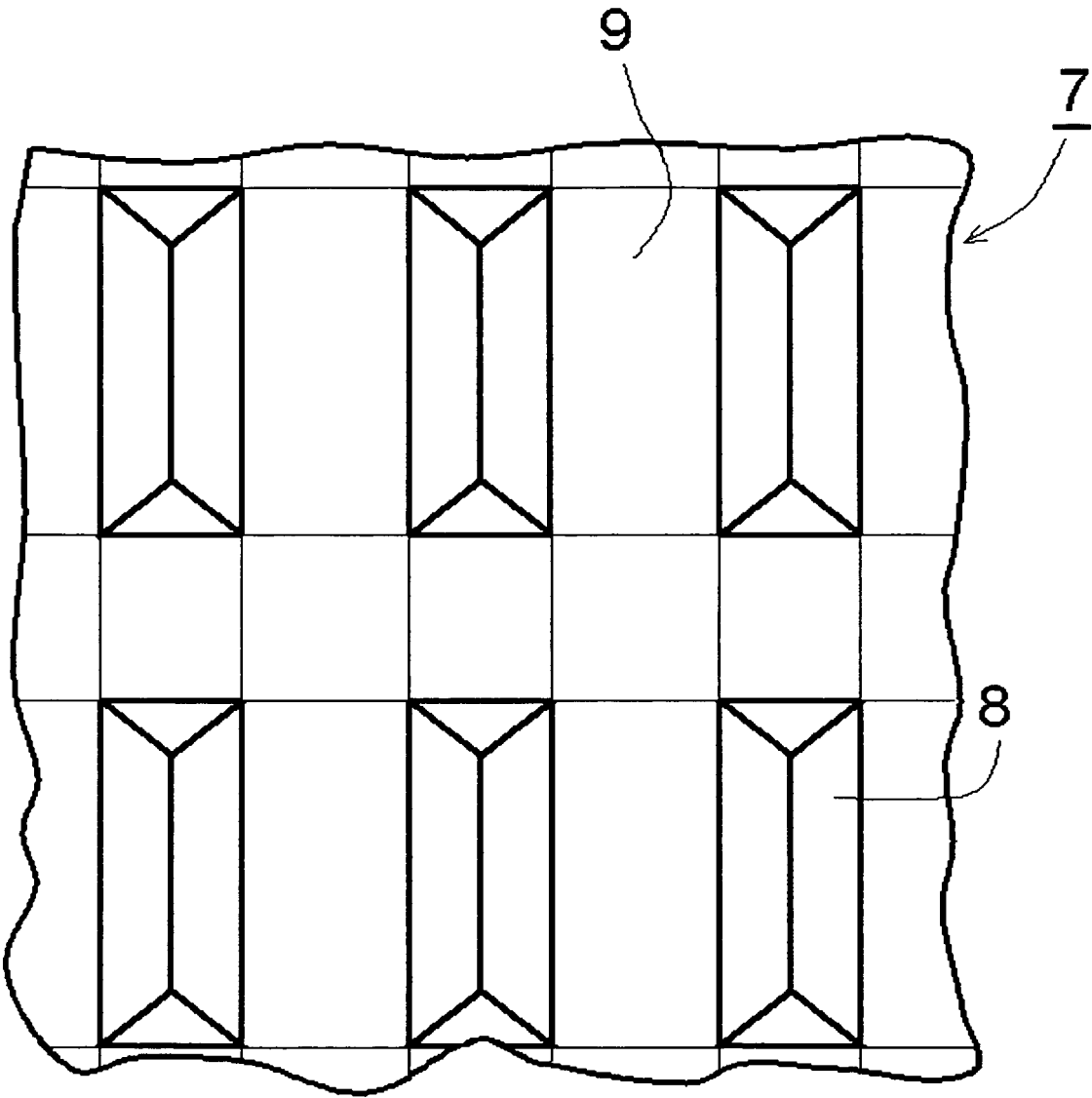


Fig. 6

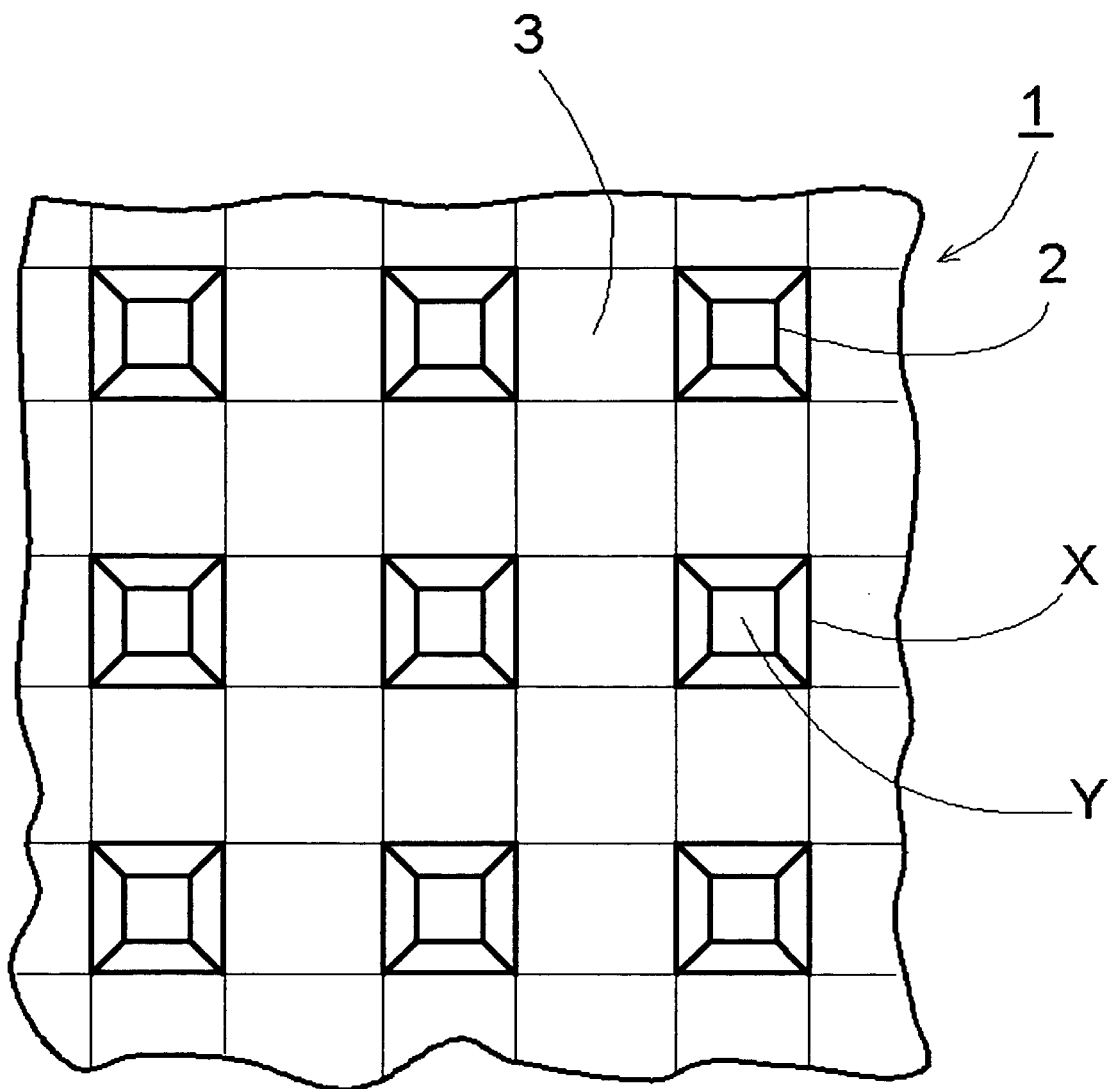


Fig. 7

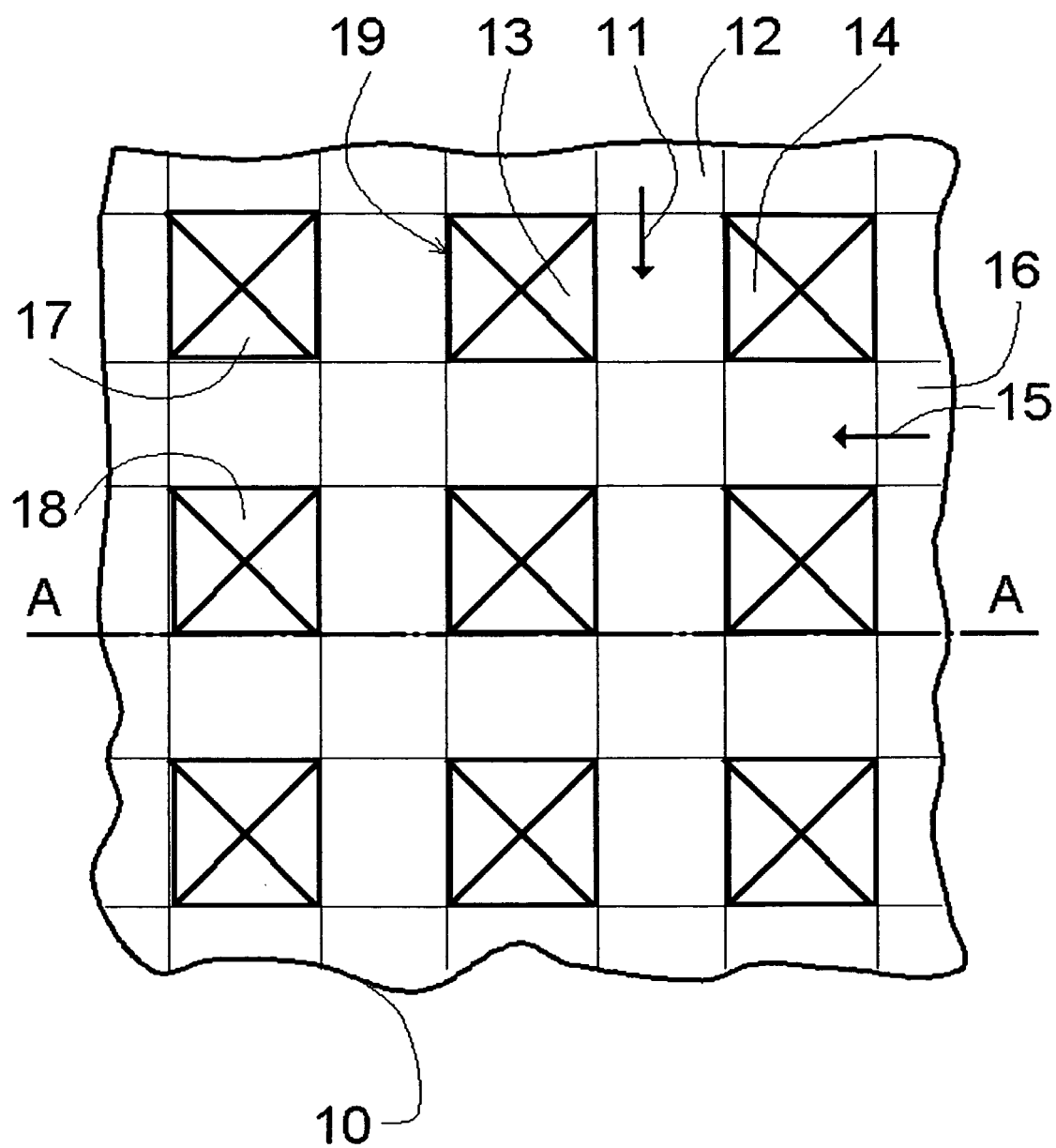


Fig. 8

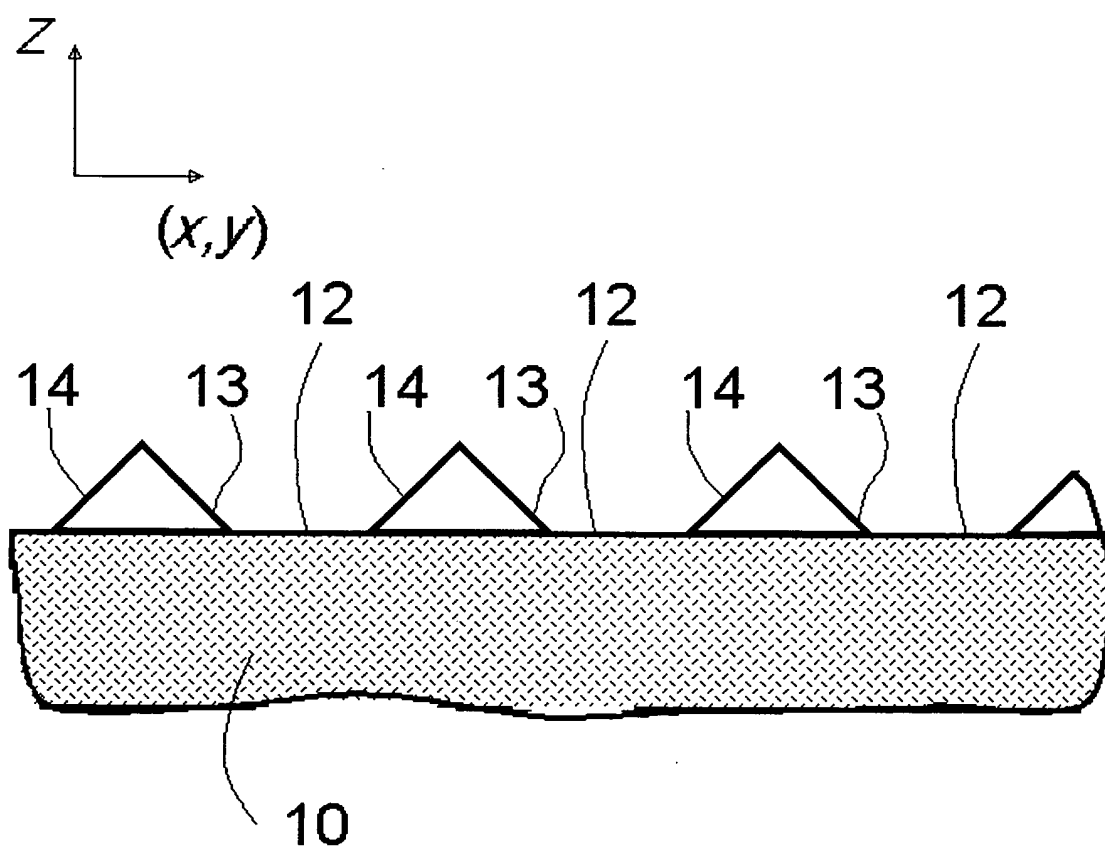


Fig. 9

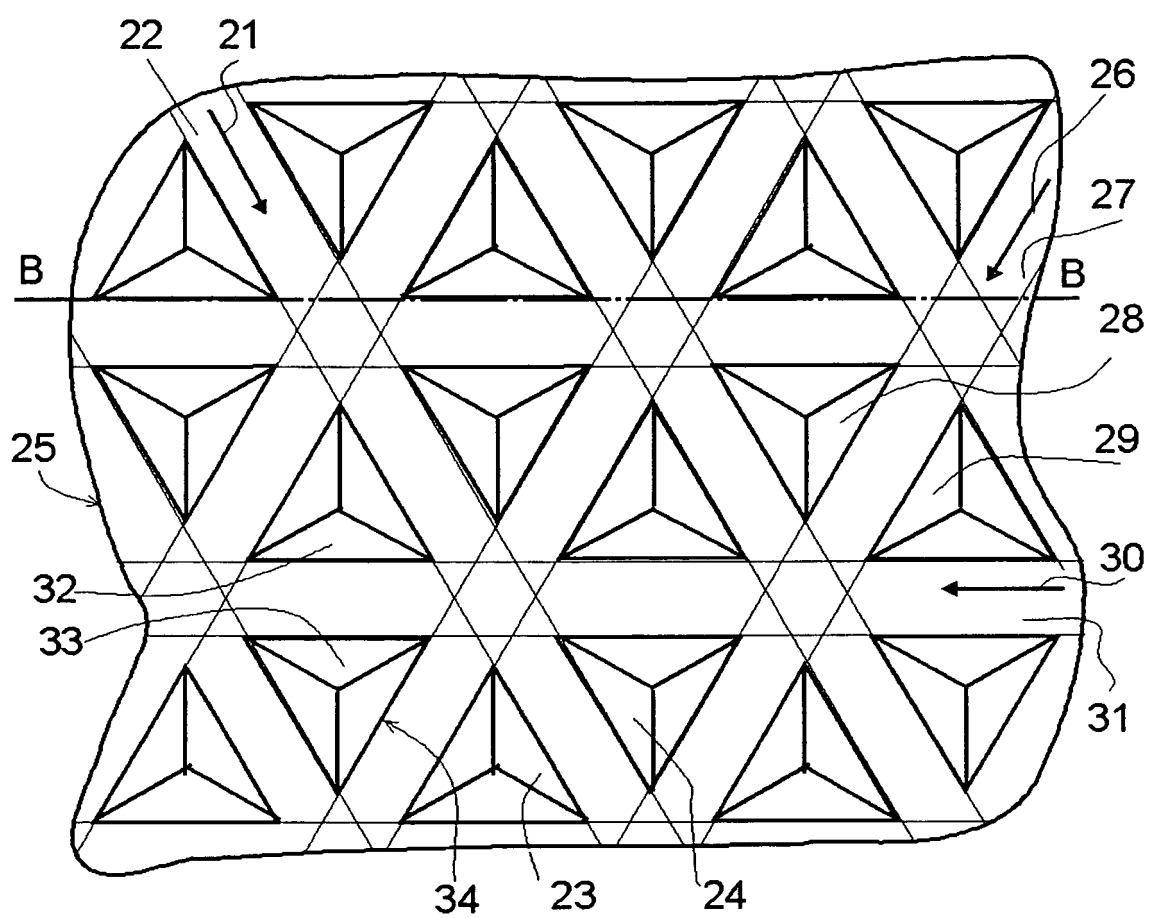


Fig. 10

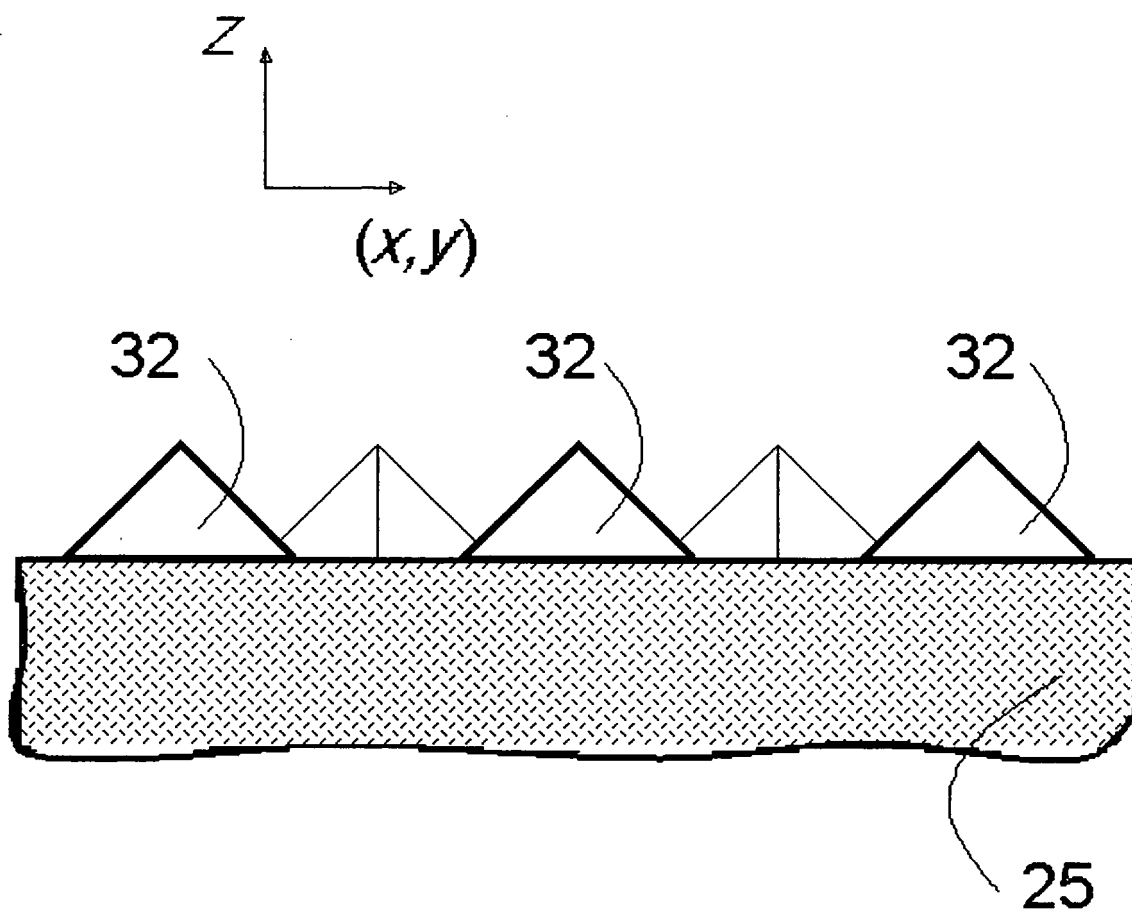


Fig. 11

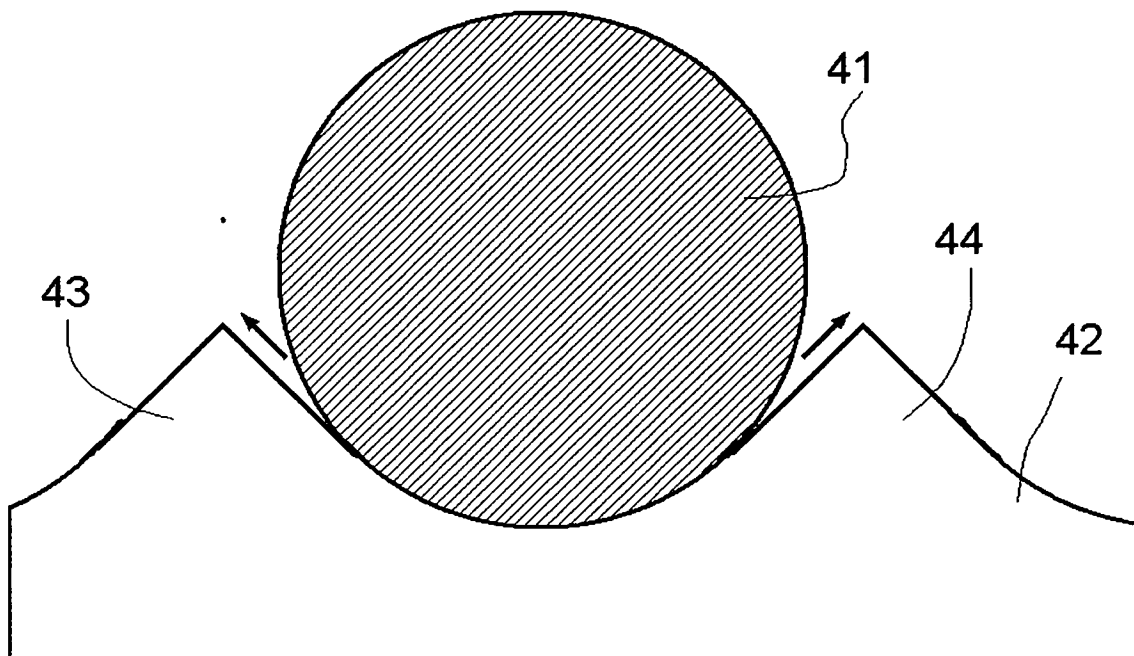


Fig. 12

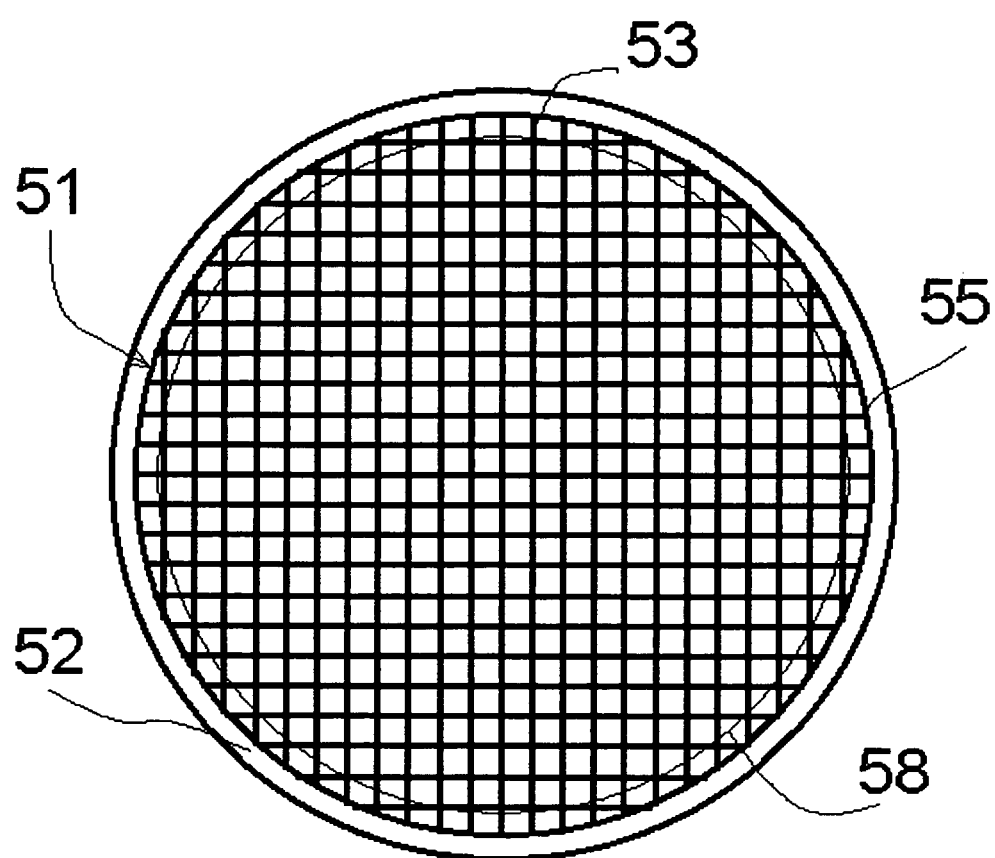


Fig. 13

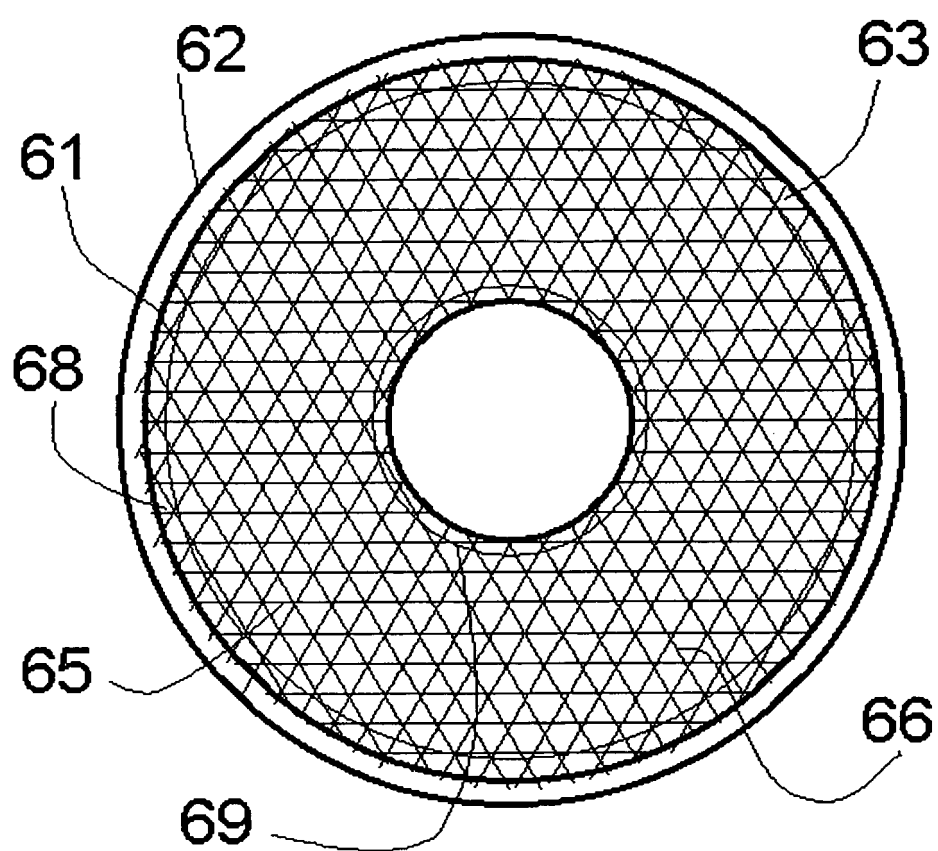


Fig. 14

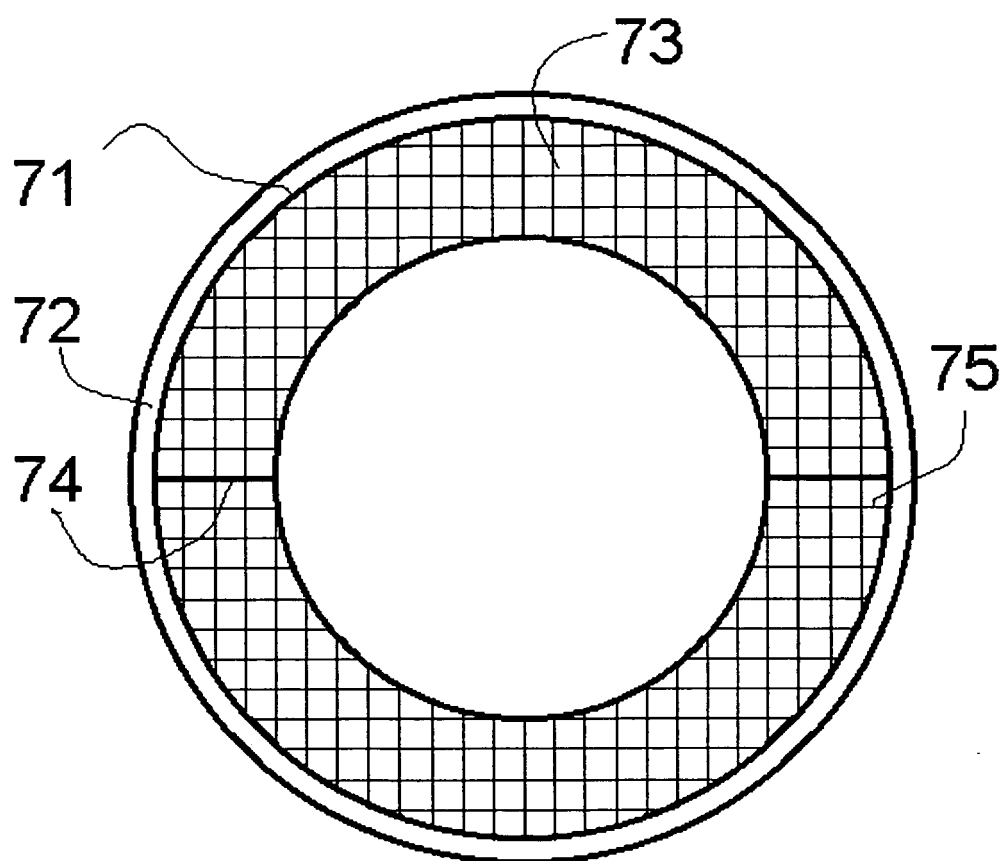


Fig. 15

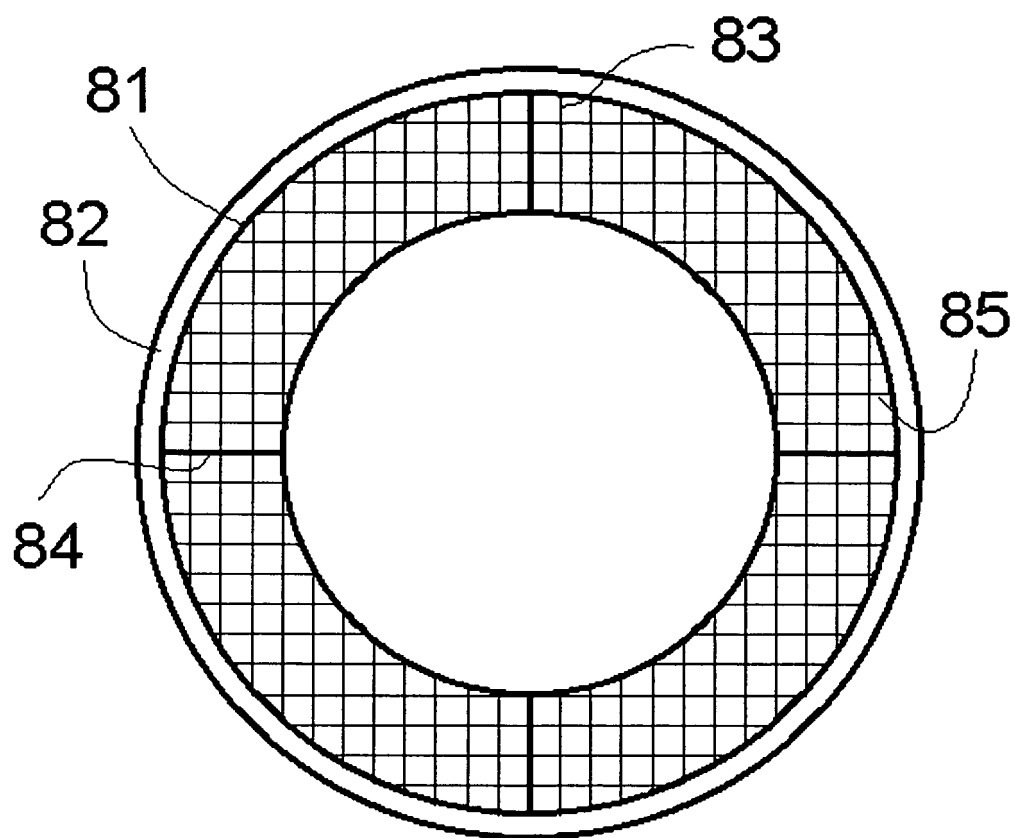


Fig. 16

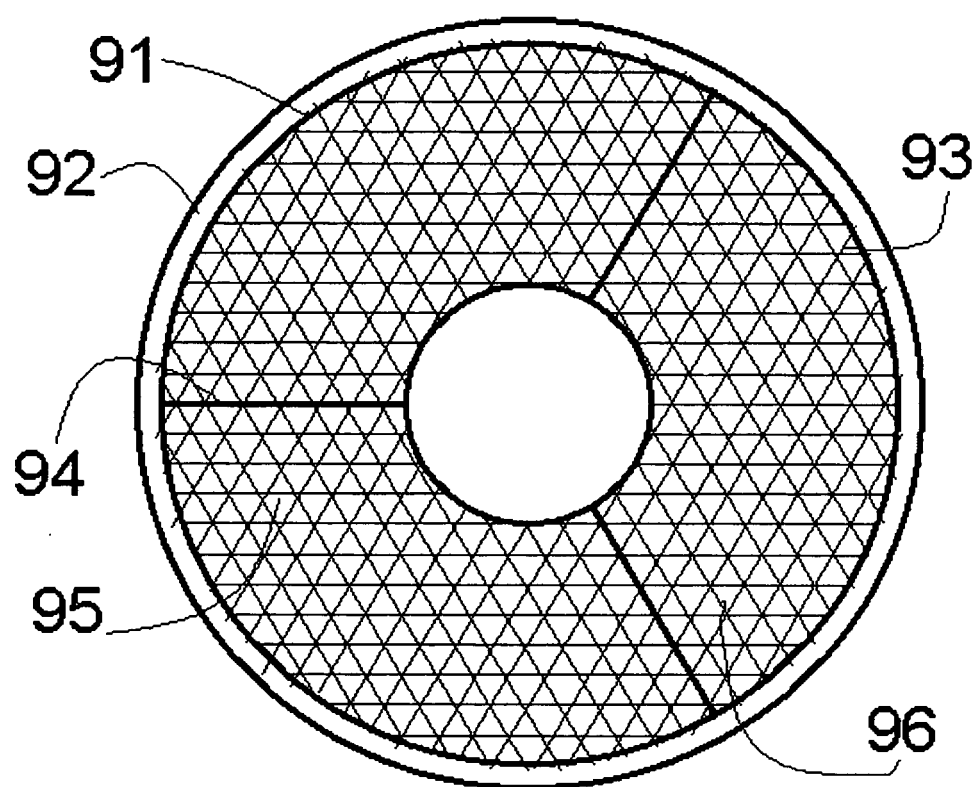
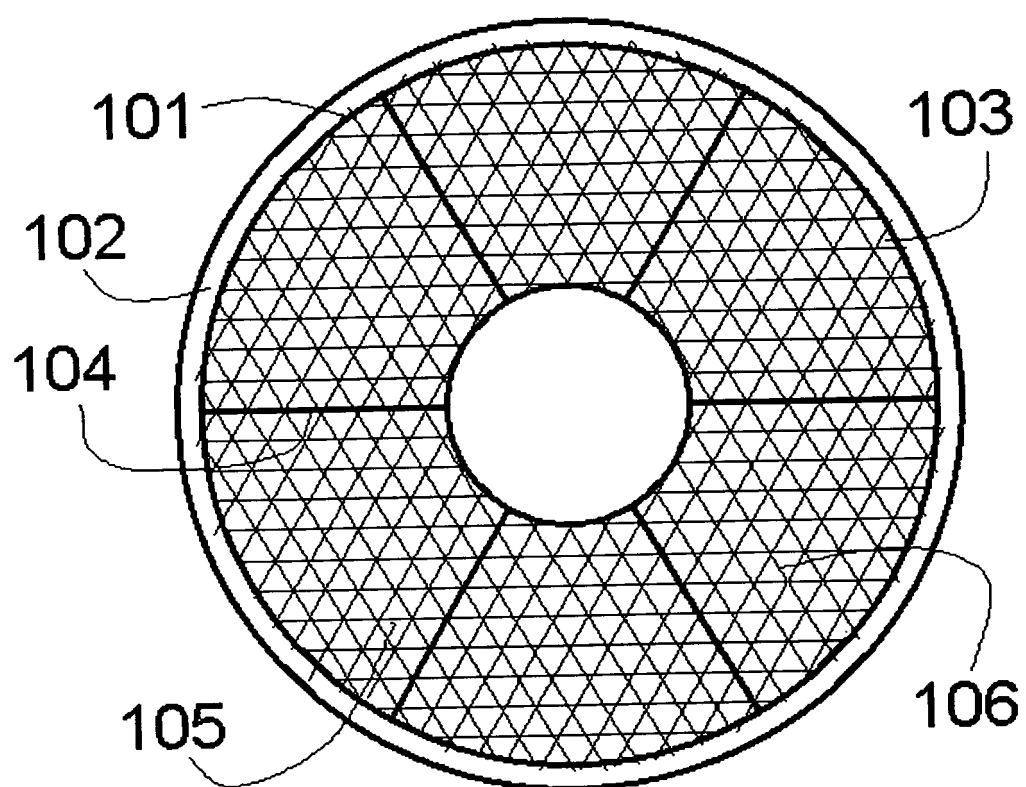


Fig. 17



INTERNATIONAL SEARCH REPORT

International application No.

PCT/JP2006/316737

A. CLASSIFICATION OF SUBJECT MATTER <i>B24D3/00(2006.01) i, B24B37/00(2006.01) i, B24B53/12(2006.01) i</i>		
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) <i>B24D3/00, B24B37/00, B24B53/12</i>		
Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched Jitsuyo Shinan Koho 1922-1996 Jitsuyo Shinan Toroku Koho 1996-2006 Kokai Jitsuyo Shinan Koho 1971-2006 Toroku Jitsuyo Shinan Koho 1994-2006		
Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)		
C. DOCUMENTS CONSIDERED TO BE RELEVANT		
Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
Y	JP 10-71559 A (Asahi Diamond Industrial Co., Ltd.), 17 March, 1998 (17.03.98), Full text; all drawings (Family: none)	1-26
Y	JP 8-243927 A (Fuji Xerox Co., Ltd.), 24 September, 1996 (24.09.96), Full text; all drawings (Family: none)	1-26
Y	JP 2001-347454 A (Kabushiki Kaisha Komura Toishi Seisakusho), 18 December, 2001 (18.12.01), Par. Nos. [0015] to [0017] (Family: none)	2
☒ Further documents are listed in the continuation of Box C. ☐ 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 application or patent but published on or after the international filing date "L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified) "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 27 November, 2006 (27.11.06)		Date of mailing of the international search report 05 December, 2006 (05.12.06)
Name and mailing address of the ISA/ Japanese Patent Office		Authorized officer
Facsimile No.		Telephone No.

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INTERNATIONAL SEARCH REPORT

International application No.

PCT/JP2006/316737

C (Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
Y	JP 2003-511255 A (Hunatech Co., Ltd.), 25 March, 2003 (25.03.03), Par. Nos. [0053] to [0054]; Figs. 4A, 6A & WO 2001/026862 A1 & US 6439986 B1 & KR 200175263 Y & DE 10085092 T & CN 1391506 A & AU 7691900 A & TW 467802 B	14-21
A	JP 58-199776 A (Sumitomo Electric Industries, Ltd.), 21 November, 1983 (21.11.83), (Family: none)	1-26

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REFERENCES CITED IN THE DESCRIPTION

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- JP 2002337050 A [0007]
- JP 2004291184 A [0007]
- JP 10071559 A [0007]