

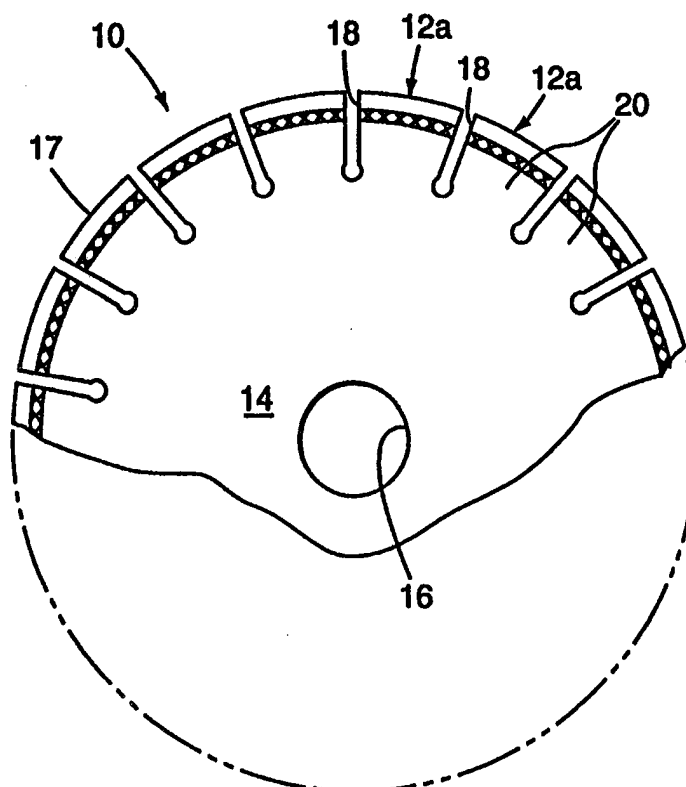


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**(54) Title:** SUPERABRASIVE CUTTING SURFACE**(57) Abstract**

An abrasive surface for cutting and grinding tools and having abrasive particles embedded in a filler material. The abrasive surface is bonded to the perimeter edge of a rigid hub and has a circumferential dimension and a width dimension. The abrasive surface is divided along both the circumferential dimension and the width dimension into a plurality of hard regions and soft regions. The hard regions wear more slowly than the soft regions and so different patterns of hard regions and soft regions produce different cutting profiles. A method for fabricating the abrasive surface includes forming a laminated sheet from a plurality of laminated layers. Each laminated layer includes at least a layer of soft, easily deformable material and a layer of abrasive particles. The layers of abrasive particles can be formed into staggered rows to form the pattern of hard regions and soft regions. The layers of the laminated layers are sintered together to form the laminated sheet from which the abrasive surface is cut.



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## **SUPERABRASIVE CUTTING SURFACE**

### **Background of the Invention**

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#### **Field of the Invention**

The present invention relates generally to cutting and grinding tools. In particular the present invention includes a superabrasive surface for use with circular cutting and grinding tools and a method for making the same.

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#### **Description of the Related Art**

Materials such as granite, marble, filled concrete, asphalt and the like are typically cut using superabrasive saw blades. These blades include a circular steel disc having a work surface made up of a plurality of spaced segments about the perimeter of the disk, the segments having superabrasive surfaces for the cutting of the material. Further, plastic and glass lenses for optical devices such as eyeglasses are commonly shaped using grinding wheels which have a superabrasive work surface. The abrasive portions of these saw blades or grinding wheels usually include particles of super hard or abrasive material, such as diamond, cubic boron nitride, or boron suboxide surrounded by a filler material and/or embedded in a metal matrix. It is these abrasive particles that act to cut or grind a work piece as it is placed against a rotating work surface of the cutting or grinding tool.

The arrangement of the particles of abrasive material in the work surface is important to performance of the cutting or grinding tool. First, an unvarying or homogeneous concentration or hardness of abrasive material in a direction along the circumference of the cutting surface results in reduced cutting performance. As such it is advantageous to be able to vary the concentration or hardness of abrasive particles in the cutting surface to produce a surface of varying abrasiveness. For example, Fisher, in U.S. Patent No. 5,518,443 for a Superabrasive Tool issued May 21, 1996, discloses a tool having a cutting surface divided in the circumferential direction into segments having varying

concentrations of abrasive particles. Regions of lower concentration of abrasive material will wear faster than regions of higher concentrations of abrasive particles exposing fresh high concentration regions. These fresh regions cut more effectively than worn regions of higher concentration of cutting material  
5 thereby increasing the cutting performance of the tool.

Second, it is known in the art to form cutting surfaces in which the concentration of abrasive particles in the cutting surface varies in a direction of the axis of rotation of the abrasive tool. For example, Wiand, in U.S. Patent No. 4,131,436 for Ophthalmic Flat Roughing Wheel, issued December 26,  
10 1978, discloses a grinding wheel in which the concentration of abrasive particles in the surface of the grinding wheel comprises layers which define a zone of high abrasive particle concentration in the axial center of the wheel with zones of lower abrasive particle concentration on either side. However, as noted above, a region of lower concentration of abrasive particles will wear down  
15 faster than a region of relatively higher concentration of abrasive particles. Thus, after a period of use, a cutting or grinding tool of the type disclosed in Wiand develops a characteristic edge pattern across the width of the cutting surface in the direction of the axis of rotation of the tool. This characteristic edge is known as the tool's wear profile.

20 The wear profile of a superabrasive cutting or grinding tool affects the quality of the cut performed on a work object. For example, it is likely that the type of tool disclosed in Wiand would develop a rounded, convex wear profile that has radially low spots at the outer edges of the tool in the direction of the axis of rotation of the tool and radially high spots in the center of the tool  
25 between the low spots. This type of wear profile is generally undesirable because it can produce a somewhat ragged-edge cut and the circular steel disk can be unexpectedly exposed at the radially low edges of the tool during a cut, causing unintended cutting results.

It is more desirable to have a concave wear profile wherein high spots  
30 are created at the edges of the profile and a low spot is created in the center of

the profile. This type of wear profile can produce a clean-edged cut and tends not to expose the circular steel disk prematurely and allows more efficient use of abrasive material. Also, it may also be desirable to have slightly different, and more complex, cutting profiles dependent upon the work object and the type of cut desired.

Third, the life of the tool and the speed of the cut are also dependent upon the arrangement of the particles in the work surface and the composition of the work surface. A work surface in which abrasive particles are embedded in a relatively soft bond material can cut faster because the worn particles are pulled from the soft bond material relatively rapidly, exposing fresh abrasive particles. This type of work surface, however, can wear relatively quickly. On the other hand, abrasive particles embedded in a relatively hard bond material can cut relatively more slowly because worn particles are not pulled from the hard bond material so quickly to expose fresh abrasive particles. This type of work surface, however, can have a relatively long life.

Finally, abrasive material used in such cutting or grinding tools is relatively expensive; thus, it is desirable to reduce the quantity of abrasive material necessary without reducing the performance of the cutting or grinding tool.

As such, it is advantageous to be able to control the wear profile of a superabrasive cutting or grinding tool. Further, it is advantageous to have a work surface which will provide relatively rapid cutting with a relatively long life. Also, such a tool should be efficient and relatively inexpensive to manufacture.

### **Summary of the Invention**

The present invention includes a circular tool for cutting and grinding and having a work surface mounted to a rigid circular hub such that the work surface has a circumferential dimension orthogonal to an axial dimension. The work surface also has abrasive particles embedded therein and is divided along

the circumferential dimension and the axial dimension into a plurality of first regions having a first region and a plurality of second regions. Each first region is more wear resistant than each second region. As such, second regions will wear faster than first regions. In this way different patterns of first and second regions in the circumferential dimension and axial dimension will produce different wear profiles and a desirable compromise between cutting speed and tool life can be obtained.

A method of fabricating the work surface includes forming a laminated sheet having a plurality of laminated layers. Each laminated layer includes at least a layer of bond or filler material, and a layer of abrasive particles. The concentration and/or type of abrasive particles in at least one of the layers of abrasive particles is varied across a width and/or length of the layer to form the first and second regions of the work surface. The laminated layers are sintered to form the laminated sheet from which the work surface is cut.

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### **Brief Description of the Drawings**

Figure 1 is a front view of a cutting tool including abrasive segments in accordance with the present invention mounted about a perimeter of the cutting tool.

Figure 2 is an isometric view of an abrasive segment of the type shown in Figure 1.

Figure 3A is a sectional view of the abrasive segment shown in Figure 2 taken along line 3A-3A of Figure 2.

Figure 3B is a sectional view of the abrasive segment shown in Figure 2, after the segment has been used sufficiently to define a wear profile at its edge, taken along line 3B-3B of Figure 3A.

Figure 4A is a sectional view of a second embodiment of an abrasive segment of the type shown in Figure 2 taken along a section line equivalent to line 3A-3A of Figure 2.

Figure 4B is a sectional view of the abrasive segment shown in Figure 4A, after the segment has been used sufficiently to define a wear profile at its edge, taken along line 4B-4B.

5 Figure 5A is a sectional view of a third embodiment of an abrasive segment of the type shown in Figure 2 taken along a section line equivalent to 3A-3A of Figure 2.

Figure 5B is a sectional view of the abrasive segment shown in Figure 5A, after the segment has been used sufficiently to define a wear profile at its edge, taken along line 5B-5B.

10 Figure 6A is a sectional view of a fourth embodiment of an abrasive segment of the type shown in Figure 2 taken along a section line equivalent to line 3A-3A of Figure 2.

Figure 6B is a sectional view of the abrasive segment shown in Figure 6A, after the segment has been used sufficiently to define a wear profile at its edge, taken along line 6B-6B.

Figure 7 is a sectional view of a fifth embodiment of an abrasive segment of the type shown in Figure 2 taken along a section line equivalent to line 3A-3A of Figure 2.

20 Figure 8 is a sectional view of a sixth embodiment of an abrasive segment of the type shown in Figure 2 taken along a section line equivalent to line 3A-3A of Figure 2.

Figure 9 is a front view of a grinding tool having an abrasive surface in accordance with the present invention.

25 Figure 10 is a sectional view of the abrasive surface shown in Figure 9, after the surface has been used sufficiently to define a wear profile at its edge, taken along line 10-10.

Figure 11 is a top view of a laminated sheet of material that can be used to fabricate the abrasive segment shown in Figure 2 or the abrasive surface shown in Figure 9.

Figure 12A is a front exploded view of a first embodiment of the laminated sheet of material shown in Figure 11 including a plurality of layers bond material, a plurality of layers of porous material, and a plurality of layers of abrasive particles.

5        Figure 12B is a front exploded view of a second embodiment of the laminated sheet of material shown in Figure 11 including two different types of abrasive particles arranged in rows in abrasive particle layers.

Figure 13A is a top view of a first embodiment of a layer of porous material for use with the present invention.

10       Figure 13B is a top view of a second embodiment of a layer of porous material for use with the present invention.

Figure 14 is an exploded front view of a second embodiment of the laminated sheet of material shown in Figure 11 including a layer of adhesive substrate.

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### **Detailed Description of the Preferred Embodiments**

Figure 1 shows an abrasive wheel or saw blade 10 for cutting hard materials such as granite, marble and concrete and including abrasive segments 12a forming an abrasive work surface 17 in accordance with the present invention. Wheel 10 includes a circular center hub 14 formed from steel or  
20       other rigid material. A hole 16 is formed in the center of hub 14 for conventionally mounting wheel 10 onto a drive means (not shown) to rotatably drive wheel 10. Circumferentially spaced slots 18 preferably extend from the outer perimeter of wheel 10 inward towards the center thereof in a radial  
25       direction to form support members 20 in hub 14 between adjacent slots 18. Each abrasive segment 12a is mounted at the outer edge of a support member 20 by laser beam fusion welding, electron beam fusion welding, soldering, brazing, or other methods known in the art. Suppliers of soldering and brazing equipment and supplies include: Engelhard Corp., Metal Joining Group of



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Warwick, RI; Cronatron Welding Systems, Inc. of Charlotte, NC; and Atlantic Equipment Engineers of Berginfield, NJ.

Figure 2 is an isometric view of an individual segment 12a shown in Figure 1. In the embodiment of Figure 2, segment 12a is in the shape of an arcuate section of a circular band having a curvature substantially equal to that of circular hub 14 to which segment 12a is to be mounted. Segment 12a is elongated in the direction of the circumference of the circular band and has a width in the direction of the axis of rotation of wheel 10, which is orthogonal to the circumferential direction. As such, work surface 17 has an axial dimension orthogonal to a circumferential dimension. Preferably, segment 12a has an arc of about 7 to 20 degrees.

Segment 12a contains particles of abrasive or hard material such as diamond, cubic boron nitride, boron carbide, boron suboxide, and/or silicon carbide suspended in a matrix of bond or filler material which can also be abrasive. As such, by mounting wheel 10 to a rotatably driven rod through hole 16, an edge of segment 12a acts to cut a work object placed against the perimeter edge of rotating wheel 10.

The type and arrangement of the superabrasive particles and the type of bond material of segment 12a is important to the wear profile created on work surface 17 and, therefore, the cutting performance thereof. Segment 12a is divided into hard regions and soft regions. Soft regions can contain a lower concentration of abrasive material than hard regions or a less abrasive type of material than hard regions, or a combination of both a lower concentration of abrasive material and a less abrasive type of materials. Accordingly, hard regions have a higher concentration of abrasive material and/or a more abrasive type of material than soft regions, or a combination of both. Hard and soft regions are so named because a more abrasive particle of similar size and shape is typically a harder particle. It is also contemplated to use different compositions of bond material in the work surface 17. Bond materials can also be harder and softer. By varying the concentration and type of abrasive

particles and the compositions of the bond material in work surface 17, soft regions can wear more rapidly than hard regions.

Soft regions and hard regions are circumferentially spaced in segment 12a, that is, spaced in the circumferential dimension of wheel 10, and axially spaced in segment 12a, that is spaced in the direction of the axis of rotation of wheel 10. In this way, the wear profile of work surface 17 can be determined by the position of hard regions and soft regions in segment 12a.

Also, by varying the concentration and/or type of abrasive material, and/or by varying the composition of the bond material, at the cutting surface of segment 12a, the cutting efficiency of wheel 10 can be improved. That is, the life of the work surface 17 can be improved while retaining relatively high cutting speed. Finally, by having regions of reduced concentration of expensive abrasive particles, such as diamonds, wheel 10 can be relatively less expensive to produce than a cutting or grinding tool having a cutting surface with a continuously high concentration of expensive abrasive particles.

Figure 3A, which is a sectional view of segment 12a along line 3A-3A of Figure 2, shows one embodiment of the present invention including a first arrangement of superabrasive material in segment 12a. Shaded areas in Figure 3A show hard regions 22a and unshaded areas show soft regions 24a. As shown in Figure 3a, segment 12a can be divided into 7 axial thickness layers 30a, 32a, 33a, 34a, 35a, 36a, and 38a. Although in the embodiment of Figure 3A, thickness layers 30a, 32a, 33a, 34a, 35a, 36a, and 38a are of substantially equal width in the axial direction, that is width along a direction of the axis of rotation of wheel 10, it is within the ambit of the present invention for thickness layers to be of different axial width. Exterior thickness layers 30a and 38a completely comprise hard regions 22a. In each interior thickness layer 32a, 33a, 34a, 35a, and 36a, hard regions 22a are circumferentially spaced, that is, spaced in the direction of the circumference of wheel 10, between soft regions 24a. Soft regions 24a are of approximately equal circumferential length, that is of approximately equal length in a direction along the circumference of wheel 10,

as hard regions 22a. Further, the hard regions 24a of alternate interior thickness layers 32a, 34a, and 36a are circumferentially offset, that is, offset in a direction along the circumference of wheel 10, from the hard regions 24a of alternate interior thickness layers 33a and 35a. Accordingly, the arrangement of abrasive particles in segment 12a forms a checker board pattern of zones having different abrasiveness which alternate in both the axial and circumferential direction and are sandwiched between exterior thickness layers 30a and 38a, each being an entirely hard region 22a.

As wheel 10 is used, soft regions 24a will wear more rapidly than hard regions 22a. As such, the interior thickness layers 32a through 36a will wear more rapidly than exterior thickness layers 30a and 38a. Figure 3B is a sectional view of segment 12 taken along line 3B-3B of Figure 3A and shows an estimation of the wear profile that is expected to be produced in segment 12a. The wear profile has a radially lower area, that is an area having a smaller radius on wheel 10, axially across interior thickness layers 32a through 36a of segment 12a and radially higher areas, that is areas having larger radii on wheel 10, axially across exterior thickness layers 30 and 38. This type of wear profile produces a precise cut. Further use of a tool having this type of wear profile can reduce the possibility of the cutting surface prematurely wearing to hub 14.

Figures 4A, 5A, 6A, 7, and 8 show alternate embodiments of the arrangement of hard regions and soft regions in abrasive segments of the type shown in Figure 2 in the same view as shown in Figure 3A. Elements in Figures 4A-8 that are functionally similar to elements in Figures 1, 2, 3A, and 3B are labeled with like numerals designated by different letters. These alternate arrangements wear at different overall speeds and produce different wear profiles and, hence, abrade the work object in different ways. The specific use of the cutting tool determines the desirability of the different wear patterns produced.

Figure 4A shows a segment 12b having five axial thickness layers 30b, 32b, 34b, 36b and 38b of preferably substantially equal axial width. Exterior

thickness layers 30b and 38b are similar to exterior thickness layers 30a and 38a, respectively, shown in Figure 3A. The side interior thickness layers 32b and 36b each has hard regions 22b circumferentially spaced with soft regions 24b of approximately three times the circumferential length of hard regions 22b thereof. Center interior thickness layer 34b has hard regions 22b circumferentially spaced with soft regions 24b of approximately equal circumferential length as hard regions 22b thereof. Also, the placement of hard regions 22b are circumferentially offset from thickness layer 32b to thickness layer 34b to thickness layer 36b by approximately the circumferential length of a hard region 22b. As such, the spacing arrangement in both the circumferential direction and the axial direction in segment 12b forms a zigzag pattern of zones having different abrasiveness and sandwiched between exterior thickness layers 30b and 38b. This arrangement results in approximately three times the area of soft region 24b in each side interior thickness layer 32b and 36b than in center interior thickness layer 34b. Therefore, side interior thickness layers 32b and 36b will wear more rapidly than center interior thickness layer 34b. And, as with segment 12a, the exterior thickness layers 30b and 38b, which have no soft regions 24b, will wear slower than any of the interior thickness layers 32b, 34b, and 36b.

Figure 4B is a sectional view of segment 12b taken along line 4B-4B of Figure 4A and shows an estimation of the wear profile that is expected to be produced in segment 12b. The wear profile has a radially lower area axially across side interior thickness layers 32b and 36b, a radially intermediate height area across center interior layer 34b and radially high areas on either exterior edge along thickness layers 30b and 38b.

Figure 5A shows a segment 12c having 5 thickness layers 30c, 32c, 34c, 36c, and 38c of substantially equal axial width. Exterior thickness layers 30c and 38c are similar to exterior thickness layers 30a and 38a, respectively, shown in Figure 3. Each interior thickness layer 32c, 34c, and 36c has hard regions 22c circumferentially spaced between soft regions 24c of approximately one quarter

the circumferential length of adjacent hard regions 22a thereof. Also, the hard regions 22c of side interior thickness layers 32c and 36c are aligned with each other in an axial direction and the hard regions 22c of center interior thickness layer 34c are circumferentially offset therefrom. As such, the hard regions 22c of center interior thickness layer 34c circumferentially overlap with the hard regions 22c of side interior thickness layers 32c and 36c. As with segments 12a and 12b, this construction advantageously results in a segment having abrasive zones that vary both in the circumferential direction as well as in the direction of the axis of rotation of wheel 10.

Because there is a relatively smaller amount of soft region 24c in interior layers 32c, 34c and 36c, these layers will wear relatively more slowly than the interior thickness layers 32a, 34a, and 36a of segment 12a. However, because there substantially equal ratios of soft region 24c to hard region 22c in each interior layer 32c, 34c, and 36c, each layer will wear at approximately the same rate. Thus, the expected wear profile is shown in Figure 5B, which is a sectional view of segment 12c taken along line 5B-5B of Figure 5A.

Figure 6A shows a segment 12d having 5 thickness layers 30d, 32d, 34d, 36d, and 38d with preferably substantially equal axial width. External thickness layers 30d and 38d are similar to external thickness layers 30a and 38a, respectively, shown in Figure 3A. Side interior thickness layers 32d and 36d have hard regions 22d circumferentially spaced between soft regions 24d of approximately equal circumferential length as hard regions 22d thereof. Center interior thickness layer 34d has no area of soft region 24d and, thus, is continuous hard region 22d. As such, center interior thickness layer 34d will wear at approximately the same rate as exterior thickness layers 30d and 38d. Because side interior thickness layers 32d and 36d have areas of soft region 24d, these layers will wear faster. As such, the expected wear profile is shown in Figure 6B, which is a sectional view of section 12d taken along line 6B-6B of Figure 6A.

Figure 7 shows a segment 12e consisting of only three layers 32e, 34e and 36e, which are similar to interior layers 32a, 33a, and 34a of segment 12a. The exterior thickness layers 30a and 38a of segment 12a, however, are not included in segment 12e. Thus, the wear profile will be relatively uniform axially across layers 32e, 34e, and 36e.

Figure 8 shows segment 12f consisting of three layers 32f, 34f, and 36f, which are similar to layers 32b, 34b, and 36b of segment 12b. The exterior thickness layers 30b and 38b of segment 12b, however, are not included in segment 12f. Thus, the wear profile would appear substantially as the wear profile of segment 12b, shown in Figure 4B, axially across interior thickness layers 32b, 34b and 36b.

It is also within the ambit of the present invention to form a segment of a type similar to segment 12a but having only three layers with the arrangement of hard regions and soft regions the same as that of layers 32c, 34c and 36c of segment 12c shown in Figure 5A or the same as that of layers 32d, 34d, and 36d of segment 12d shown in Figure 6A.

The above described embodiments divide the work surface of a cutting tool into regions having relatively high abrasiveness and relatively low abrasiveness. However, it is also contemplated to form a work surface of a cutting tool divided into regions of more than two different levels of abrasiveness. That is, the work surface could be divided circumferentially and axially into regions of three or more different levels of abrasiveness. Each type of region can include relatively high, intermediate, and low concentrations of abrasive material, respectively, and/or relatively highly abrasive, moderately abrasive, and less abrasive materials, respectively.

Further, though the embodiments of the present invention specifically described above have either 3, 5 or 7 layers, it is also contemplated to form a segment of a type similar to segment 12a having 1, 2, 4, 6, 8, or any number of layers that is desirable to provide a cutting function and wear profile depending on the desired application. Moreover, thicknesses of the layers need not be the

same. Also, the layers can have any circumferentially and axially alternating configuration of regions of different levels of abrasiveness.

It is also contemplated to use a harder or softer bond material in one or more thickness layers. Using a harder bond material can cause a layer to wear  
5 slower and using a softer bond material can cause a layer to wear more rapidly. As such, the wear profile and cutting life of cutting surface 17 can be advantageously varied.

It is also within the ambit of the present invention to form a continuous closed circular band of abrasive cutting material rather than only the segments  
10 12a-12f of cutting material described above. Such a continuous band can be used as a grinding wheel 40, a side view of which is shown in Figure 9. Grinding wheel 40 is formed from a disk of abrasive material in accordance with the present invention. The center of the disk has been removed to form hole 44 for mounting the wheel 40 onto a rotatably driven shaft (not shown). The outer  
15 circumferential surface of wheel 40 comprises circular work surface 46 of abrasive material which has a circumferential dimension and an axial dimension. It is also within the ambit of the present invention to form a grinding wheel having a circular band of abrasive material in accordance with the present invention mounted by brazing or other known method to the perimeter of a rigid  
20 circular hub or blank.

Figure 10A is a sectional view of surface 46 taken along line 10-10. Like segment 12a, circular work surface 46 is divided along its circumferential dimension and its axial dimension into hard regions 22g and soft regions 24g. Shaded areas in Figure 10A show hard regions 22g and unshaded areas show  
25 soft regions 24g. Abrasive surface 46 can be divided into 7 thickness layers 30g, 32g, 33g, 34g, 35g, 36g, and 38g of substantially equal axial width, that is, width in the direction of the axis of rotation of wheel 40. Exterior thickness layers 30g and 38g are completely hard regions. In each interior thickness layer 32g, 33g, 34g, 35g, and 36g, hard regions 22g are circumferentially spaced, that  
30 is spaced in the direction of the circumference of wheel 40, between soft regions

24g. Soft regions 24g are of approximately equal circumferential length, that is of approximately equal length in a direction along the circumference of wheel 40, as hard regions 22g. Further, the hard regions 24g of alternate interior thickness layers 32g, 34g, and 36g are circumferentially offset, that is offset in a direction along the circumference of wheel 40, from the hard regions 24g of alternate interior thickness layers 33g and 35g. Accordingly, the arrangement of abrasive particles in surface 46 forms a checker board pattern of hard regions 22g and soft regions 24g alternating in a circumferential direction and an axial direction and sandwiched between exterior thickness layers 30g and 38g which are each entirely hard region 22g.

Because the surface 46 has the same pattern of hard regions 22g and soft regions 24g as segment 12a, the wear profile which is expected to be produced for surface 46 will be substantially the same as that for segment 12a. As shown in Figure 10B, which is a sectional view of surface 46 taken along line 10B-10B of Figure 10A, the approximate wear profile of surface 46 has radially high areas across exterior thickness layers 30g and 38g and radially lower areas across interior thickness layers 32g through 36g.

It is also within the ambit of the present invention to form a grinding wheel of the type shown in Figure 9 having a work surface with axially and circumferentially alternating patterns of soft regions and hard regions the same as those shown in Figures 4A, 5A, 6A, 7, and 8, or any other pattern of circumferentially and axially alternating arrangements of soft regions and hard regions.

A method of fabricating abrasive segments such as segment 12a or abrasive wheels such as wheel 40 includes alternating layers of bond or filler material with layers of abrasive particles and sintering the layers together. To form the alternating patterns of soft regions and hard regions, certain layers of abrasive particles are arranged in alternating groups of different types of abrasive particles or different concentrations of abrasive particles, or both.



Methods of sintering material to form abrasive articles are well known in the art and disclosed in Tselesin, U.S. Patent No. 5,620,489 for a Method for Making Powder Preform and Abrasive Articles Made Therefrom, issued April 15, 1997; Tselesin, U.S. Patent No. 5,203,880 for Method and Apparatus for Making Abrasive Tools, issued April 20, 1993 and Reexamination Certificate Serial No. B1, 5,203,880 issued therefor on October 17, 1995; deKok et al., U.S. Patent No. 5,092,910 for Abrasive Tool issued March 3, 1992 and Reexamination Certificate Serial No. B1 5,092,910 issued therefor on September 26, 1995; Tselesin, U.S. Patent No. 5,049,165 for Composite Material issued September 17, 1991 and Reexamination Certificate Serial No. B1 5,049,165 issued therefor on September 26, 1995; deKok et al., U.S. Patent No. 4,925,457 issued May 15, 1990 and Reexamination Certificate Serial No. B1 4,925,457 issued therefor on September 26, 1995; and Tselesin, U.S. Patent No. 5,190,568 issued March 2, 1993 and Reexamination Certificate Serial No. B1 5,190,568 issued therefor on March 12, 1996. Each of these references is hereby incorporated by reference in its entirety.

To form an abrasive segment of the type shown in Figure 2 or an abrasive wheel of the type shown in Figure 9, a laminated sheet 80, shown in a top view in Figure 11, is formed. Laminated sheet 80 has a front edge 82 and a side edge 84. For each thickness layer desired, sheet 80 preferably is made up of a layer of bond material and a layer of abrasive particles. Sheet 80 can also include a sheet of porous material and/or a sheet of adhesive substrate for each thickness layer desired. To form the patterns of soft regions and hard regions which enable the present invention to produce a desired wear profile and, hence, a desired type of cut, the abrasive particles can be arranged in alternating groups having either different types of abrasive particles, different concentrations of abrasive particles, or both. The groups can be arranged in openings of layers of porous material or can be arranged on layers of adhesive substrate, or both. If layers of porous material are used, the porous layer can be removed before sintering but need not be. The groups can also be arranged adjacent to the bond

material without any layers of porous material or adhesive substrate. The layers are sintered together to form sheet 80 in which the individual layers of bond material, abrasive particles, porous material and adhesive substrate are no longer discernible.

5           Figure 12 is a front view of front edge 82 of sheet 80 showing the stack up of layers which can be used in the making of segment 12a. Segment 12a is made up of seven thickness layers 30a, 32a, 33a, 34a, 35a, 36a, and 38a. Each thickness layer 30a, 32a, 33a, 34a, 35a, 36a, and 38a includes a bond material layer 50a, 52a, 53a, 54a, 55a, 56a, and 58a, respectively; a porous material layer  
10   60a, 62a, 63a, 64a, 65a, 66a, and 68a, respectively; and an abrasive particle layer 70a, 72a, 73a, 74a, 75a, 76a, and 78a, respectively. Each abrasive particle layer 72a through 76a is arranged in rows in the porous material as explained in more detail below. These layers are sintered together by top punch 84 and bottom punch 85 to form laminated sheet 80. As noted above, sintering  
15   processes suitable for the present invention are well known in the art and described in, for example, in U.S. Patent No. 5,620,489, to Tselesin, which has been incorporated by reference in its entirety. Though Figure 12 shows a single bond material layer for each thickness layer, it is also contemplated to include 2 or more bond layers for each thickness layer.

20           As shown in Figure 12A, to form the alternating arrangement of hard regions and soft regions of segment 12a, the first abrasive particle layer 70a and the seventh abrasive particle layer 78a is each essentially continuous. That is, each opening 90 in porous layers 60a and 68a contains a superabrasive particle 92 of particle layers 70a and 78a, respectively. However, abrasive particle  
25   layers 72a through 76a are arranged in rows staggered with each other on alternating porous material layers. As such, abrasive particle layers 72a through 76a are discontinuous and, as shown in Figure 11, consist of rows having widths corresponding to two rows of openings 90 in porous material layers 62a through 66a, respectively. The widths of the rows of abrasive particles 92  
30   corresponds to the lengths in a circumferential direction of the hard regions 22a

of segment 12a. It is also within the ambit of the present invention to form rows of abrasive particles of widths equal to one, three, four, or any number of adjacent rows of openings 90 in porous material layers 62a through 66a.

To form the checkerboard pattern of hard regions and soft regions of segment 12a, the rows of abrasive particle layers 72a, 74a, and 76a are shifted  
5 in a direction perpendicular to the rows a distance equal to the width of two adjacent rows of openings 90 in porous material layers 62a, 64a, and 66a, respectively, from the position of the rows of abrasive particle layers 73a and 75a.

10 It is further within the ambit of the present invention to place abrasive particles in the rows that in Figure 12A have no abrasive particles, as shown in the embodiment of Figure 12B, which is a front view of a front edge of a sheet such as sheet 80 shown in Figure 11. Elements in Figure 12B identical to those of Figure 12A are labeled with the same alphanumeric characters and elements  
15 in Figure 12B functionally similar to those of Figure 12A are labeled with the same numeral followed by a different letter. In Figure 12B, layers of abrasive particles 72b, 73b, 74b, 75b, and 76b are arranged into two rows of two types of abrasive particles, 92a depicted in Figure 12B as diamond shapes, and 92b, depicted in Figure 12B as circles. Particles 92a are more abrasive than particles  
20 92b. For example, particles 92a can be diamond and particles 92b can be silicon carbide. Accordingly, hard regions will contain diamond particles and soft regions will contain less hard silicon carbide particles.

The thickness layers 30a, 32a, 33a, 34a, 35a, 36a, and 38a are all sintered together by top punch 84 and bottom punch 85. Segments 12a are then  
25 cut by laser from resulting laminated sheet 80 of abrasive material substantially as shown in phantom in Figure 11. The circumferential edge of segment 12a is cut substantially perpendicular to the rows of abrasive particles in abrasive particle layers 72a, 73a, 74a, 75a, and 76a.

The bond material can be any material sinterable with the abrasive  
30 particle layers and is preferably soft, easily deformable flexible material (SEDF)

the making of which is well known in the art and is disclosed in U.S. Patent No. 5,620,489 to Tselesin which has been incorporated by reference in its entirety. Such SEDF can be formed by forming a paste or slurry of bond material or powder such as tungsten carbide particles or cobalt particles, and a binder composition including a cement such as rubber cement and a thinner such as rubber cement thinner. Abrasive particles can also be included in the paste or slurry but need not be. A substrate is formed from the paste or slurry and is solidified and cured at room temperature or with heat to evaporate volatile components of the binder phase. The SEDF used in the embodiment shown in Figure 12 to form bond material layers 50a, 52a, 53a, 54a, 55a, 56a, and 58a can include methylethylketone:toluene, polyvinyl butyral, polyethylene glycol, and dioctylphthalate as a binder and a mixture of copper, iron nickel, tin, chrome, boron, silicon, tungsten carbide, cobalt, and phosphorus as a bond material. Certain of the solvents will dry off after application while the remaining organics will burn off during sintering. Examples of exact compositions of SEDFs that may be used with the present invention are set out below and are available a number of suppliers including: All-Chemie, Ltd. of Mount Pleasant, SC; Transmet Corp. of Columbus, OH; Valimet, Inc., of Stockton, CA, CSM Industries of Cleveland, OH; Engelhard Corp. of Seneca, SC; Kulite Tungsten Corp. of East Rutherford, NJ; Sinterloy, Inc. of Selon Mills, OH; Scientific Alloys Corp. of Clifton, NJ; Chemalloy Company, Inc. of Bryn Mawr, PA; SCM Metal Products of Research Triangle Park, NC; F.W. Winter & Co. Inc. of Camden, NJ; GFS Chemicals Inc. of Powell, OH; Aremco Products of Ossining, NY; Eagle Alloys Corp. of Cape Coral, FL; Fusion, Inc. of Cleveland, OH; Goodfellow, Corp. of Berwyn, PA; Wall Colmonoy of Madison Hts, MI; and Alloy Metals, Inc. of Troy, MI. It should also be noted that not every bond layer forming sheet 80 need be of the same composition, it is contemplated that one or more bond material layers could have different compositions.

The porous material can be virtually any material so long as the material is highly porous (about 30% to 99.5% porosity). Suitable materials are metallic non-woven materials, or wire woven mesh materials such a copper wire mesh. Particularly suitable for use with the present invention is a stainless steel wire mesh. In the embodiment shown in Figure 12, a mesh is formed from a first set of parallel wires crossed perpendicularly with a second set of parallel wires to form porous layers 60a, 62a, 63a, 64a, 65a, 66a, and 68a. The exact dimensions of a stainless steel wire mesh which can be used with the present invention is disclosed below in the Examples section.

As shown in Figure 13A, which is a top view of a single thickness layer 32a of sheet 80, the first set of parallel wires 61 can be placed parallel with front edge 82 and the second set of parallel wires 69 can be placed parallel to side edge 84. However, as shown in Figure 13B it is also possible to angle the porous layer such that the sets of parallel wires 61 and 69 are at a 45 degree angle with front edge 82 and side edges 84. The latter arrangement has the advantage of exposing more abrasive particles at the cutting edge of a work surface when a segment, for example, is cut from sheet 80.

The abrasive particles 92 can be formed from any relatively hard substance such as diamond, cubic boron nitride, boron suboxide, boron carbide, and/or silicon carbide. Preferably diamonds of a diameter and shape such that they fit into the holes of the porous material are used as abrasive particles 92. The particles 92 can either be placed individually in openings 90 in the porous layers 60a, 62a, 63a, 64a, 65a, 66a, and 68a, or they can be prearranged on adhesive substrates 100a, 102a, 103a, 104a, 105a, 106a, and 108a. Figure 14 is a front exploded view of a sheet of the type shown in Figure 11 including adhesive substrates 100a, 102a, 103a, 104a, 105a, 106a, and 108a to which the abrasive particles 92 have been attached. Elements in Figure 14 identical to those of Figure 12A are labeled with identical numerals. The adhesive substrates 100a, 102a, 103a, 104a, 105a, 106a, and 108a can then be sintered with the remainder of the layers that make up sheet 80. Also, the particles 92

can simply be arranged adjacent to the bond material layers 50a, 52a, 53a, 54a, 55a, 56a, and 58a without any porous material layers or adhesive substrate layers. Details of using adhesive substrates to retain abrasive particles to be used in a sintering process are disclosed in U.S. Patent No. 5,380,390 to  
5 Tselesin which has been incorporated by reference in its entirety. If layers of porous material 60a, 62a, 63a, 64a, 65a, 66a, and 68a are used, they can be removed after placement of the abrasive particles 92 and before sintering but need not be.

As will be understood by one skilled in the art, the width of the rows of  
10 abrasive particles can be varied to produce varying lengths in a circumferential direction of hard regions and soft regions. Also, the staggering of the rows in the layers of abrasive particles between the different rows can be varied to produce a desired pattern of hard regions and soft regions. Moreover, the types of abrasive particles can be varied to produce desired patterns of regions having  
15 higher abrasiveness and regions having lower abrasiveness. In particular, the arrangements of hard regions and soft regions of segments 12b through 12f can be achieved by such varying of width of abrasive particle rows and position of rows in the layers of abrasive particles and/or types of abrasive particles in the rows.

20 Further, the layers of abrasive particles do not need to be arranged in rows. Rather, they can be arranged in groups of abrasive particles which can vary in concentration and type of abrasive particle along both a length and width of the layers of abrasive particles.

Bands of abrasive material such as wheel 40 can also be fabricated from  
25 the sheet of abrasive material 80. Wheel 40 can be cut by a laser from sheet 80 as shown in phantom in Figure 11. The size of sheets of the type shown in Figure 11 can be varied for fabricating different sizes of grinding wheels.

### Examples

The following general procedure was used to prepare the saw segments of the present invention.

An open mesh screen having openings approximately 0.6 mm per side and 0.17 mm diameter stainless wire, was cut to 12.7 cm by 12.7 cm (5 inches by 5 inches). An abrasive particle, either diamond or silicon carbide, of approximately 0.42 mm diameter was dropped into each of the screen openings. Three patterns of abrasive particles were used: "full" - every screen opening had one diamond particle; "A" - alternating double rows of diamond and silicon carbide particles, where each opening of the first two rows had a silicon carbide particle; "B" - alternating double rows of diamond and silicon carbide particles, where each opening of the first two rows had a diamond particle.

Each of the powder mixtures of Bonds I, II, III and IV (in Table 1) were mixed with the following ingredients and knife coated onto a release liner to provide a flexible sheet of metal powder: 600 parts Bond, 67 parts 1.5:1 methylethylketone:toluene, 6 parts polyvinyl butyral, 2.26 parts polyethylene glycol having a molecular weight of about 200, and 3.74 parts dioctylphthalate. Each sheet was 161 cm<sup>2</sup> (25 in<sup>2</sup>), approximately 5.6 mm (22 mils) thick and approximately 0.98 grams/in<sup>2</sup>.

**Table 1**

|                  | Bond I | Bond II | Bond III | Bond IV |
|------------------|--------|---------|----------|---------|
| Copper           | 35.9   | 22.9    | 10.8     | 24      |
| Iron             | 35.1   | 22.1    | 9.9      | 22      |
| Nickel           | 7.8    | 30.5    | 1.1      | 16      |
| Tin              | 4.1    | 2.4     | 1.4      | 3       |
| Chrome           | 5.6    | 7.9     | 3.4      | 6       |
| Boron            | 0.8    | 2       | 0.9      | 2       |
| Silicon          | 0.8    | 2       | 0.9      | 2       |
| Tungsten carbide | 9      | 9.2     | 60.4     | 23      |
| Cobalt           | 0.8    | 0.8     | 0.9      | 2       |
| Phosphorus       | 0.2    | 0.2     | 0.5      | 0       |

The screens, filled with abrasive particles, and flexible sheets of metal powder were stacked upon each other to form a laminar composite. The specific layering sequence is detailed in each Example. The layered construction was sintered at approximately 1000°C under a pressure of approximately 400 kg/cm<sup>2</sup> for about 4 minutes.

The composite was then cut into 33 arcuate segments 4 cm long with a laser, and then the segments were equally spaced on the periphery of a 35.5 cm (14 inch) diameter steel saw blade core.

Example 1 was prepared as described in the general procedure. The resulting layered construction was as follows:

|    |         |
|----|---------|
|    | Bond IV |
|    | "full"  |
|    | Bond II |
|    | Bond II |
| 15 | "A"     |
|    | Bond II |
|    | Bond II |
|    | "full"  |
|    | Bond II |
| 20 | Bond II |
|    | "B"     |
|    | Bond II |
|    | Bond II |
|    | "full"  |
| 25 | Bond II |
|    | Bond II |
|    | "A"     |
|    | Bond II |
|    | Bond II |
| 30 | "full"  |
|    | Bond II |
|    | Bond II |
|    | "B"     |
|    | Bond II |
| 35 | Bond II |
|    | "full"  |
|    | Bond IV |



Example 2 was prepared as described in the general procedure. The resulting layered construction was as follows:

5       Bond IV  
           "full"  
       Bond IV  
       10 Layers Bond II with 6.25 volume percent diamond to the metal  
           powder  
       Bond IV  
       "full"  
 10       Bond IV

Comparative Example A was a concrete saw commercially available from Diamont Boart Felker (Kansas City, MO) under the trade designation "Gold Star Supreme".

15       Examples 1 and 2 and Comparative Example A were tested on cured  
       "Houston Hard" aggregate concrete using a gas powered walk-behind saw  
       operating at approximately 2700 rpm with water supplied to each side of the  
       blade. Cut rate and projected saw life are reported in Table 2.

**Table 2**

| Example | Cut Rate<br>cm-meters/min (inch-ft/min) | Projected Life<br>cm-meters (inch-ft) |
|---------|---|---------------------------------------|
| 1       | 10.1 (13)                               | 2322 (3000)                           |
| 2       | 11.6 (15)                               | 1355 (1750)                           |
| Comp. A | 7.7 (10)                                | 1935 (2500)                           |

Example 3 was prepared as described in the general procedure. The resulting layered construction was as follows:

Bond IV  
 "full"  
 5 Bond I  
 Bond I  
 "A"  
 Bond I  
 Bond I  
 10 "full"  
 Bond I  
 Bond I  
 "B"  
 Bond I  
 15 Bond I  
 "full"  
 Bond I  
 Bond I  
 "A"  
 20 Bond I  
 Bond I  
 "full"  
 Bond IV

25 Comparative Example B was a concrete saw commercially available from Cushion Cut Company of Torrance, CA under the trade designation "CC-24 Supreme 6.0".

Example 3 and Comparative Example B were tested on cured "Denver  
 Medium Hard" aggregate concrete using a gas powered walk-behind saw  
 30 operating at approximately 2700 rpm with water supplied to each side of the  
 blade. Cut rate and projected saw life are reported in Table 3.

**Table 3**

| Example | Cut Rate<br>cm-meters/min<br>(inch-ft/min) | Projected Life<br>cm-meters (inch-ft) |
|---------|--|---------------------------------------|
| 3       | 27.9 (36)                                  | 9290 (12000)                          |
| Comp. B | 18.6 (24)                                  | 7742 (10000)                          |

Comparative Example C was a concrete saw commercially available from Terra Diamond Industrial (Salt Lake City, UT).

Example 4 was prepared as described in the general procedure. The resulting layered construction was as follows:

|    |          |
|----|----------|
| 5  | Bond III |
|    | "full"   |
|    | Bond III |
|    | Bond III |
|    | "A"      |
| 10 | Bond III |
|    | Bond III |
|    | "full"   |
|    | Bond III |
|    | Bond III |
| 15 | "B"      |
|    | Bond III |
|    | Bond III |
|    | "full"   |
|    | Bond III |
| 20 | Bond III |
|    | "A"      |
|    | Bond III |
|    | Bond III |
|    | "full"   |
| 25 | Bond III |

Example 4 and Comparative Example C were tested on green "Denver Medium Hard" aggregate concrete using a gas powered walk-behind saw operating at approximately 2700 rpm with water supplied to each side of the blade. Cut rate and projected saw life are reported in Table 4.

**Table 4**

| Example | Cut Rate<br>cm-meters/min<br>(inch-ft/min) | Projected Life<br>cm-meters (inch-ft) |
|---------|--|---------------------------------------|
| 4       | 34.8 (45)                                  | 14518 (18752)                         |
| Comp. C | 23.2 (30)                                  | 12387 (16000)                         |

Though the present invention has been described with reference to preferred embodiments, those skilled in the art will recognize that changes can be made in form and detail without departing from the spirit and scope of the invention.

CLAIMS

What is claimed is:

1. A tool for cutting and grinding comprising:  
an abrasive work surface having a circumferential dimension orthogonal  
5 to an axial dimension;  
a plurality of first regions spaced in the circumferential dimension and  
the axial dimension on the abrasive work surface; and  
a plurality of second regions spaced in the circumferential dimension and  
the axial dimension on the abrasive work surface, wherein each  
10 first region is more wear resistant than each second region such  
that each second region will wear faster than each first region.
2. The tool of claim 1 wherein the work surface is divided in the axial  
dimension into a plurality of layers extending in the circumferential dimension  
15 and orthogonal to the axial dimension.
3. The tool of claim 2 wherein a first exterior layer forms a first external  
edge of the work surface, a second external layer forms a second external edge  
of the work surface, and a plurality of interior layers are located between the  
20 first exterior layer and the second exterior layer.
4. The tool of claim 3 wherein each of the plurality of interior layers is  
divided along the circumferential direction into first regions and second regions  
and the first exterior layer includes only a first region and the second exterior  
25 layer includes only a first region.
5. The tool of claim 4 wherein each layer has substantially the same width.

6. The tool of claim 5 wherein the first regions and the second regions of the interior layers are all of approximately equal circumferential length and the first regions and the second regions of adjacent interior layers are offset from each other along the circumferential dimension by a distance equal to the  
5 circumferential length of each first region.
7. The tool of claim 6 including anywhere from one to seven interior layers.
8. The tool of claim 5 including:  
10 a first interior layer adjacent to the first exterior layer;  
a second interior layer adjacent to the second exterior layer, the first interior layer and the second interior layer each having first regions of approximately one-third the circumferential length of second regions thereof; and  
15 a third interior layer located between the first and second interior layers and having first regions of approximately the same circumferential length as second regions thereof.
9. The tool of claim 8 wherein the first regions of the interior layers are all  
20 of approximately equal length and the first regions of adjacent interior layers are all offset from each other along the circumferential dimension by a distance equal to the circumferential length of each first region.
10. The tool of claim 5 wherein the first regions of each interior layer are all  
25 approximately four times the circumferential length of the second regions of each interior layer and centers along the circumferential dimension of the first regions of adjacent interior layers are aligned with centers along the circumferential dimension of the second regions thereof.
- 30 11. The tool of claim 10 including three interior layers.

12. The tool of claim 5 including:  
a first interior layer adjacent to the first exterior layer;  
a second interior layer adjacent to the second exterior layer, the first  
interior layer and the second interior layer each having first  
regions of approximately equal circumferential length as second  
regions thereof; and  
a third interior layer located between the first interior layer and the  
second interior layer and including only a first region.
- 10 13. The tool of claim 2 including:  
a first layer divided in the circumferential dimension into first regions  
and second regions, each second region having approximately  
three times a circumferential length of each first region;  
a second layer divided in the circumferential dimension into first regions  
and second regions, each second region having approximately  
three times a circumferential length of each first region; and  
a third layer divided along the circumferential dimension into first  
regions and second regions, each first region having a  
circumferential length approximately equal to that of each second  
region thereof wherein the first regions of adjacent interior layers  
are all offset from each other along the circumferential dimension  
by a distance equal to the circumferential length of the first  
regions.
- 25 14. The tool of claim 2 including three layers wherein each layer is divided  
in the circumferential dimension into first regions and second regions, the first  
regions having approximately equal circumferential length as the second  
regions, wherein the first regions of adjacent layers are offset in the  
circumferential dimension by a distance equal to the circumferential length of  
the first and second regions.
- 30

15. The tool of claim 1 wherein the work surface is formed from a plurality of arcuate segments of approximately equal length.
16. The tool of claim 15 including a rigid circular hub having a perimeter surface to which the plurality of arcuate segments are attached.
17. The tool of claim 1 wherein the work surface is a continuous circular band having a curvature approximately equal to that of the circular hub.
18. The tool of claim 1 wherein the first regions and the second regions include abrasive particles.
19. The tool of claim 1 wherein the abrasive particles included in each first region are harder than the abrasive particles included in each second region.
20. The tool of claim 19 wherein the abrasive particles included in each first region include diamonds and the abrasive particles included in each second region include silicon carbide particles.
21. The tool of claim 1 wherein the concentration of abrasive particles included in each first region is higher than the concentration of abrasive particles included in each second region.
22. The tool of claim 1 wherein the first regions and the second regions include bond material.



23. A method of manufacturing an abrasive surface for a cutting and grinding tool comprising the steps of:
- providing a plurality of layers of bond material;
  - providing a plurality of layers of abrasive particles;
  - 5 forming at least a first group and at least a second group of abrasive particles in at least a first layer of the plurality of layers of abrasive particles;
  - interleaving the plurality of layers of abrasive particles with the layers of bond material;
  - 10 sintering the layers of bond material with the layers of abrasive particles to form a laminated sheet; and
  - cutting the abrasive surface from the laminated sheet.
24. The method of claim 23 wherein the step of forming at least a first group and at least a second group of abrasive particles includes forming at least two rows of abrasive particles.
25. The method of claim 24 wherein the step of forming at least a first group and at least a second group of abrasive particles includes:
- 20 forming at least first and second rows of abrasive particles in a plurality of layers of abrasive particles; and
  - shifting the first and second rows of abrasive particles in adjacent layers of abrasive particles out of alignment in a direction perpendicular to the layers of abrasive particles.
26. The method of claim 25 wherein the step of forming at least a first group and at least a second group of abrasive particles includes forming a first row of abrasive particles having abrasive particles that are different from the abrasive particles of the second row of abrasive particles.

27. The method of claim 26 wherein the step of forming at least a first group and at least a second group of abrasive particles includes forming a first row of abrasive particles having diamonds and a second row of abrasive particles having silicon carbide particles.

5

28. The method of claim 25 wherein the step of forming at least a first group and at least a second group of abrasive particles includes: forming a first row of abrasive particles having a higher concentration of abrasive particles than the second row of abrasive particles.

10

29. The method of claim 23 including the additional steps of:  
providing a plurality of layers of porous material; and  
interleaving a plurality of layers of porous material with the plurality of  
layers of bond material and the plurality of layers of abrasive  
particles.

15

30. The method of claim 29 wherein the step of sintering the plurality of layers of bond material with the plurality of layers of abrasive particles includes sintering the plurality of layers of porous material with the plurality of layers of  
bond material and the plurality of layers of abrasive particles.

20

31. The method of claim 29 including the additional step of:  
placing each abrasive particle of each layer of abrasive particles into a  
single opening in an associated layer of porous material.

25

32. The method of claim 31 wherein the step of providing a plurality of layers of porous material includes providing a plurality of layers of porous material wherein each layer of porous material includes a metallic mesh having a first set of parallel wires crossing perpendicularly to a second set of parallel  
wires.

30

33. The method of claim 32 wherein the step of forming at least a first group and at least a second group of abrasive particles includes forming at least first rows of abrasive particles and second rows of abrasive particles parallel to the first set of parallel wires of each layer of porous material.

5

34. The method of claim 32 wherein the step of forming at least a first group and at least a second group of abrasive particles includes forming at least first rows and second rows at a 45 degree angle to the first set of parallel wires of each layer of porous material.

10

35. The method of claim 29 wherein:  
the step of providing a plurality of layers of bond material includes  
providing seven layers of bond material; and  
the step of interleaving a plurality of layers of porous material with the  
plurality of layers of bond material and the plurality of layers of  
abrasive particles includes overlaying each layer of bond material  
with a layer of porous material.

15

36. The method of claim 25 wherein the step of cutting the abrasive surface from the laminated sheet includes cutting the abrasive surface such that the first and second rows are substantially perpendicular to a working edge of the abrasive surface.

20

37. The method of claim 36 wherein the step of cutting the abrasive surface from the laminated sheet includes cutting a plurality of arcuate segments from the laminated sheet.

25

38. The method of claim 36 wherein the step of cutting the abrasive surface from the laminated sheet includes cutting a circular band from the laminated sheet.

30

39. The method of claim 25 wherein the step of providing a plurality of layers of bond material includes providing a plurality of layers of soft, easily deformable flexible material.

- 5 40. The method of claim 25 including the additional steps of:  
providing a plurality of adhesive substrates;  
attaching each layer of abrasive particles to an adhesive substrate; and  
interleaving the plurality of adhesive substrates with the plurality of  
layers of bond material, the plurality of layers of abrasive  
10 particles, and the plurality of layers of porous material.

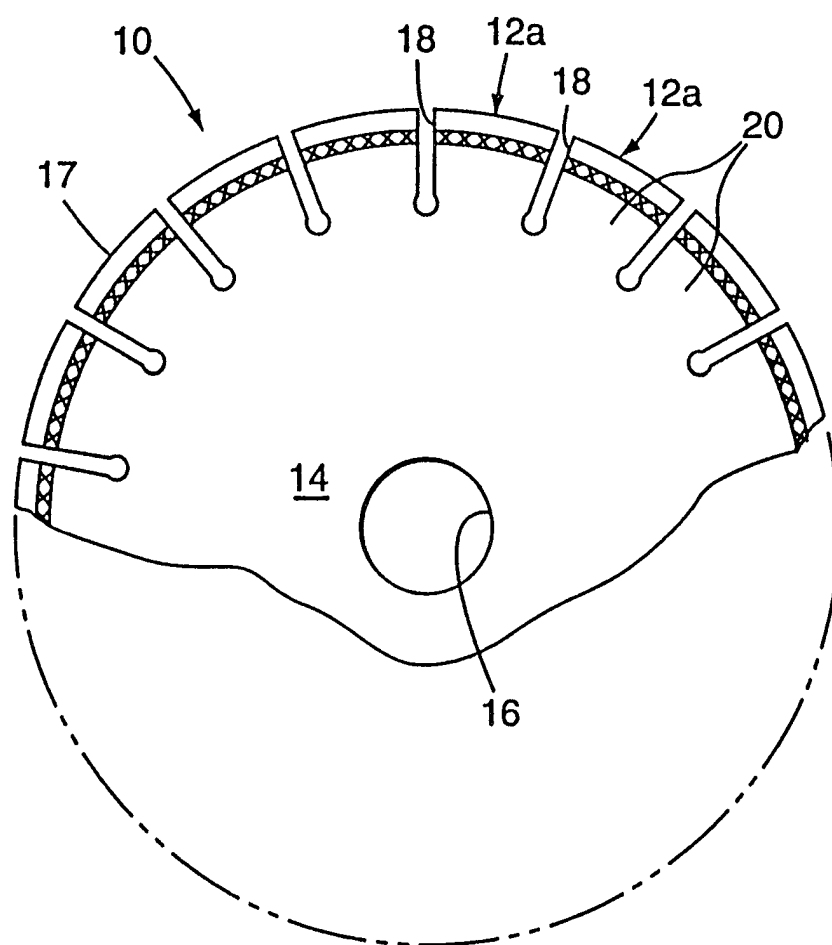


Fig. 1

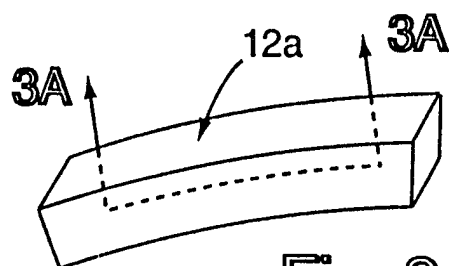
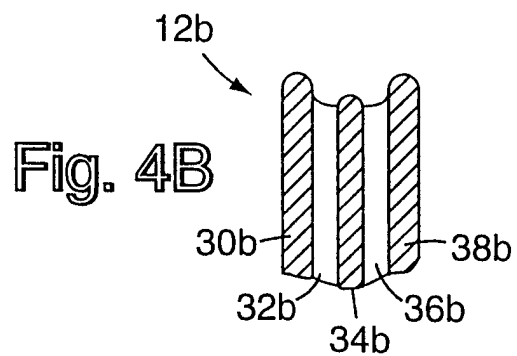
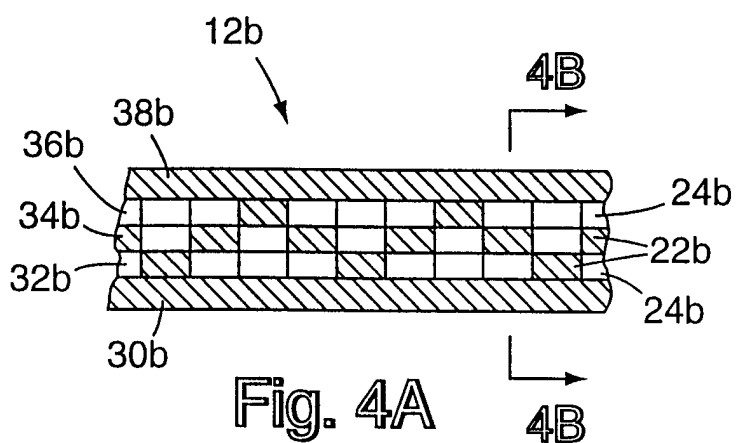
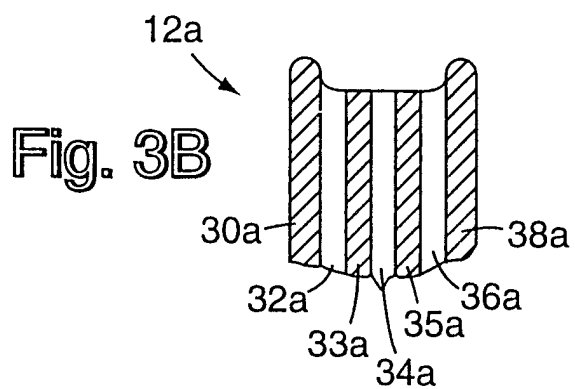
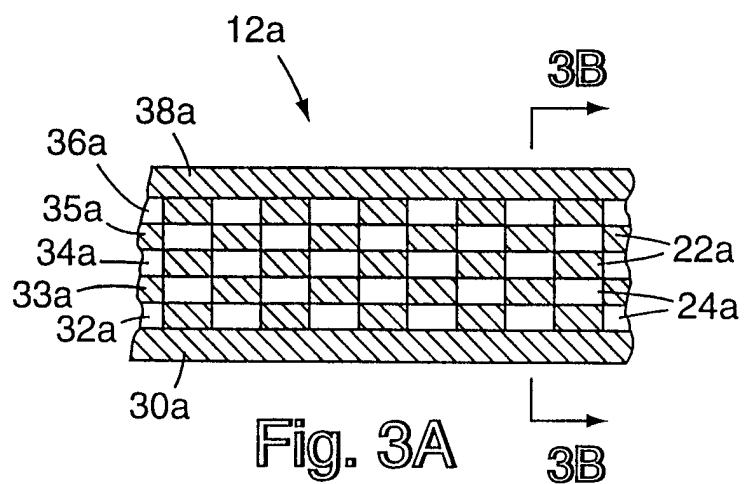
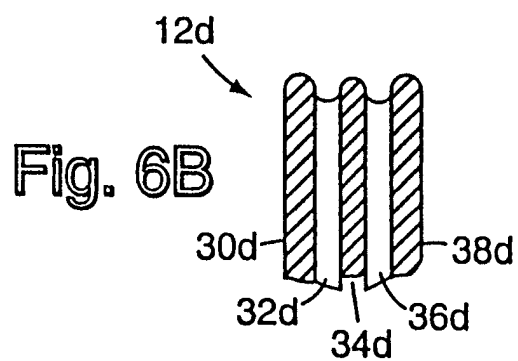
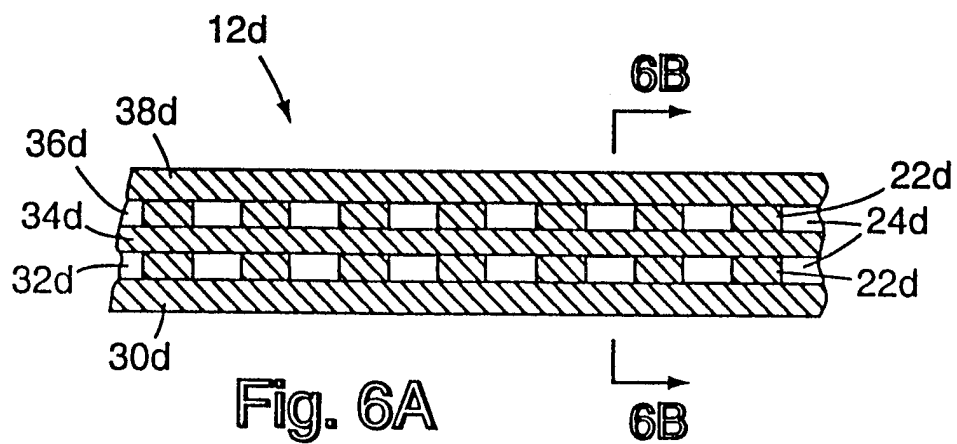
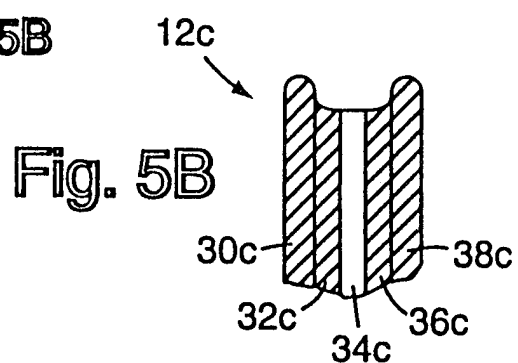
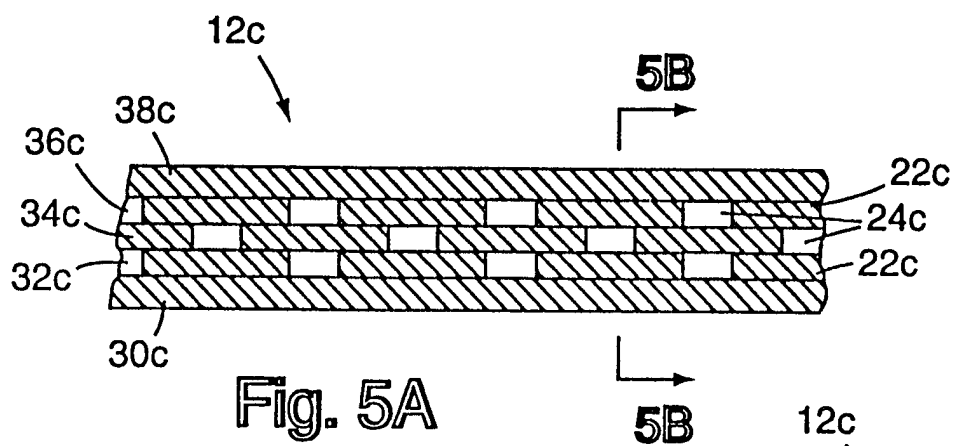


Fig. 2





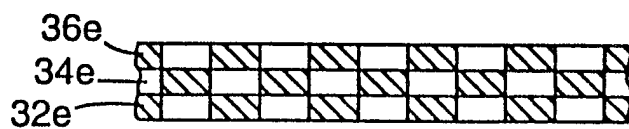


Fig. 7

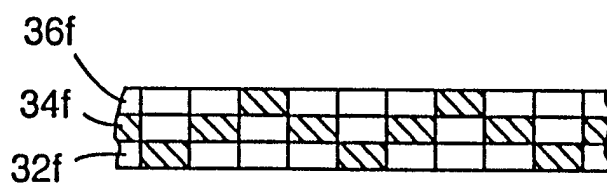


Fig. 8

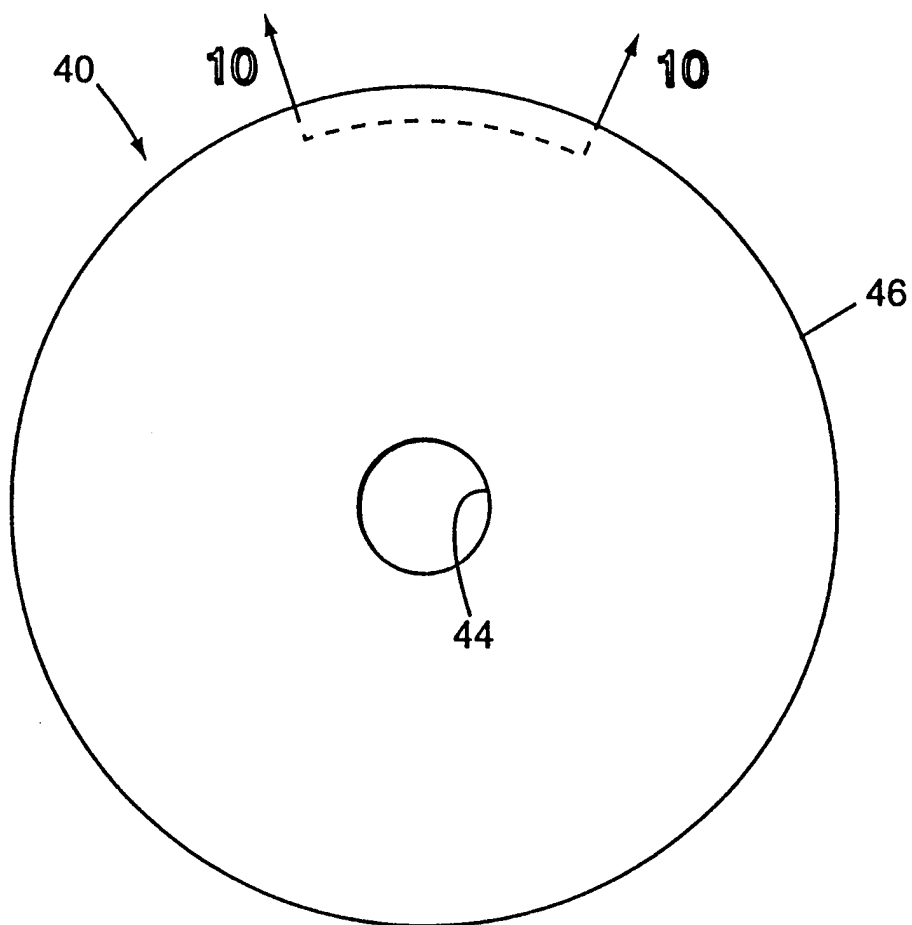
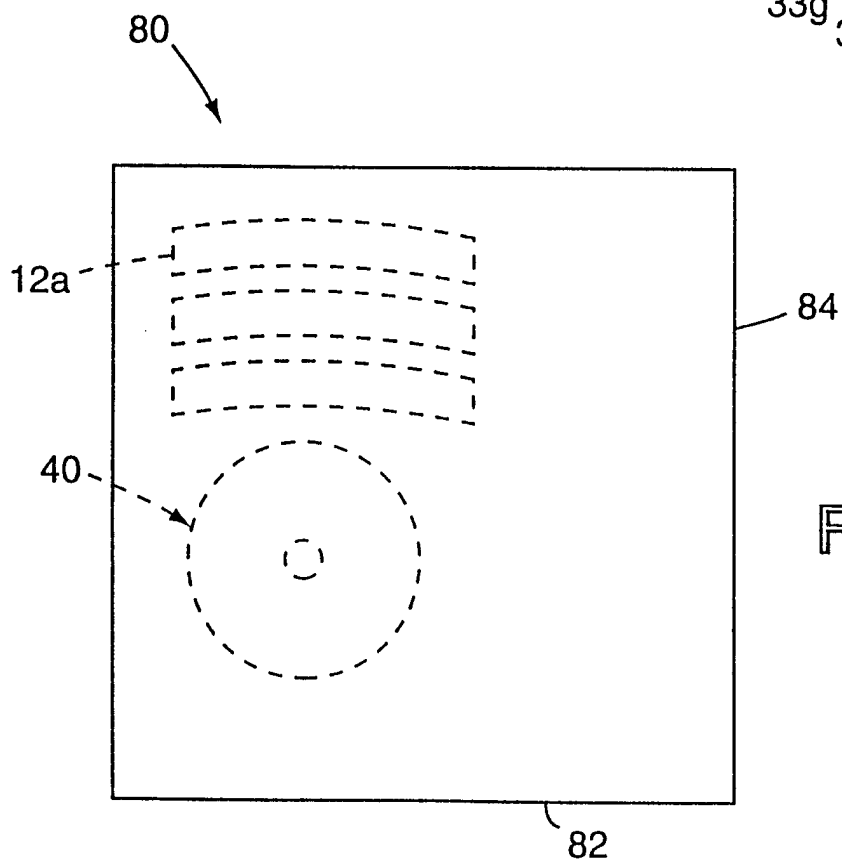
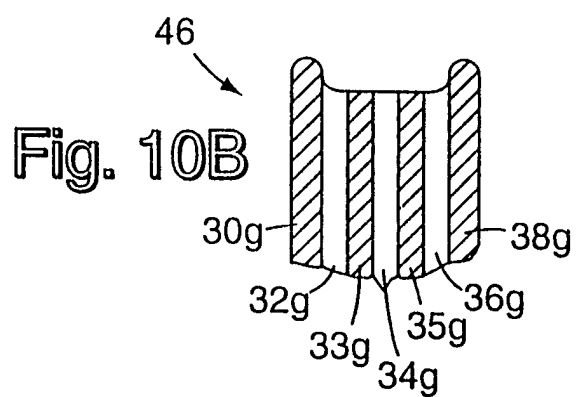
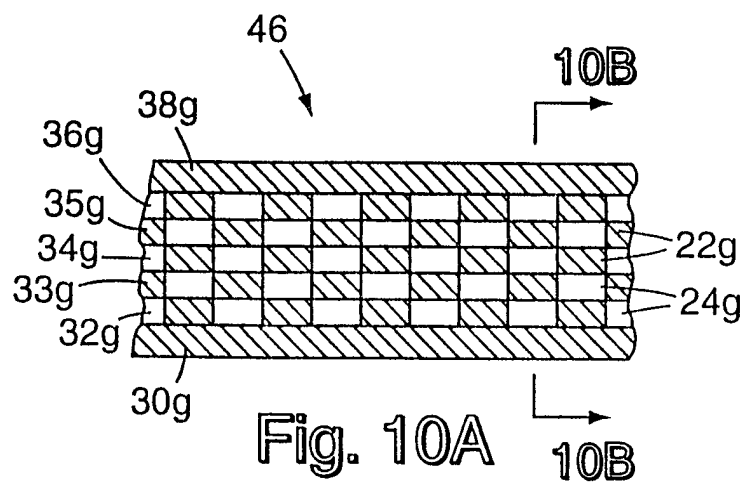


Fig. 9





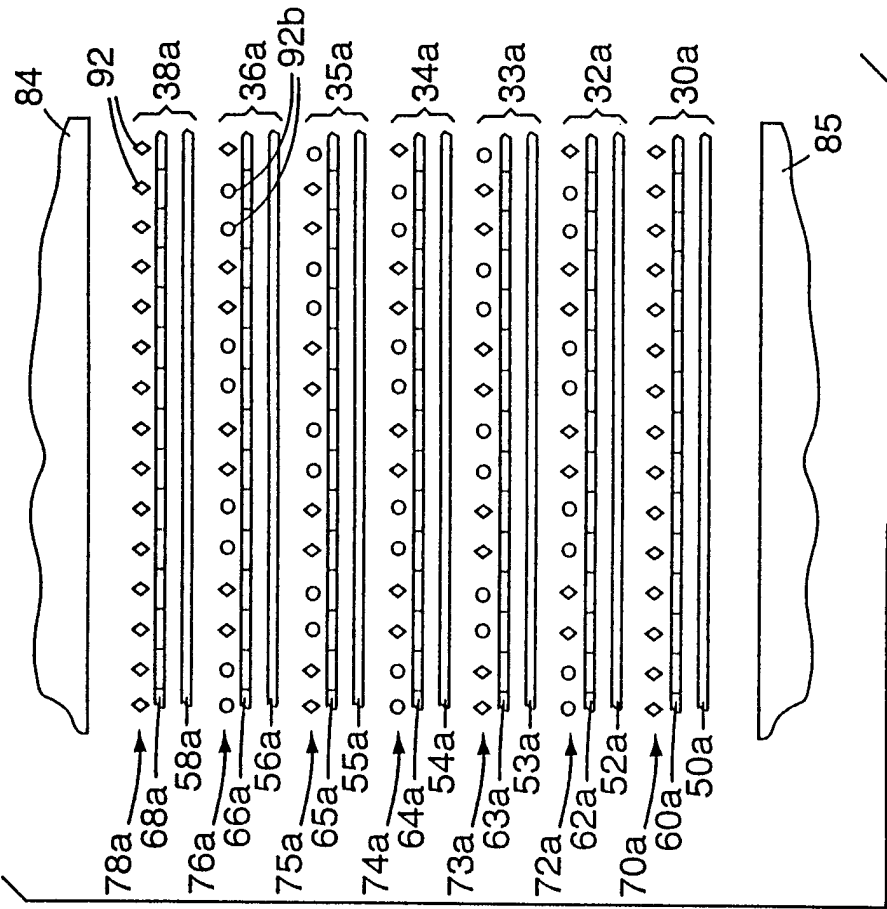


Fig. 12B

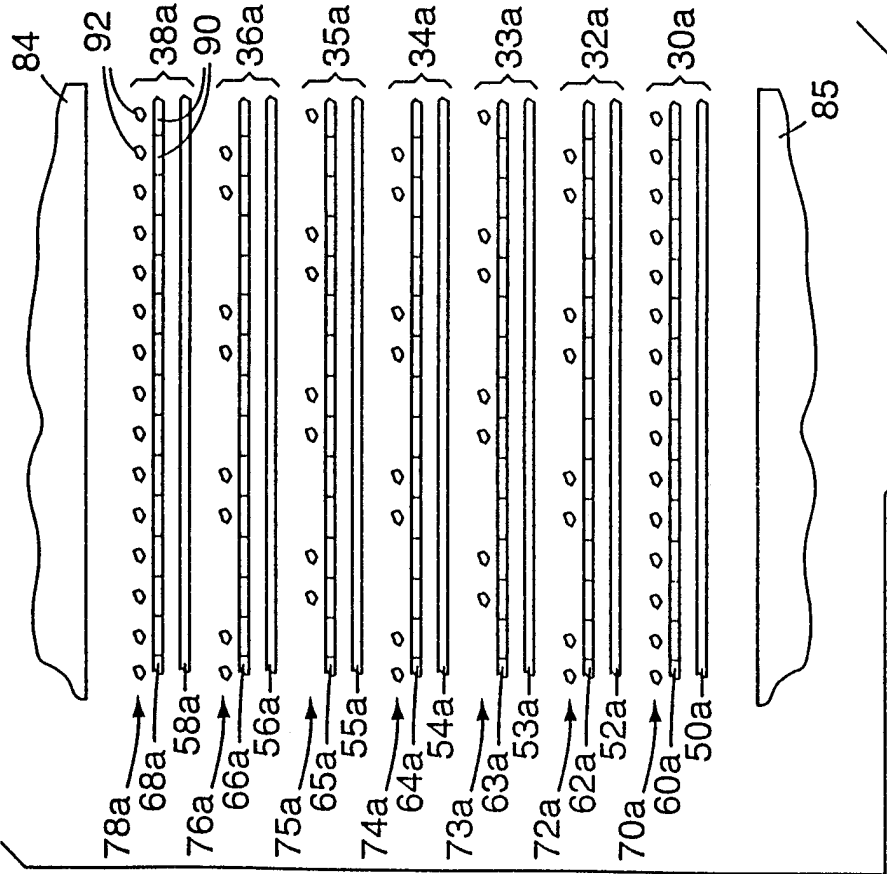


Fig. 12A

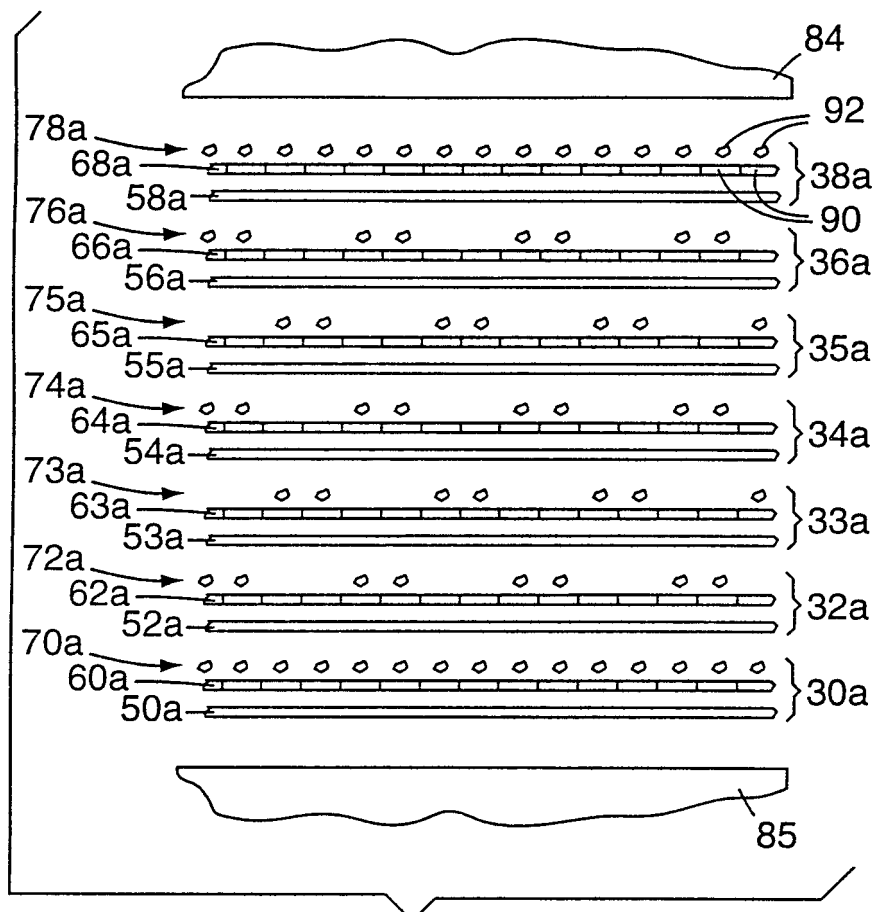


Fig. 12A

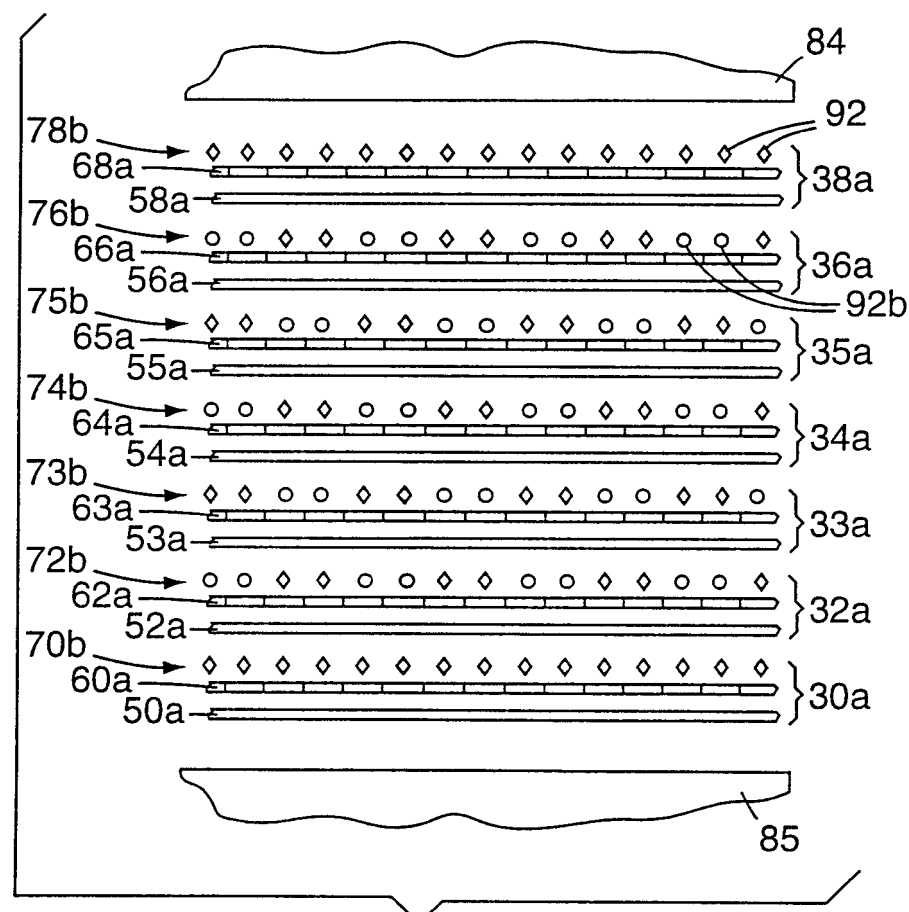
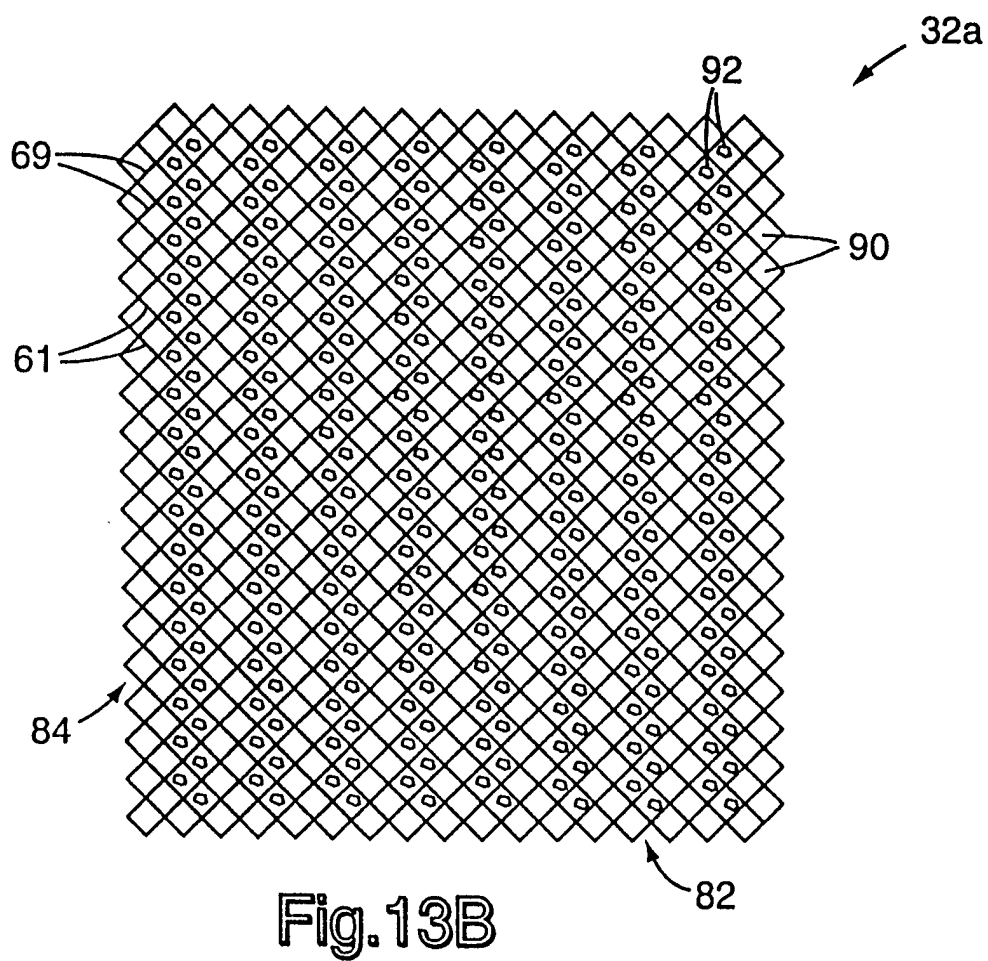
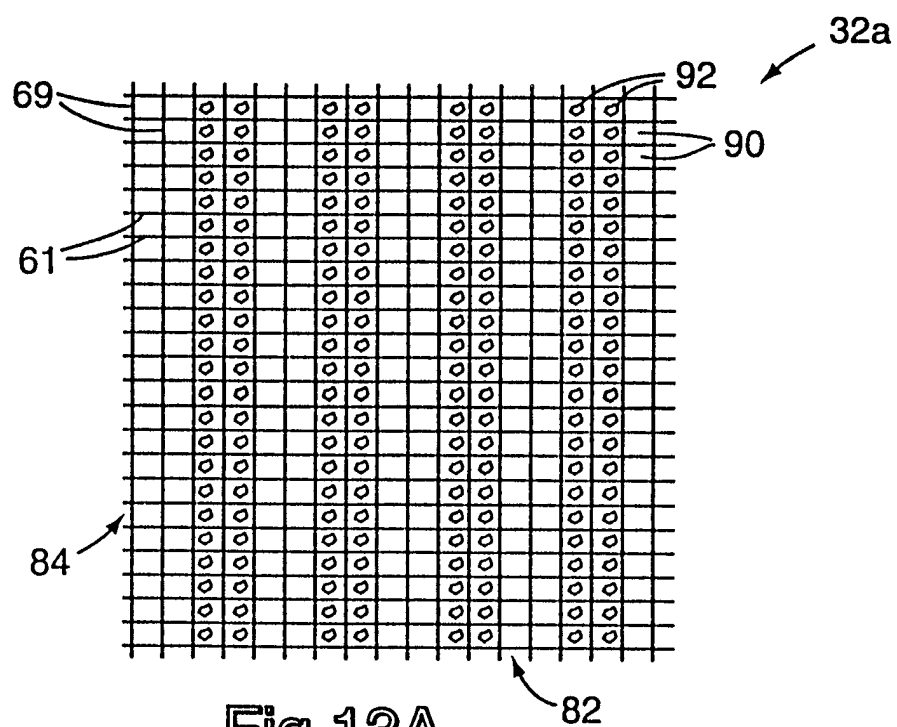


Fig. 12B



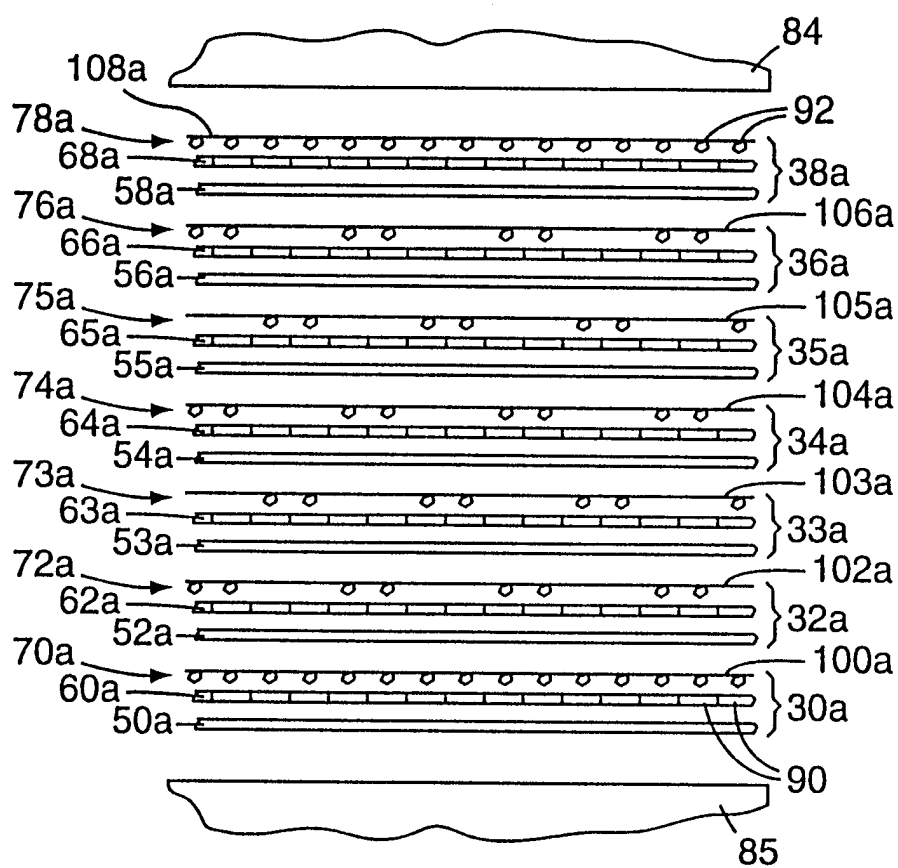


Fig.14

# INTERNATIONAL SEARCH REPORT

International Application No  
PCT/US 98/11862

**A. CLASSIFICATION OF SUBJECT MATTER**  
IPC 6 B24D5/14 B24D5/06

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)  
IPC 6 B24D

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)

**C. DOCUMENTS CONSIDERED TO BE RELEVANT**

| Category °          | Citation of document, with indication, where appropriate, of the relevant passages  | Relevant to claim No.   |
|---------------------|---|---|
| X<br>A<br><br><br>A | <p>US 4 341 532 A (OIDE KUNIMASA)<br/>27 July 1982<br/>see column 1, line 36 - line 61</p> <p>see column 9, line 33 - line 68; figures<br/>14-16</p> <p style="text-align: center;">---</p> <p>PATENT ABSTRACTS OF JAPAN<br/>vol. 012, no. 485 (M-777),<br/>19 December 1988<br/>&amp; JP 63 207565 A (SHUJI SHIMAMOTO),<br/>26 August 1988<br/>see abstract</p> <p style="text-align: center;">---</p> <p style="text-align: center;">-/--</p> | <p>1-3,15,<br/>18,19,22<br/>4,13,14,<br/>20,23,24</p> <p>1,23</p> |



Further documents are listed in the continuation of box C.



Patent family members are listed in annex.

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Date of the actual completion of the international search

16 September 1998

Date of mailing of the international search report

24/09/1998

Name and mailing address of the ISA

European Patent Office, P.B. 5818 Patentlaan 2  
NL - 2280 HV Rijswijk  
Tel. (+31-70) 340-2040, Tx. 31 651 epo nl,  
Fax: (+31-70) 340-3016

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Eschbach, D

# INTERNATIONAL SEARCH REPORT

International Application No

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## C.(Continuation) DOCUMENTS CONSIDERED TO BE RELEVANT

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|------------|---|-----------------------|
| A          | <p>PATENT ABSTRACTS OF JAPAN<br/> vol. 095, no. 002, 31 March 1995<br/> &amp; JP 06 312376 A (NORITAKE DIA KK),<br/> 8 November 1994<br/> see abstract</p> <p style="text-align: center;">-----</p> | 1,23                  |

# INTERNATIONAL SEARCH REPORT

Information on patent family members

International Application No

PCT/US 98/11862

| Patent document<br>cited in search report | Publication<br>date | Patent family<br>member(s) | Publication<br>date |
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