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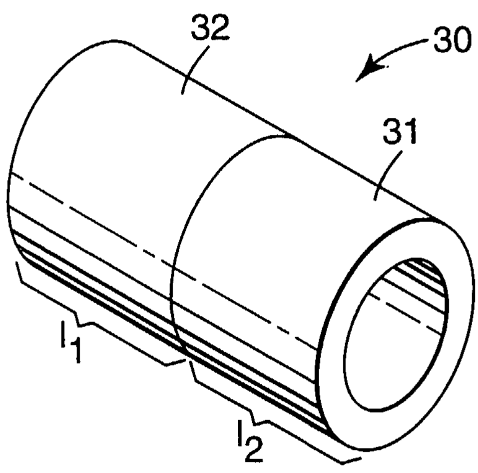
(54) Title: ABRASIVE ARTICLE, APPARATUS AND PROCESS FOR FINISHING GLASS OR GLASS-CERAMIC RECORDING DISKS



(57) Abstract: A process, multi-functional grinding wheel (30) and apparatus for mirror-finishing the edge of at least one of a cut unfinished glass recording disk (10) or a cut unfinished glass-ceramic recording disk. The process includes (a) rough grinding the edge of the at least one of the unfinished glass recording disk (10) or the unfinished glass ceramic recording disk with a diamond abrasive wheel to shape the edge into a trapezoid cross section; (b) grinding the trapezoid-shaped edge of the at least one of the glass recording disk (10) or the unfinished glass ceramic recording disk with a first resin bonded grinding wheel (31) which comprises abrasive grains having an average particle size in the range from about 75 micrometers to about 15 micrometers and has an axis of rotation and an annular shape with an inside curved surface and an outside curved surface extending along the axis of rotation; and (c) grinding the edge of the trapezoid-shaped recording disk with a second resin bonded grinding wheel (32) which comprises abrasive grains having an average particle size in the range from about 3 micrometers to about 0.2 micrometer and has an axis of rotation and an annular shape with an inside curved surface and an outside curved surface extending along the axis of rotation. The multi-functional grinding wheel (30) comprises the first grinding wheel coaxially attached to the second grinding wheel.

ABRASIVE ARTICLE, APPARATUS AND PROCESS FOR FINISHING GLASS OR GLASS-CERAMIC RECORDING DISKS

Background

Field of the Invention

The present invention relates to a process and apparatus for mirror-finishing the edge of an unfinished blank glass or glass-ceramic recording disk and a resin bonded grinding wheel useful in such a process.

Related Art

Conventionally, disk materials have been widely used as substrates for information recording media such as hard disks for personal computers. In recent years, there have been ever-increasing demands for glass or glass-ceramic plates capable of recording information with high density, and attention has been focused on the development of finishing processes for making glass or glass-ceramic memory disks.

When a glass or glass-ceramic plate is processed into a disk substrate for an information recording medium, a glass or glass-ceramic plate is typically first punched out by a glass cutter to form an unfinished recording disk. The edge of the as-punched out plate is sharp and dangerous to handle. A chamfering process for cutting the corners of the edge off and a finishing process must thereafter be carried out.

Conventionally, the edge of the unfinished punched out disk is ground and shaped into trapezoid cross-section by a diamond wheel. A plurality of the unfinished disks are then superposed and edge polished. Polishing typically employs a brush while supplying cerium oxide slurry thereto as a polishing adjuvant to carry out the edge polishing process.

During the initial grinding and shaping processes by use of a diamond wheel, however, a number of unwanted pits are created on the polished disk face which the subsequent brush polishing process fails to completely remove. Consequently, fine particles derived from shavings and polishing adjuvant enter the remaining pits as foreign matter, and are often ejected during the subsequent processes, causing contamination on the substrate surface. Moreover, this conventional method generates a large amount of waste water containing cerium oxide that may be a soil pollutant, resulting in high waste-water treatment costs.

Japanese Patent Kokai Publication No. 5759/1989, published January 10, 1989, reports a method for grinding the edge of an unfinished glass hard disk by using a grinding wheel. However, this method needs to use a grinding wheel together with elastic members, resulting in a complex grinding operation with associated high costs.

Japanese Patent Application No. 212690/1998, published on February 15, 2000 as Japanese Patent Kokai Publication No. 2000-042889, reports a method for grinding the unfinished edge of a recording disk which may solve some of the above-mentioned problems. In this method, the pitted edge of an edge-ground disk as punched out is polished by using a resin bonded grinding wheel composed of a comparatively soft bonding agent. As a result, it is possible to reduce the size of pits remaining on the face being ground.

In recent years, demands for higher recording density in the recording media, has dictated that the pits on the edge of the substrate which cause contamination on the substrate surface be substantially eliminated.

Japanese Patent Application No. 212690/1998 also reports a process to effectively eliminate the pits from the edge of an unfinished glass disk that has been ground and shaped into trapezoid. In this process it is necessary to independently grind the edge of the upper face and the right and left slanting faces of the trapezoid by using three different grinding wheels. For this reason, a complicated operation is required in which the three grinding wheels need to be precisely positioned and removably attached to three different shafts. This operation tends to cause offsets in the mounting positions, resulting in deviation in the quality of the finished substrate and reduction in the grinding wheel service life.

Japanese Patent Kokai Publication No. 164291/1995, published June 27, 1995, reports a method for grinding the edge of a semiconductor wafer in which a grinding wheel is made into a cylinder shape, a semiconductor wafer having a disk shape is inserted in an inner space of the cylinder, and the inside surface of the grinding wheel is used as a grinding surface. This publication also describes that there is an increase in the area of contact between the semiconductor wafer circumference and the grinding surface due to this grinding method, thus shortening the period required for grinding.

The above publication does not, however, teach or suggest process conditions required for mirror-finishing the edge of an unfinished glass or glass-ceramic recording disk which eliminate pits from the disk edge. The present invention is directed at solving edge pitting problem caused when the edge of a punched out glass or glass-ceramic disk is ground by a diamond wheel to shape the edge into a trapezoid cross-section. The diamond grinding, thus, leaves a pitted surface that is difficult to polish by presently known methods.

Summary of the Invention

The present invention substantially solves certain of the above-mentioned problems, and provides a process for finishing the ground edge of at least one of an unfinished glass recording disk or an unfinished glass-ceramic recording disk which substantially eliminates pits on the disk edge and which is easily operated substantially without causing any loss in the quality of the finished recording medium.

The present invention provides a process for mirror-finishing the edge of a cut of at least one of an unfinished glass or a glass-ceramic recording disk. The process comprising:

a. rough grinding the edge of the unfinished glass or the glass-ceramic recording disk with a diamond abrasive wheel to shape the edge into a trapezoid cross section;

b. grinding the trapezoid-shaped edge of the glass recording disk or the glass-ceramic recording disk with a first resin bonded grinding wheel which comprises abrasive grains having an average particle size in the range from about 53 micrometers to about 9.5 micrometers (e.g., graded according to one of JIS#220 (which has an average particle size of about 53 micrometers), JIS#240 (which has an average particle size of about 57 micrometers), JIS#280 (which has an average particle size of about 48 micrometers), JIS#320 (which has an average particle size of about 40 micrometers), JIS#360 (which has an average particle size of about 35 micrometers), JIS#500 (which has an average particle size of about 30 micrometers), JIS#600 (which has an average particle size of about 20 micrometers), JIS#700 (which has an average particle size of about 17 micrometers), JIS#800 (which has an average particle size of about 14 micrometers), JIS#1000 (which has an average particle size of about 11.5 micrometers), or JIS#1200 (which has an average particle size of about 9.5 micrometers)) and has an axis of rotation and an annular shape with an inside curved surface and an outside curved surface extending along the axis of rotation; and

c. after step b, grinding the edge of the trapezoid-shaped recording disk with a second resin bonded grinding wheel which comprises abrasive grains having an average particle size in the range from about 2.5 micrometers to about 0.45 micrometer (e.g., graded according to one of JIS#5000 (which has an average particle size of about 2.5 micrometers), JIS#6000 (which has an average particle size of about 2 micrometers), JIS#8000 (which has an average particle size of about 1.2 micrometer), JIS#10000 (which has an average particle size of about 0.6 micrometer), JIS#15000 (which has an average particle size of about 0.5 micrometer), or JIS#20000 (which has an average particle size of about 0.45 micrometer) and has an axis of rotation and an annular shape with an inside curved surface and an outside curved surface extending along the axis of rotation. In one embodiment, the process further comprises, between steps a and b, the step of grinding the trapezoid-shaped edge of the at least one of the glass recording disk or the unfinished glass-ceramic recording disk with a resin bonded grinding wheel which comprises abrasive grains having an average particle size of about 106 micrometers to about 53 micrometers (e.g., graded according to one of JIS#120 (which has an average particle size of about 106 micrometers), JIS#150 (which has an average particle size of about 75 micrometers), JIS#180 (which has an average particle size of about 63 micrometers), or JIS#220 (which has an average particle size of about 53 micrometers)) and has an axis of rotation and an annular shape with an inside curved surface and an outside curved surface extending along the axis of rotation.

In another aspect, the invention provides a multi-functional grinding wheel comprising at least one resin bonded grinding wheel annular segment which has an axis of rotation and an inside curved surface and an outside curved surface extending along its axis of rotation and which comprises abrasive grains having an average particle size in the range from about 53 micrometers to about 9.5 micrometers (e.g., graded according to one of JIS#220 (which has an average particle size of about 53 micrometers), JIS#240 (which has an average particle size of about 57 micrometers), JIS#280 (which has an average particle size of about 48 micrometers), JIS#320 (which has an average particle size of about 40 micrometers), JIS#360(which has an average particle size of about 35 micrometers), JIS#500 (which has an average particle size of about 30 micrometers), JIS#600 (which has an average particle size of about 20 micrometers), JIS#700 (which has an average particle size of about 17 micrometers), JIS#800 (which has an average particle size of about 14 micrometers), JIS#1000 (which has an average particle size of about 11.5 micrometers), or JIS#1200 (which has an average particle size of about 9.5 micrometers)) coaxially attached to at least one other grinding wheel annular segment which comprises abrasive grains having an average particle size from about 2.5 micrometers to about 0.45 micrometer (e.g., graded according to one of JIS#5000 (which has an average particle size of about 2.5 micrometers), JIS#6000 (which has an average particle size of about 2 micrometers), JIS#8000 (which has an average particle size of about 1.2 micrometer), JIS#10000 (which has an average particle size of about 0.6 micrometer), JIS#15000 (which has an average particle size of about 0.5 micrometer), or JIS#20000 (which has an average particle size of about 0.45 micrometer). Optionally, the multi-functional grinding wheel further comprises at least one resin bonded grinding wheel annular segment which has an axis of rotation and an inside curved surface and an outside curved surface extending along its axis of rotation and which comprises abrasive grains having an average particle size in the range from about 106 micrometers to about 53 micrometers (e.g., graded according to one of JIS#120 (which has an average particle size of about 106 micrometers), JIS#150 (which has an average particle size of about 75 micrometers), JIS#180 (which has an average particle size of about 63 micrometers), or JIS#220 (which has an average particle size of about 53 micrometers)) coaxially attached to at least one other grinding wheel annular segment.

In a further aspect, the invention provides an apparatus for grinding a glass or glass-ceramic disk having a diamond-ground trapezoid-shaped pitted edge comprising:

a multi-functional grinding wheel comprising at least one resin bonded grinding wheel annular segment which has an axis of rotation and an inside curved surface and an outside curved surface extending along its axis of rotation and which comprises abrasive grains having an average particle size in the range from about 53 micrometers to about 9.5 micrometers (e.g., graded according to one of JIS#220 (which has an average particle size of about 53 micrometers), JIS#240 (which has an average particle size of about 57 micrometers), JIS#280 (which has an average particle size of about 48 micrometers), JIS#320 (which has an average particle size of about 40 micrometers), JIS#360 (which has an average particle size of about 35 micrometers), JIS#500 (which has an average particle size of about 30 micrometers), JIS#600 (which has an average particle size of about 20 micrometers), JIS#700 (which has an average particle size of about 17 micrometers), JIS#800 (which has an average particle size of about 14 micrometers), JIS#1000 (which has an average particle size of about 11.5 micrometers), or JIS#1200 (which has an average particle size of about 9.5 micrometers)) coaxially attached to at least one other grinding wheel annular segment which comprises abrasive grains having an average particle size from about 2.5 micrometers to about 0.45 micrometer (e.g., graded according to one of JIS#5000 (which has an average particle size of about 2.5 micrometers), JIS#6000 (which has an average particle size of about 2 micrometers), JIS#8000 (which has an average particle size of about 1.2 micrometer), JIS#10000 (which has an average particle size of about 0.6 micrometer), JIS#15000 (which has an average particle size of about 0.5 micrometer), or JIS#20000 (which has an average particle size of about 0.45 micrometer);

a motor for rotating the multi-functional grinding wheel about its axis of rotation in at least one direction;

a clamp for transversely holding the glass or glass-ceramic disk on a rotatable shaft;

a motor for peripherally rotating the transversely deployed glass or glass-ceramic disk in a direction opposite to that of the grinding wheel; and

a lift mechanism for causing the glass or glass-ceramic disk to move vertically and horizontally to sequentially contact the first and second segments of the rotating grinding wheel under load to cause the grinding wheel segments to remove pits from the pitted surface of the disk edge. Optionally, the multi-functional grinding wheel further comprises at least one resin bonded grinding wheel annular segment which has an axis of rotation and an inside curved surface and an outside curved surface extending along its axis of rotation and which comprises first abrasive grains having an average particle size in the range from about 106 micrometers to about 53 micrometers (e.g., graded according to one of JIS#120 (which has an average particle size of about 106 micrometers), JIS#150 (which has an average particle size of about 75 micrometers), JIS#180 (which has an average particle size of about 63 micrometers), or JIS#220 (which has an average particle size of about 53 micrometers)) coaxially attached to at least one other grinding wheel annular segment, and the lift mechanism can move vertically and horizontally to sequentially contact the segments of the rotating grinding wheel under load to cause the grinding wheel segments to remove pits from the pitted surface of the disk edge.

In the present invention, the recording medium disk refers a disk material used as a hard disk substrate for information recording on and from which electronic information may be written and read, such as a hard-disk glass or glass-ceramic substrate.

Brief Description of the Drawings

FIG. 1 is a schematic outline cross-sectional view that shows the shape of the edge of a glass recording disk that has been ground and shaped to a trapezoid shape by using a diamond wheel.

FIG. 2 is a schematic outline cross-sectional view that shows the shape of a groove that is formed on the outside surface or the inside surface of a grinding wheel used in the present invention.

FIG. 3 is a perspective view that shows one example of a multi-functional wheel used in the present invention.

FIGS. 4(a)-(c) are various schematic outline cross-sectional views that show a dressing process carried out on a grinding wheel used in the present invention.

FIG. 5 is a cross-sectional view that shows one example of the multi-functional grinding wheel to be used in the process according to the present invention.

FIG. 6 is a perspective view that shows one example of a grinding apparatus for conducting the process according to the present invention.

Detailed Description

FIG. 1 shows a schematic outline cross-sectional view of the shape of an edge of a recording disk 10 that has been ground and shaped by a diamond wheel into a trapezoidal cross-section. The thickness of the glass (or glass-ceramic) plate from which the disk is cut is typically about 0.4 to about 1.4 mm, more preferably, 0.6 to 0.8 mm. In the case when the thickness of the disk plate is 0.6 mm, the upper side "a" of the trapezoid has a length of approximately 300 micrometers, and the angle of inclination (θ) on both of the sides is approximately 45°.

Upon grinding and shaping a fragile material such as glass or glass-ceramic by using a diamond wheel, pits are usually formed all through the ground surface. Therefore, on the edge of ground and shaped disk 10, there are typically pits usually having a diameter of 20 to 50 micrometers all through the ground surface.

In the present invention, pits are eliminated by mirror-finishing the edge of the unfinished disk that has been ground and shaped into a trapezoid shape. A process according to the invention includes at least two grinding operations after the diamond shaping operation. A grinding process according to the present invention preferably uses a supply of water to prevent scattering of ground glass or glass-ceramic powder generated during the grinding process. It is not necessary to provide a grinding aid such as a slurry of cerium oxide powder. Therefore, no waste water containing cerium oxide as a soil pollutant is generated during the grinding process, thereby making it possible to reduce cleanup costs.

In the first grinding operation, the grinding is carried by using a resin bonded grinding wheel (hereinafter, referred to as "first grinding wheel") having an average particle size in the range from about 53 micrometers to about 9.5 micrometers, preferably, about 40 micrometers to about 14 micrometers, more preferably, about 30 micrometers to about 20 micrometers. In terms of abrasive grain graded according to Japanese Industrial Standards ("JIS") in the range of JIS#220 to JIS#1200, preferably JIS#320 to JIS#800, and more preferable, JIS#400 to JIS#600. Currently JIS#220 to JIS#8000 is graded according to JIS R 6001 (1998 Edition) and JIS R 6002 (1998 Edition), wherein for JIS#220, the particles are graded with sieves, and the particle size is the mesh size of the sieve on which not less than 40% of the particles remain at the third stage; and wherein for JIS#240 to JIS#8000, grading is via electrical resistance, and the particle size is 50% point of cumulative height of the electrical resistance values measured; and for JIS#10000 and JIS#15000, grading is via sedimentation, and the particle size is the diameter at 50% point of cumulative sedimentation heights. For JIS#20000, grading is via laser light diffraction method using laser light diffraction laser light diffraction particle size analysis meter system obtained from Nikkiso K.K., Japan under the trade designation “MICRO TRAC”, wherein the particle size is the particle diameter at 50% point of cumulative laser beam intensity heights.

Particle sizes greater than about JIS#220 sometimes results in new unwanted pits on the edge of the glass plate during the grinding process. Particle sizes finer than about JIS#1200 requires unreasonably long process times for eliminating the pits.

Any conventional glass polishing abrasive grains may be used as the abrasive material, for example, fused aluminum oxide (including white fused alumina, heat-treated aluminum oxide and brown aluminum oxide), ceria, silicon carbide, boron carbide, titanium carbide, diamond, cubic boron nitride, garnet, fused alumina-zirconia, and sol-gel-derived abrasive particles, and the like. The sol-gel-derived abrasive particles may be seeded or non-seeded. Examples of sol gel abrasive particles include those described U.S. Pat. Nos. 4,314,827 (Leitheiser et al.), 4,518,397 (Leitheiser et al.), 4,623,364 (Cottringer et al.), 4,744,802 (Schwabel), 4,770,671 (Monroe et al.), 4,881,951 (Wood et al.), 5,011,508 (Wald et al.), 5,090,968 (Pellow), 5,139,978 (Wood), 5,201,916 (Berg et al.), 5,227,104 (Bauer), 5,366,523 (Rowenhorst et al.), 5,429,647 (Larmie), 5,498,269 (Larmie), and 5,551,963 (Larmie).

The first grinding wheel preferably has a shore D hardness of at least about 80; more preferably, the shore D hardness is in the range of about 85 to 95. A shore hardness D less than about 80 may result in the grinding face being too abrasive, resulting in a short service life of the grinding wheel. At a shore hardness D exceeding about 95 the wheel may form unwanted large pits on the edge of the glass or glass-ceramic plate during the grinding process.

The density of the first grinding wheel is preferably in the range of about 1.6 to about 2.5 g/cm^3. At a density less than about 1.6 g/cm^3, the grinding face may result in its being too abrasive, resulting in a short service life of the grinding wheel. At a density exceeding about 2.5 g/cm^3, the wheel may form unwanted large size pits on the edge of the glass or glass-ceramic plate during the grinding process.

The wheel bonding agent may be any suitable bonding material that will produce a grinding wheel having the above physical properties. A suitable bonding material is a polyurethane resin. A preferred polyurethane is disclosed in Japanese Patent Kokai Publication No. 294336/1990, published December 5, 1990, and U.S. Pat. No. 4,933,373 (Moren et al.). This reference discloses cross-linked polyurethane which has a glass transition temperature of approximately 10°C and a glass transition temperature range of approximately higher than 70°C.

The first grinding wheel is preferably manufactured by using a method disclosed in Japanese Patent Kokai Publication No. 294336/1990, published December 5, 1990, and U.S. Pat. No. 4,933,373 (Moren et al.). Such grinding wheels are generally known as a foamed elastic grinding material, and examples thereof include that sold under the trade designation "DLO WHEEL" by Sumitomo 3M K.K., Japan.

The first grinding wheel may be provided with a groove that corresponds to the shape of the desired trapezoidal edge shape of the diamond ground disk. The groove may be located on the outside surface or the inside surface of the wheel. That is, the groove would have an inverted trapezoidal shape and would be deployed in a direction transverse to the axis of rotation. FIG. 2 is a schematic outline cross-sectional view that shows the shape of the groove formed on the outside surface or the inside surface of the grinding wheel used in the process according to the present invention. In this case, the upper face and right and left slanting faces of the edge of the disk are simultaneously ground by using a single grinding wheel. One groove or a plurality of grooves may be formed. The edges of a plurality of disks may be simultaneously ground by using a grinding wheel with a plurality of grooves.

The grinding wheel is preferably formed into an annular shape with an inner curved surface and an outer curved surface, as shown in FIG. 3. The inner curved surface portion of the wheel is preferably used to finish the edge of the unfinished disk.

In the grinding process, the grinding wheel and disk are preferably respectively rotated in opposite directions and a load is applied to the disk edge so as to allow the wheel to come into contact with the edge of the disk. The grinding conditions are properly adjusted depending on the level of the finishing required. In general, the conditions are set as follows: The peripheral velocity of the grinding wheel is set in the range of approximately 1000 to 3000 m/min., the peripheral velocity of the disk is set in the opposite direction in the range of 20 to 500 m/min., the load is set in the range of approximately 0.2 to 5 kg, and the grinding time is in the range of 5 to 60 seconds, more preferably, 10 to 30 seconds.

The second grinding process is carried out by using a resin bonded grinding wheel (hereinafter, referred to as the "second grinding wheel") containing abrasive grains having an average particle size in the range from about 2.5 micrometers to about 0.45 micrometer, preferably, about 2 micrometers to about 0.5 micrometer, more preferably, about 1.2

micrometer to about 0.6 micrometer. In terms of abrasive grain graded according to Japanese Industrial Standards ("JIS") in the range of JIS#5000 to JIS#20000, preferably JIS#6000 to JIS#15000, and more preferably, JIS#8000 to JIS#10000. Such grinding wheels are generally known as a foamed elastic grinding material, and examples thereof include that sold under the trade designation "DLO WHEEL" by Sumitomo 3M K.K., Japan.

Abrasive grains having particle sizes larger than JIS#5000 tend to cause insufficient pit removal. The abrasive grains having particle sizes finer than JIS#20000 tend to be insufficient to polish at an economical rate, thus taking too long a time in eliminating pits. The density of the second grinding wheel is preferably in the range of about 1.6 to about 2.5 g/cm^3. At a density less than about 1.6 g/cm^3, the grinding face may become too abrasive, and may result in a short service life of the grinding wheel. At a density exceeding about 2.5 g/cm^3, pits may be created on the edge of the glass or glass-ceramic disk during the grinding process.

Except for the different particle size of the abrasive grains as described above, the second grinding wheel can have the same structure as the first grinding wheel. Therefore, the second grinding wheel may be manufactured in the same manner as the first grinding wheel.

The grinding process of a disk with the second grinding wheel is the same as that of the first grinding wheel. The grinding conditions may be properly adjusted depending on the level of the finishing required. In general, the conditions are set as follows: The peripheral velocity of the grinding wheel is set in the range of approximately 100 to 3000 m/min., the peripheral velocity of the disk is preferably in the range of 20 to 500 m/min., the load is preferably in the range of approximately 0.2 to 5 kg, and the grinding time is preferably in the range of 5 to 60 seconds, more preferably, 10 to 30 seconds.

The trapezoid-shaped edge of an unfinished glass or glass-ceramic disk may also be mirror-finished by carrying out three grinding processes. In this case, in the first grinding process, grinding is carried out by using a resin bonded grinding wheel containing abrasive grains having a particle size of JIS#120, JIS#150, JIS#180, or JIS#220 (about 106 micrometers to about 53 micrometers), in the second grinding process, grinding is carried out by using a resin bonded grinding wheel containing abrasive grains having an average particle size in the range from about 53 micrometers to about 9.5

micrometers (e.g., graded to one of JIS#220 (which has an average particle size of about 53 micrometers), JIS#240 (which has an average particle size of about 57 micrometers), JIS#280 (which has an average particle size of about 48 micrometers), JIS#320 (which has an average particle size of about 40 micrometers), JIS#360 (which has an average particle size of about 35 micrometers), JIS#500 (which has an average particle size of about 30 micrometers), JIS#600 (which has an average particle size of about 20 micrometers), JIS#700 (which has an average particle size of about 17 micrometers), JIS#800 (which has an average particle size of about 14 micrometers), or JIS#1000 (which has an average particle size of about 11.5 micrometers), more preferably, about 30 micrometers to about 20 micrometers (e.g., graded a JIS grade selected from the group consisting of JIS#400 (which has an average particle size of about 30 micrometers), of JIS#500 (which has an average particle size of about 25 micrometers) JIS#600 (which has an average particle size of about 20 micrometers), and in the third grinding process, grinding is carried out by using a third resin bonded grinding wheel containing abrasive grains having an average particle size from about 11.5 micrometers to about 0.45 micrometer (e.g., graded to one of JIS#1000 (which has an average particle size of about 11.5 micrometers), JIS#1200 (which has an average particle size of about 9.5 micrometers), JIS#1500 (which has an average particle size of about 8 micrometers), JIS#2000 (which has an average particle size of about 6.7 micrometers), JIS#2500 (which has an average particle size of about 5.5 micrometers), JIS#3000 (which has an average particle size of about 4 micrometers), JIS#4000 (which has an average particle size of about 3 micrometers), JIS#6000 (which has an average particle size of about 2 micrometers), JIS#8000 (which has an average particle size of about 1.2 micrometer), JIS#10000 (which has an average particle size of about 0.6 micrometer), JIS#15000 (which has an average particle size of about 0.5 micrometer), or JIS#20000 (which has an average particle size of about 0.45 micrometer)), more preferably, about 1.2 micrometer to about 0.6 micrometer (e.g., graded to one of JIS#8000 or JIS#10000).

The grinding wheels used in the grinding processes on the present invention may be used as an independent device in each of the grinding processes. Preferably, the first grinding wheel and the second grinding wheel are joined to form a multi-functional grinding wheel, and this may be used in the respective grinding processes.

FIG. 3 shows a perspective view of one example of an annular-shaped multi-functional grinding wheel 30 to be used in the process according to the present invention. In FIG. 3, a first grinding wheel segment 31 and a second grinding wheel segment 32 are laminated and joined to each other coaxially. In this case, shifting is made from the first grinding process to the second process by only moving the disk in the axial direction; therefore, it is possible to eliminate time consuming tasks to exchange the wheels when shifting is made from the first grinding process to the second grinding process, consequently simplifying the grinding processes.

Moreover, the coaxially laminated and joined structure preliminarily makes it possible to minimize the grinding face of the first grinding wheel and the second grinding wheel, and consequently to uniformly finish the edge of the glass or glass-ceramic disk substrate.

In general, an attaching or detaching process of a mono-functional grinding wheel may cause an error in the mounting position. For this reason, each time the grinding wheel is attached or detached in a grinding process for the edge of a disk, offsets may occur in the circularity and concentricity of the disk, resulting in deviations in the dimensional precision and quality in the recording medium substrate. However, in the case when the multi-functional grinding wheel according to the present invention is used, neither the attaching nor the detaching operation of a wheel is required upon shifting from the first grinding process to the second grinding process and thus no deviation occurs in the quality of the finished recording medium substrate.

The method for bonding one abrasive wheel segment to another segment may easily be accomplished, for example, with double sided adhesive tape, a bonding agent, or with bolts.

In FIG. 3 the width l_1 of the first grinding wheel segment and the width l_2 of the second grinding wheel segment are not necessarily the same, and may be appropriately changed. In the case when one of them is more abrasive, it is preferable to increase the thickness of the more abrasive one.

Thus, the service lives of the two wheels can be made coincident with each other when the two wheels are used in the same grinding process. More preferably, the widths of the respective grinding wheel segments are proportional to the degree abrasiveness of the wheel segments.

The multi-functional grinding wheel may be provided with a groove that corresponds in shape to the trapezoid edge shape of the unfinished glass or glass-ceramic disk. That is, the groove has an inverted trapezoidal shape, transverse to the shaft, as shown in FIG. 5. One groove or a plurality of grooves may be formed. In the case when there is a difference in the abrasive property of the respective grinding wheel segments constituting a multi-functional grinding wheel, it is preferable to increase the number of grooves in the more abrasive grinding wheel segment in the same manner as the width of the grinding wheel.

In the case when a plurality of unfinished glass or glass-ceramic plate edges are simultaneously ground, the gap between the grooves is preferably constantly spaced all over the entire length of the multi-functional grinding wheel. In this case, the respective grinding wheel segments constituting the multi-functional grinding wheel would have a number of grooves in proportion to the respective length of each segment.

A structure in which a plurality of the first grinding wheel segments are coaxially laminated and a structure in which a plurality of the second grinding wheel segments are coaxially laminated may be further laminated and combined coaxially to form another multi-functional grinding wheel. Moreover, in order to deal with the grinding operation consisting of the three processes, three different types of grinding wheel segments may be laminated and combined coaxially to form a multi-functional wheel.

FIG. 5 is a cross-sectional view that shows one example of the multi-functional grinding wheel 50 which may be used in the process according to the present invention formed by joining 3 different grinding wheel segments 51, 52 and 53, respectively. The combined grinding wheel 50 is annular in shape, and is intended to grind the trapezoidal edge of a glass or glass-ceramic plate by using the inside surface of the grinding wheel as grinding surface. Grinding wheel 50 is rotated about axis of rotation 55 in use.

In this grinding wheel, a first grinding wheel segment 51, a second grinding wheel segment 52, and a third grinding wheel segment 53 are laminated and joined to each other coaxially. The trapezoidal edge of a glass or glass-ceramic plate makes contact with the grinding surface on the inside surface of the grinding wheel to provide grinding efficiency. The grinding wheel is provided with plurality of internal radial grooves 54, each of which corresponds in shape to the trapezoidal edge of the glass or glass-ceramic plate to be finished.

FIG. 6 is a perspective view that shows one example of a grinding apparatus for conducting the process according to the present invention, by using the above described multi-functional grinding wheel 50. The grinding apparatus has a rotatable annular grinding wheel 50 which includes internal grooves 54, the circumferencial trapezoidal edge 61 of a glass plate 60 is pressed into a grinding groove 54 provided on the inside surface of the grinding wheel 50, and the trapezoidal edge of the glass plate 60 is ground to remove pits.

Grinding wheel 50 is made with a radial curvature which is larger than that of the glass plate 60, and the grinding wheel 50 is able to contain the trapezoidal edge of the glass plate 60. Plural grooves 54 correspond in shape to the trapezoidal edge of the glass plate 60 and extend in a circle along the inner surface of annular grinding wheel 50. Grinding wheel 50 is rotatably supported by mechanism 62 which is rotated by a suitable motor 63.

Trapezoidal edge-shaped plate 60 is supported for rotation on suction plate 64 which holds under vacuum plate 60. A motor 65 supported in a suitable frame 66 is provided for rotating glass plate 60. A lift mechanism (not shown) is provided for moving glass plate 60 vertically or horizontally. Glass plate 60 is introduced into inside of annular grinding wheel 50, and its circumferencial edge 61 is pressed into grinding groove 54 while the glass plate and the grinding wheel are rotated in opposite directions.

When the edge of the glass (or glass-ceramic) disk is ground according to the above-described grinding apparatus, the circumference of the glass (or glass-ceramic) disk is in contact with the grinding groove for a longer period of time than by use of the exterior surface of a flat grinding wheel.

In general, a grinding wheel needs to be subjected to a dressing process to recover its grinding strength and shape after a predetermined service time. For example, in the case of a grinding wheel having a groove in its peripheral portion with a shape corresponding to the shape of an object to be ground, the dressing process is generally carried out as follows: First, a grinding wheel is removed from the driving shaft of a grinding device, and this is attached to a driving device. Next, a dresser is pressed onto the inside surface of the grinding wheel to grind it to a flat face. Thereafter, another dresser having the same shape as the object to be ground is pressed onto the inside surface of the grinding wheel to form a groove corresponding to the shape of the object to be ground.

The grinding wheel according to the present invention which has an internal groove corresponding to the shape of the edge of an unfinished trapezoidal edge disk is dressed more easily than with conventional dressing processes.

FIG. 4 shows a cross-sectional outline view that shows the method for carrying out the dressing process on a grinding wheel used in the process according to the present invention. Fig. 4(a) shows a cross-sectional outline shape of the peripheral face of a grinding wheel at the initial stage of a grinding process. Here, an unfinished trapezoidal edge disk 40 is ground by a groove 41 having an inverted trapezoidal shape.

FIG. 4(b) shows a cross-sectional shape of the peripheral face of the grinding wheel that has been used for a predetermined time. The groove 42 becomes deeper due to abrasion, and a protrusion 43 between grooves is formed. Since the protrusion 43 between grooves wears down surface 44 of the disk 40, it is necessary to remove protrusion 43 through a dressing process.

FIG. 4(c) schematically shows a dressing method which features a dresser 45, which has the same outer diameter and the same edge shape as a trapezoidal edged disk 40 and also has a thickness "m" that is not less than the groove pitch "n" of the grinding wheel.

The application of the dresser having the above-mentioned specific dimensions makes it possible to carry out a dressing process on the grinding wheel without the need for preliminarily carrying out a grinding process so as to make the grinding face of the grinding wheel flat.

In dressing the grinding wheel depicted in FIG. 6, it is not necessary to remove the grinding wheel from the driving shaft of the grinding device; thus, the operation is simplified. Moreover, since the outer diameter of the dresser is the same as that of the unfinished trapezoidal edge disk, the dressing operation is carried out in the same manner as the grinding operation except that the disk is replaced by a dresser. Therefore, it is possible to reduce equipment costs and also to simplify the operation.

Examples

The invention is further illustrated by the following examples wherein all parts and percentages are by weight unless otherwise noted.

Example 1

A glass disk, 2 mm in thickness, 63.5 mm in diameter and 20 mm in hole diameter, was prepared as an unfinished recording disk plate. The edge of this disk plate was ground and shaped into a trapezoid shape as illustrated in FIG. 1 by using a JIS#500 (average particle size of about 25 micrometers) diamond grinding wheel having a diameter of 63.5 mm and a hole diameter of 20 mm, the wheel being available under the trade designation "MED 500" from Mitsubishi Material K.K., Japan. The length of the upper side "a" of the trapezoid was approximately 400 micrometers, and the angle of inclination (θ) on both of the ends was approximately 45°. Pits were formed on the upper face of the edge of the glass disk being finished and the right and left slanting faces.

The abrasive wheels included a first abrasive wheel, a JIS#600 (average particle size of about 20 micrometers) alumina grinding wheel having a diameter 160 mm, a density 1.8 g/cm^3, a shore D hardness 90 available under the trade designation "DLO WHEEL" from Sumitomo 3M K.K., Japan and a second abrasive wheel, a JIS#10000 (average particle size of about 0.6 micrometer) cerium oxide grinding wheel having a diameter 160 mm, a density 2.0 g/cm^3, a shore D hardness 95 available under the trade designation "DLO WHEEL" from Sumitomo 3M K.K., Japan. A groove having a shape corresponding to the shape of the edge of the glass disk was formed on each of the grinding wheels by using a dresser.

First, the edge of the glass disk being finished was ground by using the JIS#600 (average particle size of about 20 micrometers) alumina grinding wheel. The following grinding method was used. The JIS#600 (average particle size of about 20 micrometers) alumina grinding wheel and the edge ground disk plate were respectively rotated in opposite directions, and a load was applied so as to allow them to contact each other. The grinding conditions were: a peripheral velocity of 2000 m/min of the grinding wheel, a peripheral velocity of 46 R.P.M. of the glass disk being finished, a load of 2 to 5 kg, and a grinding time of 10 seconds.

Next, the JIS#600 (average particle size of about 20 micrometers) alumina grinding wheel was replaced by the JIS#10000 (average particle size of about 0.6 micrometer) cerium oxide grinding wheel, and the same method was carried out to grind the edge of the glass disk being finished. The grinding conditions were: a peripheral velocity of 2000 m/min. of the grinding wheel, a peripheral velocity of 46 R.P.M. of the partially finished disk plate, under a load of 2 to 5 kg, and for a grinding time of 10 seconds.

After the grinding process, the ground face was visually observed under a laser microscope, and a pit removing rate was calculated. An outline measuring device (made by "Mitsuotoyo" K.K.) was used to measure the curvature of the angle of the end face. Table 1 (below) shows the results of the tests.

In the present example, upon making a shift from the first grinding process to the second grinding process, the grinding wheels were exchanged on the grinding device which caused an error in the mounting position of the grinding wheel, and the peripheral face "a" of the disk plate (see FIG. 1) was not made completely flat.

Example 2

The edge of the unfinished recording disk plate of the type described in Example 1 was ground and shaped into a trapezoid shape in the same manner as Example 1.

The abrasive wheel segments included a JIS#600 (average particle size of about 20 micrometers) aluminum oxide grinding wheel ("DLO WHEEL" made by Sumitomo 3M K.K., diameter 160 mm, density 1.8 g/cm^3, shore D hardness 90) and a JIS#10000 (average particle size of about 0.6 micrometer) cerium oxide grinding wheel ("DLO WHEEL" made by Sumitomo 3M K.K., diameter 160 mm, density 2.0 g/cm^3, shore D hardness 95). These two segments were bonded to each other with their axes being coincident with a bonding agent ("SCOTCH-WELD DP-420" made by Sumitomo 3M K.K.). A groove having a shape corresponding to the shape of the trapezoidal edge of the unfinished disk plate was formed on the inner annular surface of each of the grinding wheel segment by using a dresser.

First, the JIS#600 (average particle size of about 20 micrometers) aluminum oxide grinding wheel segment was used to grind the edge of the disk. In the grinding process, the grinding wheel and the glass disk plate were rotated in opposite directions, and a load was applied to allow contact between the disk edge and the groove. The grinding conditions were: a peripheral velocity of 2000 m/min. of the grinding wheel, a peripheral velocity of 46 R.P.M. of the disk plate, under a load of 2 to 5 kg, and for a grinding time of 10 seconds.

Next, the partially finished glass disk plate was axially shifted, and the JIS#10000 (average particle size of about 0.6 micrometer) cerium oxide grinding wheel segment was used to grind the edge of the partially finished glass disk plate. The grinding conditions were: a peripheral velocity of 2000 m/min. of the wheel, a load of 2 to 5 kg, a peripheral velocity of 46 R.P.M. of the glass disk plate, and a grinding time of 20 seconds.

The pit removing rate of the ground face and the curvature of the angle of the end face were calculated in the same manner as Example 1. The results are shown in Table 1 (below).

In this Example, since no exchanging process of grinding wheels was made upon making a shift from the first grinding process to the second grinding process, no error occurred in the mounting position of the grinding wheel; therefore, the disk peripheral face shown as “a” in FIG. 1 was made completely flat.

Comparative Example A

The edge of the same type of recording glass disk plate as used in Example 1 was ground and shaped into a trapezoid shape in the same manner as Example 1. A plurality of these discs was superposed and fixed to a rotary shaft.

The edge of the disk plate was ground with grinding brush. The grinding method was as follows: The grinding brush and the unfinished disk plate were rotated in opposite directions, and while supplying a water slurry containing 10 to 20 weight % of cerium oxide as a grinding aid at a rate of 10 liter/min, and then the edge of the unfinished glass disk plate and the brush were allowed to contact each other. The grinding conditions were: a peripheral velocity of 1000 m/min. of the grinding brush, a peripheral velocity of 46 R.P.M. of the glass disk plate and periods of grinding time of 60 seconds and 3600 seconds.

The pit removing rate of the ground face and the curvature of the angle of the end face were calculated in the same manner as Example 1. The results are shown in Table 1 (below).

In the conventional brush grinding method, since a plurality of the unfinished glass disk plates were superposed, the brush was not sufficiently applied to portions at which the disks are adjacent to each other, resulting in an insufficient pit removing rate. In contrast, at the tip of the edge of the unfinished glass disk plate, since abrasion by the brush developed rapidly, the curvature of the edge became too great after the grinding process.

Comparative Example B

Comparative Example B was Example 1 in the specification of Japanese Patent Application No. 212690/1998, published February 15, 2000, as Japanese Patent Kokai Publication No. 2000-042889.

The edge of an unfinished recording disk plate of the type described in Example 1 was ground and shaped into a trapezoid shape in the same manner as Example 1.

A JIS#220 (average particle size of about 53 micrometers) aluminum oxide grinding wheel ("DLO WHEEL" made by Sumitomo 3M K.K., diameter 160 mm, density 1.0 g/cm^3, shore D hardness 35) was prepared. A groove having a shape corresponding to the shape of the edge of the unfinished disk plate was formed on this grinding wheel by using a dresser.

The edge of the unfinished disk plate was ground by using this grinding wheel. The following grinding method was used. The grinding wheel and the disk were rotated in opposite directions, and a load was applied so as to allow them to contact each other. The grinding conditions were: a peripheral velocity of 2000 m/min. of the grinding wheel, a peripheral velocity of 46 R.P.M. of the disk, a load of 2 to 5 kg, and a grinding time of 10 seconds.

The pit removing rate of the ground face and the curvature of the angle of the end face were calculated in the same manner as Example 1. The results are shown in Table 1 (below).

Comparative Example C

Comparative Example C was Example 2 in the specification of Japanese Patent Application No. 212690/1998, published February 15, 2000, as Japanese Patent Kokai Publication No. 2000-042889.

The edge of the same type of unfinished glass recording disk plate used in Example 1 was ground and shaped into a trapezoid shape in the same manner as Example 1.

Three JIS#220 (average particle size of about 53 micrometers) aluminum oxide grinding wheels ("DLO WHEEL" made by Sumitomo 3M K.K., diameter 50 mm, density 1.5 g/cm^3, shore D hardness 35) were prepared. The three grinding wheels were set to a grinding device (a hard disk end-face grinding device made by Shonan Engineering K.K.) capable of simultaneously grinding the upper face and the right and left slanting faces of the edge of the desk raw plate, and a grinding process was carried out under the conditions of a peripheral velocity of 500 mm/sec. and a grinding time of 30 seconds.

The pit removing rate of the ground face and the curvature of the angle of the end face were calculated in the same manner as Example 1. The results are shown in Table 1, below.

Table 1

		Example 1		Example 2		Comparative Example 1		Comp. Ex. 2	Comp. Ex. 3
		First	Second	First	Second				
Grinding Wheel	Hardness (Shore D)	90	95	90	95	-		35	35
	Density (g/cm^3)	1.8	2.0	1.8	2.0	-		1.0	1.0
	Abrasive grain	Al_2O_3	CeO_2	Al_2O_3	CeO_2	-		Al_2O_3	Al_2O_3
	Particle size (JIS)	600	10000	60	10000	-		220	220
Grinding Conditions	Peripheral velocity (m/min.)	2000	2000	2000	2000	1000		2000	500
	Load (kg)	2 to 5	2 to 5	2 to 5	2 to 5	-		2 to 5	0.2 to 2
	Time (sec.)	10	10	10	20	60	3600	10	30
Results of Grinding	Removing rate of large pits (%)[a]	> 95	> 95	> 95	> 95	5	95	80	95
	Removing rate of small pits (%)[b]	> 10	> 80	> 10	> 95	0	90	0	0
	Curvature (micrometer)	< 10	< 10	< 10	< 10	< 50	< 100	< 35	< 20

[a]Removal rate of large pits having a diameter of not less than 10 micrometers.
[b]Removal rate of small pits having a diameter of not more than 10 micrometers.

The present invention has now been described with reference to several embodiments thereof. It will be apparent to those skilled in the art that many changes can be made in the embodiments described without departing from the scope according to the invention. Thus, the scope of the present invention should not be limited to the structures described herein, but rather by the structures described by the language of the claims, and the equivalents of those structures.

What is claimed is:

1. A process for mirror-finishing the edge of at least one of a cut unfinished glass recording disk or an unfinished glass or glass-ceramic recording disk, said process comprising the steps of:

a. rough grinding the edge of the at least one of the unfinished glass recording disk or the unfinished glass-ceramic recording disk with a diamond abrasive wheel to shape the edge into a trapezoid cross section;

b. grinding the trapezoid-shaped edge of the at least one of the glass recording disk or the unfinished glass-ceramic recording disk with a first resin bonded grinding wheel which comprises abrasive grains having an average particle size in the range from about 53 micrometers to about 9.5 micrometers and has an axis of rotation and an annular shape with an inside curved surface and an outside curved surface extending along the axis of rotation; and

c. after step b, grinding the edge of the trapezoid-shaped recording disk with a second resin bonded grinding wheel which comprises abrasive grains having an average particle size in the range from about 2.5 micrometers to about 0.45 micrometer and has an axis of rotation and an annular shape with an inside curved surface and an outside curved surface extending along the axis of rotation.

2. The process of claim 1 wherein the abrasive grains of the first resin bonded grinding wheel are graded according to one JIS#220, JIS#240, JIS#280, JIS#320, JIS#360, JIS#500, JIS#600, JIS#700, JIS#800, JIS#1000, or JIS#1200, and wherein the abrasive grains of the second resin bonded grinding wheel are graded according to one JIS#5000, JIS#6000, JIS#8000, JIS#10000, JIS#15000, or JIS#20000.

3. The process of claim 2 wherein the first and second resin bonded grinding wheels have a shore D hardness of not less than about 80.

4. The process of claim 2 wherein the first and second resin bonded grinding wheels each have an axial groove having an inverted trapezoid cross-sectional shape in at least one of the inside curved surface or the outside curved surface.

5. The process of claim 4 wherein the groove is on the inside curved surface.

6. The process of claim 2 wherein said first resin bonded grinding wheel is coaxially attached to said second resin bonded grinding wheel.

7. The process of claim 2 wherein said grinding is carried out in the presence of a water stream.

8. The process of claim 2 wherein said grinding wheels have a density in the range of about 1.6 to about 2.5 g/cm^3.

9. The process of claim 2 wherein said abrasive material is selected from the group consisting of SiC, Al_2O_3, CeO_2, and combinations thereof.

10. The process of claim 2 wherein said wheel shore D hardness is in the range of about 85 to 95.

11. The process of claim 2 wherein said resin bonded abrasive wheels are bonded with a polyurethane resin.

12. The process of claim 2 wherein the resin bonded grinding wheel is rotated at a peripheral velocity in one direction in the range of about 1000 to 3000 m/min. and the glass disk is rotated in an opposite direction at a peripheral velocity in the range of about 20 to 500 m/min.

13. The process of claim 2 wherein said grinding is carried out under a load between the grinding wheel and the disk edge in the range of about 0.2 to 5 kg.

14. The process of claim 2 wherein the grinding time in each of steps a, b and c is in the range of about 5 to 60 seconds.

15. The process of claim 2 wherein further comprising between steps a and b, the step of:

grinding the trapezoid-shaped edge of the at least one of the glass recording disk or the unfinished glass-ceramic recording disk with a resin bonded grinding wheel which comprises abrasive grains having an average particle size in the range from about 106 micrometers to about 53 micrometers and has an axis of rotation and an annular shape with an inside curved surface and an outside curved surface extending along the axis of rotation.

16. The process of claim 2 wherein further comprising between steps a and b, the step of:

grinding the trapezoid-shaped edge of the at least one of the glass recording disk or the unfinished glass-ceramic recording disk with a resin bonded grinding wheel which comprises abrasive grains graded according to one of JIS#120, JIS#150, JIS#180, or JIS#220 and has an axis of rotation and an annular shape with an inside curved surface and an outside curved surface extending along the axis of rotation.

17. A multi-functional grinding wheel comprising at least one resin bonded grinding wheel annular segment which has an axis of rotation and an inside curved surface and an outside curved surface extending along its axis of rotation and which comprises first abrasive grains having an average particle size in the range from about 53 micrometers to about 9.5 micrometers coaxially attached to at least one other grinding wheel annular segment which comprises second abrasive grains having an average particle size from about 2.5 micrometers to about 0.45 micrometer.

18. The multi-functional grinding wheel of claim 17 wherein the first abrasive grains are graded according to one of JIS#220, JIS#240, JIS#280, JIS#320, JIS#360, JIS#500, JIS#600, JIS#700, JIS#800, JIS#1000, or JIS#1200, and wherein the second abrasive grains are graded according to one of JIS#5000, JIS#6000, JIS#8000, JIS#10000, JIS#15000, or JIS#20000.

19. The multi-functional grinding wheel of claim 18, wherein at least one of the resin bonded grinding wheel segments has a groove which is an inverted trapezoid in cross-sectional shape.

20. The multi-functional grinding wheel according to claim 19, wherein said groove is the inside curved surface.

21. The multi-functional grinding wheel of claim 18 wherein said grinding wheels have a density in the range of about 1.6 to about 2.5 g/cm^3.

22. The multi-functional grinding wheel of claim 18 wherein said abrasive material is selected from the group consisting of SiC, Al_2O_3, CeO_2, and combinations thereof.

23. The multi-functional grinding wheel of claim 18 wherein the and resin bonded grinding wheel segments comprising the first and second abrasive grains each have a shore D hardness of at least 80.

24. The multi-functional grinding wheel of claim 23 wherein the and resin bonded grinding wheel segments comprising the first and second abrasive grains each have a shore D hardness is in the range of about 85 to 95.

25. The multi-functional grinding wheel of claim 18 wherein said resin bonded abrasive wheel segments are bonded with a polyurethane resin.

26. A multi-functional grinding wheel comprising at least one resin bonded grinding wheel annular segment which has an axis of rotation and an inside curved surface and an outside curved surface extending along its axis of rotation and which comprises first abrasive grains having an average particle size in the range from about 106 micrometers to about 53 micrometers coaxially attached to at least one other grinding wheel annular segment which comprises second abrasive grains having an average particle size from about 53 micrometers to about 9.5 micrometers coaxially attached to at least one

other grinding wheel annular segment which comprises third abrasive grains having an average particle size from about 2.5 micrometers to about 0.45 micrometer.

27. The multi-functional grinding wheel of claim 26 wherein the first abrasive grains are graded according to one of JIS#120, JIS#150, JIS#180, and JIS#220, wherein the second abrasive grains are graded according to one of JIS#220, JIS#240, JIS#280, JIS#320, JIS#360, JIS#500, JIS#600, JIS#700, JIS#800, JIS#1000, or JIS#1200, and wherein the third abrasive grains are graded according to one of JIS#5000, JIS#6000, JIS#8000, JIS#10000, JIS#15000, or JIS#20000.

28. An apparatus for grinding a glass disk having a diamond ground trapezoid-shaped pitted edge comprising:

a multi-functional grinding wheel comprising at least one resin bonded grinding wheel annular segment which has an axis of rotation and an inside curved surface and an outside curved surface extending along its axis of rotation and which comprises first abrasive grains having an average particle size in the range from about 53 micrometers to about 9.5 micrometers coaxially attached to at least one other grinding wheel annular segment which comprises second abrasive grains having an average particle size from about 2.5 micrometers to about 0.45 micrometer;

a motor for rotating the multi-functional grinding wheel about its axis of rotation in at least one direction;

a clamp for transversely holding the glass disk on a rotatable shaft;

a motor for peripherally rotating the transversely deployed glass disk in a direction opposite to that of the grinding wheel; and

a lift mechanism for causing the glass disk to move vertically and horizontally to sequentially contact the first and second segments of the rotating grinding wheel under load to cause the grinding wheel segments to remove pits from the pitted surface of the disk edge.

29. The multi-functional grinding wheel of claim 28 wherein the first abrasive grains are graded according to one of JIS#220, JIS#240, JIS#280, JIS#320, JIS#360, JIS#500, JIS#600, JIS#700, JIS#800, JIS#1000, or JIS#1200, and wherein the second

abrasive grains are graded according to one of JIS#5000, JIS#6000, JIS#8000, JIS#10000, JIS#15000, or JIS#20000.

30. An apparatus for grinding a glass disk having a diamond ground trapezoid-shaped pitted edge comprising:

a multi-functional grinding wheel comprising at least one resin bonded grinding wheel annular segment which has an axis of rotation and an inside curved surface and an outside curved surface extending along its axis of rotation and which comprises first abrasive grains having an average particle size in the range from about 106 micrometers to about 53 micrometers coaxially attached to at least one other grinding wheel annular segment which comprises second abrasive grains having an average particle size from about 53 micrometers to about 9.5 micrometers coaxially attached to at least one other grinding wheel annular segment which comprises third abrasive grains having an average particle size from about 2.5 micrometers to about 0.45 micrometer;

a motor for rotating the multi-functional grinding wheel about its axis of rotation in at least one direction;

a clamp for transversely holding the glass disk on a rotatable shaft;

a motor for peripherally rotating the transversely deployed glass disk in a direction opposite to that of the grinding wheel; and

a lift mechanism for causing the glass disk to move vertically and horizontally to sequentially contact the first, second, and third segments of the rotating grinding wheel under load to cause the grinding wheel segments to remove pits from the pitted surface of the disk edge.

31. The apparatus of claim 30 wherein the first abrasive grains are graded according to one of JIS#120, JIS#150, JIS#180, and JIS#220, wherein the second abrasive grains are graded according to one of JIS#220, JIS#240, JIS#280, JIS#320, JIS#360, JIS#500, JIS#600, JIS#700, JIS#800, JIS#1000, or JIS#1200, and wherein the third abrasive grains are graded according to one of JIS#5000, JIS#6000, JIS#8000, JIS#10000, JIS#15000, or JIS#20000.

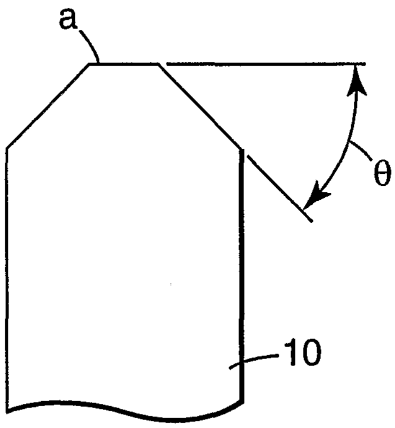


Fig. 1

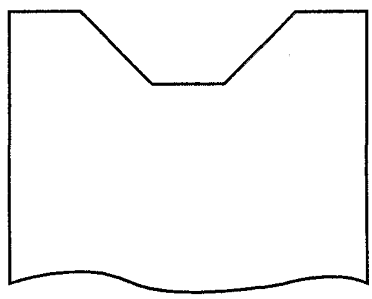


Fig. 2

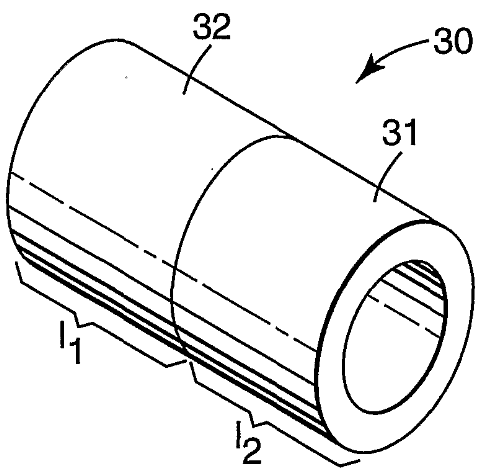


Fig. 3

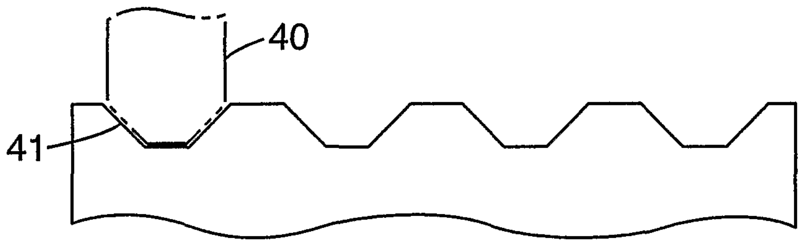


Fig. 4a

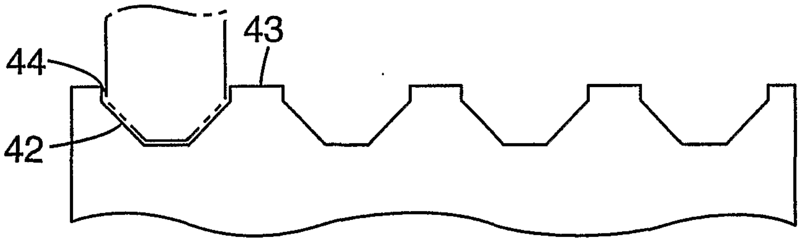


Fig. 4b

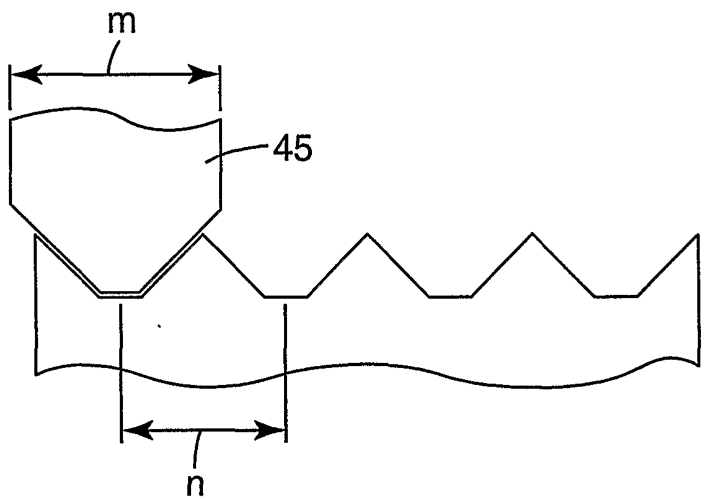


Fig. 4c

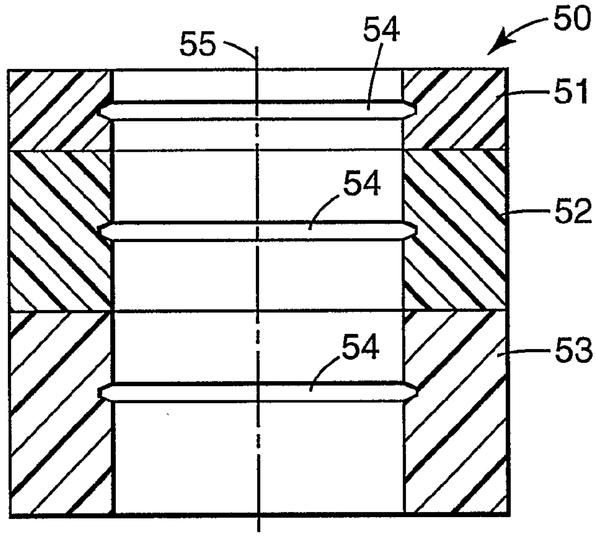


Fig. 5

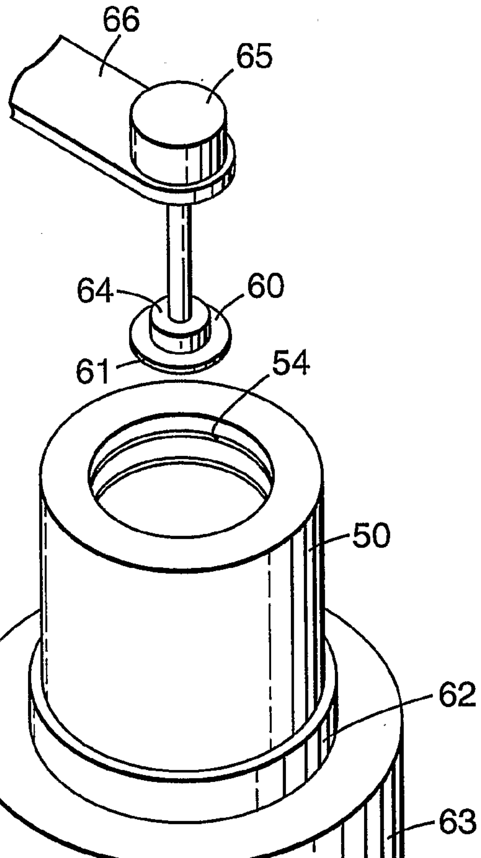


Fig. 6

INTERNATIONAL SEARCH REPORT

International Application No
PCT/US 01/19870

A. CLASSIFICATION OF SUBJECT MATTER
IPC 7 B24B9/06 B24D5/14

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 7 B24B 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)

EPO-Internal, PAJ

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category °	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	US 4 908 996 A (FRIEDMAN JOEL ET AL) 20 March 1990 (1990-03-20)	1,17,28
Y	the whole document	26,30
A	figures 1-5	6
Y	US 6 042 627 A (DESHMUKH UDAY V ET AL) 28 March 2000 (2000-03-28) column 1, line 12 - line 30 column 2, line 51 - line 61 column 4, line 55 - line 62	26,30
A	PATENT ABSTRACTS OF JAPAN vol. 011, no. 296 (M-627), 25 September 1987 (1987-09-25) & JP 62 088579 A (TOYODA MACH WORKS LTD;OTHERS: 01), 23 April 1987 (1987-04-23) abstract	1,6,17, 26,28,30

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

[X] Patent family members are listed in annex.

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Date of the actual completion of the international search	Date of mailing of the international search report
12 October 2001	26/10/2001

Name and mailing address of the ISA	Authorized officer
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	Schultz, T

INTERNATIONAL SEARCH REPORT

International Application No
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C.(Continuation) DOCUMENTS CONSIDERED TO BE RELEVANT

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