

[54] CERAMIC CUTTING INSTRUMENTS

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83/915.5, 125/30 R, 125/39

[51] Int. Cl. **B26d 1/00**, G01n 1/06

[58] Field of Search..... 83/651, 915.5; 76/101 R,
76/DIG. 8, DIG. 12; 125/30, 39

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[57] ABSTRACT

The present invention is concerned with novel cutting edges and especially razor blades and microtome knives formed from sapphire and with novel processes for making cutting edges. The cutting instruments disclosed herein are characterized by having their cutting edges within 30° and preferably parallel to the C-axis (optical axis) of the sapphire. The process for preparing such cutting edges comprises forming the cutting edge blank from the sapphire in a manner such that the C-axis thereof will be parallel or at least within 30° of being parallel to the cutting edge which is to be formed and thereafter forming the cutting edges by a combination of mechanical and one or more chemical sharpening steps.

13 Claims, 13 Drawing Figures

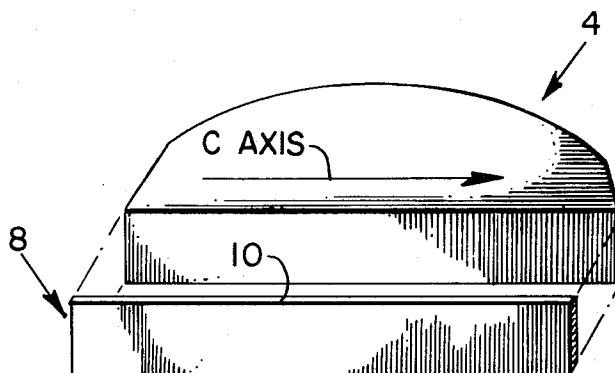


Fig. 1

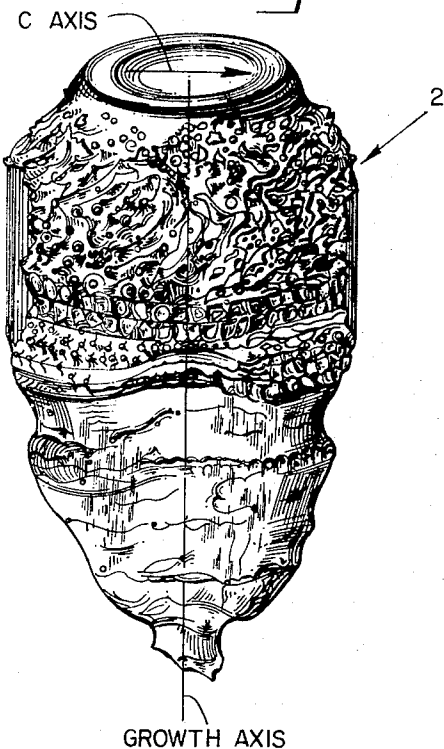


Fig. 2

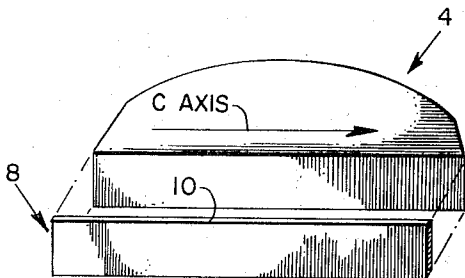
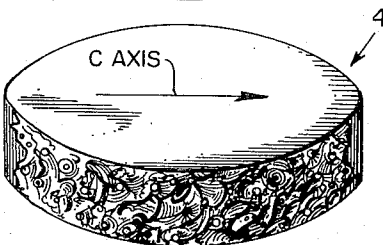
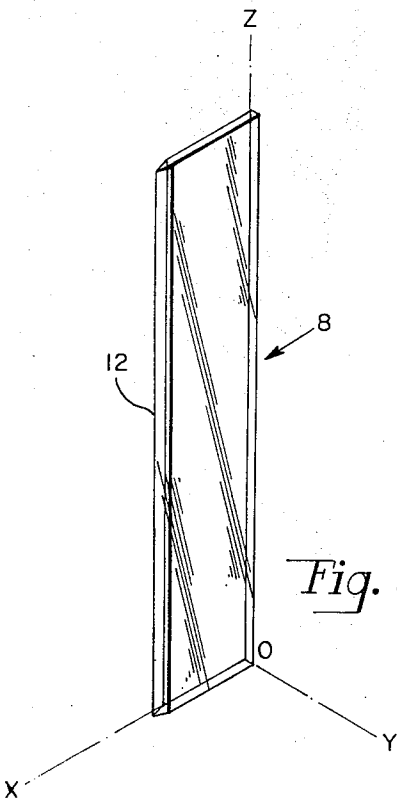


Fig. 2a

Fig. 3



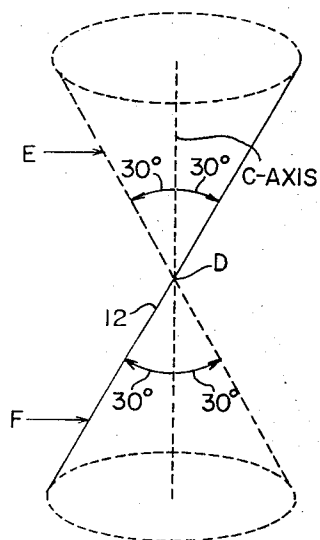


Fig. 4

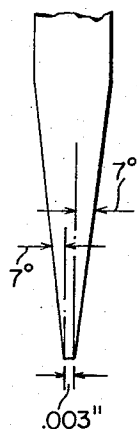


Fig. 5a

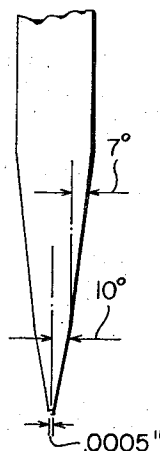


Fig. 5b

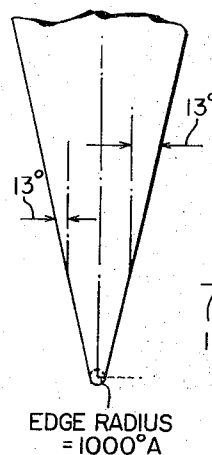


Fig. 5c

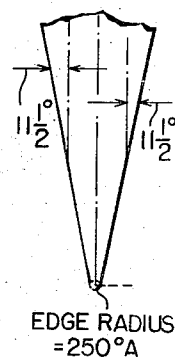


Fig. 5d

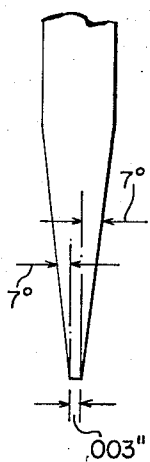


Fig. 6a

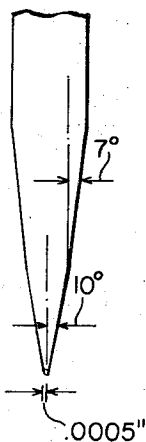


Fig. 6b

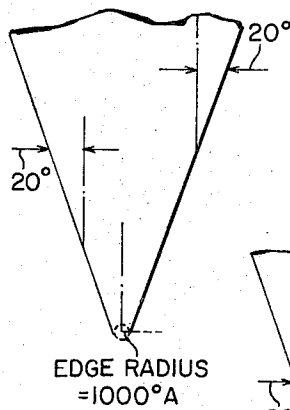


Fig. 6c

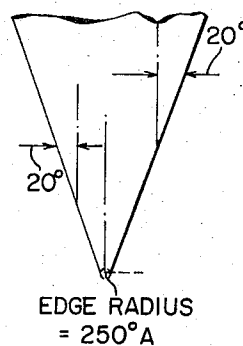


Fig. 6d

CERAMIC CUTTING INSTRUMENTS

Sapphire is a single-crystal α Al_2O_3 refractory oxide having high strength, hardness, and corrosion resistance. Because of these properties, and the fact that it can be made synthetically and economically, it has been recognized that it would make an excellent material for forming cutting edges such as razor blades and microtome knives. To date, however, considerable difficulties have been encountered in producing such cutting edges. In attempting to form such edges using mechanical sharpening methods it has been found extremely difficult, if not impossible to form such edges with low-edge radii. Further it has been found that the sapphire in the edge areas undergoes considerable deformation which makes it prone to possible fracture. The present invention is concerned with novel processes for producing sapphire cutting edges having the desired geometry and which are substantially free of any traces of deformation and the defects resulting therefrom.

One object of the present invention is to provide novel cutting edges formed from sapphire.

Another object of the present invention is to provide novel processes for producing such cutting edges.

Other objects will be apparent from the following description taken together with the drawings wherein:

FIG. 1 is a perspective view of a 90° boule of synthetic sapphire from which the blades of this invention may be formed;

FIG. 2 is a perspective view of a cylindrical cross-section sliced from the boule of FIG. 1;

FIG. 2A is a perspective view of a blade blank in spaced-apart relationship from the cylindrical cross-section of FIG. 2 from which it was cut;

FIG. 3 is a diagrammatic representation of a sapphire blade within the scope of the invention positioned relative to a three-dimensional rectangular coordinate;

FIG. 4 is a schematic representation illustrating the alignments in which the cutting edge will lie within at least 30° of being parallel to the C axis of the sapphire;

FIGS. 5A through 5D are enlarged cross-sectional views showing the cutting edge of a razor blade in various stages of formation as it is prepared by processes within the scope of the present invention; and

FIGS. 6A through 6D are enlarged cross-sectional views showing the cutting edge of a microtome knife in various stages of formation as it is prepared by process within the scope of the present invention.

Generally the cutting instruments within the scope of the present invention are prepared by first forming a blank in a manner such that the cutting edge which is to be formed therein will lie within 30° and preferably within 25° of being parallel to the "C" or optical axis of the sapphire and thereafter forming the cutting edge as hereinafter described. In especially preferred embodiments, the blank will be so formed that the cutting edge will be substantially parallel to the "C" axis. The method of forming of such a blank will, of course, depend upon the initial configuration of the sapphire from which it is formed. Although the invention is described herein in terms of forming the blade blank from a Verneuil boule, it is to be understood that the blade blank can be formed from sapphire in any other form such as strips which are commercially available; provided the sapphire can be cut in a manner such that the

cutting edge which is to be formed will lie within at least 30° of being parallel to the "C" axis of said sapphire.

Referring to FIG. 1 there is shown a Verneuil synthetic sapphire boule 2 which can be used to form the blades of the present invention. The "C" or optical axis is perpendicular to the growth axis and such a boule is generally referred to as a 90° boule. The processes for making such boules 2 are well known and form no part of this invention.

In a preferred mode of making blade blanks from a boule 2 such as shown in FIG. 1, the boule 2 is sliced parallel to the C or optical axis and perpendicular to the growth axis to provide a plurality of disks 4 such as shown in FIG. 2. Generally, the height or thickness of the disk 4 will be governed by the width which is desired for the blade. Usually the cuttings may be made quite readily using a diamond saw and a suitable lubricant such as mineral oil. The disks 4 are then formed into blade blanks 8 by making a plurality of downwardly extending cuts parallel to both the C-axis and the growth axis. The mode of making this cutting is illustrated in FIG. 2A wherein a blade blank 8 is shown in spaced-apart relationship from the disk 4 from which it was cut. As can be noted, the edge 10 along which the cutting edge is to be formed lies parallel to the C axis of the sapphire.

As pointed out above when mechanical sharpening techniques are used in forming the cutting edge on the sapphire blanks, it results in considerable deformation of the sapphire which makes the edge prone to possible fracture. In the processes described herein such deformation is substantially removed by subjecting the cutting edge to a chemical sharpening step. Generally such chemical sharpening is carried out at least subsequent to the final mechanical sharpening step which causes significant deformation of the sapphire edge. Although in carrying out the processes disclosed herein, the chemical sharpening is performed at least subsequent to the final mechanical sharpening step which causes deformation, it should be understood that, when desired, such chemical sharpening can be used in place of one or more of the mechanical sharpening steps. It has been found that such chemical sharpening, in addition to removing the deformation, also makes it possible to produce cutting edges having extremely low-edge radii, e.g. 250 Å or less. (The edge radius may be defined as the estimated radius of the largest circle which can be accommodated at the ultimate edge of a cutting instrument when viewed under an electron microscope.) Up to now, using mechanical sharpening alone, it has not been found possible to produce such edges on sapphire.

Generally such chemical sharpening comprises suspending the edge upon which the cutting edge is to be formed into a suitable solvent for the sapphire for a sufficient time to form the desired cutting edge. As an example of a suitable solvent for sapphire, mention may be made of hot orthophosphoric acid. Generally in using orthophosphoric acid, it is heated to a temperature between about 400°F and 550°F . At such temperatures the orthophosphoric acid is believed to be converted to metaphosphoric acid, (HPO_3) , which does the actual sharpening. It has been found that if temperatures much above 550°F are employed, it will result in a chemical reaction between the sapphire and the acid and result in poor edges. Generally temperatures

lower than 400° F may be employed, e.g. 300° F, but the process will be less efficient. Especially good results have been obtained by heating the acid to about 480° F.

In carrying out the chemical sharpening step, it has been found that there is a critical relationship between the orientation of the edge which is to be formed and the optical axis of the sapphire. Generally such criticality can best be illustrated by reference to FIG. 3 and FIG. 4. In FIG. 3, there is shown a sapphire blade 8 which is positioned relative to the well-known OX-OY-OZ three-dimensional rectangular coordinate. As can be noted, the blade is positioned so that its length lies along the OZ axis, its width along the OX axis, and its thickness along the OY axis. It has been found that if the optical axis of the sapphire corresponds to the OZ axis or is within 30° of being parallel to said OZ axis, cutting edges having very low-edge radii may be produced, e.g. 250 Å or less. If, however, the optical axis is perpendicular to the edge so as to be parallel to the OY axis, the cutting edges produced by the chemical sharpening will have substantially larger edge radii. Further, if the optical axis of the sapphire is perpendicular to the cutting edge in a manner such that it will be parallel to the OX axis, chemical sharpening will result only in a rounding of the edge. In FIG. 4, there is shown a schematic representation which further illustrates the alignments in which the cutting edge 12 may lie to be within 30° of being parallel to the C axis of the sapphire. As shown in FIG. 4, a cutting edge 12 has been revolved around point D on the optical axis, of the sapphire at an angle of 30° to form cones E and F which lie in an apex to apex relationship with one another. For the purposes of this invention, the cutting edge will be said to lie within 30° of being parallel to the C axis if it lies within the boundaries of said cones E and F.

Due to the hardness of the sapphire, grinding, roughing, and finishing wheels comprising diamond abrasives or their equivalents are used in the mechanical sharpening steps. Wheels of this nature are commercially available. Generally the angle to which the cutting edge will be ground will depend on the nature of the cutting instrument which is being formed. The processes of the present invention have been found to be particularly useful in making razor blades and microtome knives. In the making of the former, it has been found best to grind the edge in a manner such that the finished cutting edge will have an edge angle between 15° to 35° and preferably between 20° and 30°, and with the latter, it has been found best to grind the cutting edge so that it will have an edge angle between 30° to 40° and preferably between 35° and 40°.

Although the razor blades produced by the processes of this invention have been found useful for shaving, their shaving properties can be appreciably enhanced by applying a coating of a polymeric material which has been found useful to enhance the shave properties of steel blades. As examples of such materials, mention may be made of the organosiloxane gels set forth in U.S. Pat. No. 2,937,976 to Leon E. Granahan, Meyer J. Shnitzler and Edward M. Tuckerman; the polymeric hydrocarbons, e.g. polyethylene set forth in U.S. Pat. No. 3,071,858 to Harvey Alter and the polymeric fluorocarbons, e.g. polytetrafluoroethylene, set forth in U.S. Pat. No. 3,071,856 to Irwin W. Fischbein. Especially good results have been obtained with polytetrafluoroethylene.

Although polymeric coatings such as polytetrafluoroethylene have been found useful in enhancing the shaving properties of the blades of this invention, their adherence to the sapphire leaves something to be desired and often such coatings are removed from the cutting edge by the shaving action long before the use-life of the sapphire blade is exhausted. Generally the adherence of such coatings to the sapphire cutting edge can be enhanced by the use of a sub-coating between the polymeric coating and the sapphire cutting edge. In this regard, metallic subcoats have been found particularly useful. Generally such metallic coatings may be selected from metals and alloys such for example as ferritic and martensitic stainless steels, chromium, alloys of chromium and platinum, and alloys of chromium and palladium. A subcoat which has been found especially useful comprises a combination of chromium and platinum. Generally such metallic subcoatings may be applied by processes such as disclosed in U.S. Pat. Application No. 47,664, filed June 19, 1970, in the names of I. W. Fischbein, B. H. Alexander and A.S. Sastri, now U.S. Pat. No. 3,725,238. Usually the metallic subcoats will have thicknesses between 50 to 800 angstroms.

The following non-limiting examples illustrate the processes of the present invention.

EXAMPLE I

A 90° sapphire boule such as shown in FIG. 1 was cut parallel to the C axis and perpendicular to the growth axis with a diamond saw using mineral oil as a lubricant to provide a plurality of disks, having a thickness of ¼ inch. The disks were gang-sawed, six at a time, parallel to both the C and growth axis to provide blade blanks which were 0.020 inches thick and ¼ inch wide. The length varied up to about 1-½ inches. As shown in FIG. 5A, one edge of the blank was ground with a diamond grinding wheel to provide a cutting edge having an included angle of 14° and a flat of 0.003 inch. The edge was then ground with a diamond rougher wheel until it had an inclined angle of about 20° and a flat of about 0.0005 inch as shown in FIG. 5B and thereafter it was sharpened with a diamond finishing wheel until it had an included angle of about 26° and an edge radius of about 1,000 Å as shown in FIG. 5C. The resulting edge was suspended for three days into orthophosphoric acid which was maintained at a temperature of about 480° F in a polytetrafluoroethylene beaker. Subsequent to the chemical sharpening step, the cutting edge was substantially free of deformed sapphire, has an included angle of 23° and an edge radius of about 250 Å as shown in FIG. 5D.

EXAMPLE II

A blade blank which was made in a manner similar to that of Example I was ground using a nickel-coated diamond grinding wheel until it had an included angle of 25° and a flat of 500 microinches. The resulting edge as then chemically sharpened in orthophosphoric acid at about 480° F for a 2-week period. The orthophosphoric acid was replaced every 3 days. At the end of the chemical sharpening step, the edge had an included angle of 25° and a tip radius of about 50 microinches. Each bevel of the edge was then polished for a period of 30 seconds using a 0 to 2 micron diamond powder embedded corfam lap and the edge was further chemically sharpened in orthophosphoric acid at 480° F for

three days. The resulting edge was substantially free of deformation and had an included angle of 23° and a tip radius of 150 A.

A razor blade produced in the above Example II was cleaned for about 15 minutes using R. F. energy and then coated with a 250 A thick coating of Platinum-Chromium using methods similar to those mentioned in the above mentioned U.S. Application 47,664. A coating of polytetrafluoroethylene such as taught in U.S. Pat. No. 3,071,856 was applied to the cutting edge and the blade was shave tested. The blade had a substantially longer life than any steel blade heretofore tested.

EXAMPLE III

A microtome knife was prepared from a blank such as employed in Example I by first grinding it with a diamond grinding wheel until the edge had an included angle of about 14° and a flat of 0.003 inches, as shown in FIG. 6A, and thereafter rough grinding the edge with a diamond roughing wheel until it had an included angle of 20° and a flat of 0.0005 inches as shown in FIG. 6B. The edge was then finished by first polishing it with a 0-2 micron diamond powder embedded cor-fam lap until it had an included angle of 40° and an edge radius of 1,000 A as shown in FIG. 6C and thereafter chemically sharpening it for three days in orthophosphoric acid at 480° until it had an included angle of 40° and an edge radius of 250 A as shown in FIG. 6D.

Having thus described our invention, what is claimed is:

1. A process for forming a sapphire cutting edge, said process comprising forming a blank from sapphire in a manner such that the edge which is to be sharpened will lie within at least 30° of being parallel to the optical axis of said sapphire and forming the cutting edge thereon by a combination of mechanical and chemical sharpening, said chemical sharpening being carried out at least subsequent to any mechanical sharpening step which causes significant deformation of the sapphire in the

cutting edge.

2. A process as defined in claim 1 wherein the edge which is to be sharpened is at least within 25° of being parallel to the optical axis of the sapphire.

3. A process as defined in claim 1 wherein the edge which is to be sharpened is substantially parallel to the optical axis of the sapphire.

4. A process as defined in claim 1 wherein said chemical sharpening is carried out in hot orthophosphoric acid.

5. A process as defined in claim 4 wherein said orthophosphoric acid is heated to a temperature between about 300° F to 550° F.

6. A process as defined in claim 4 wherein said orthophosphoric acid is heated to a temperature between about 400° F to 550° F.

7. A process as defined in claim 1 wherein said cutting edge is that of a razor blade.

8. A process as defined in claim 1 wherein a metallic subcoat is applied to said cutting edge subsequent to its formation.

9. A process as defined in claim 1 wherein a polytetrafluoroethylene coating is applied to the cutting edge subsequent to its formation.

10. A process as defined in claim 8 wherein a polytetrafluoroethylene coating is applied to the metallic subcoat.

11. A sapphire cutting instrument having its cutting edge within at least 30° of being parallel to the optical axis of the sapphire and said cutting edge being formed by a combination of mechanical and chemical sharpening steps, said chemical sharpening being carried out at least subsequent to any mechanical sharpening step which causes significant deformation of the sapphire in the cutting edge.

12. A sapphire cutting instrument as defined in claim 11 which is a razor blade.

13. A cutting instrument as defined in claim 11 wherein said cutting edge is substantially parallel to the optical axis of the sapphire.

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