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[54] **ALUMINA RAZOR BLADES**

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[58] **Field of Search** 30/346.53, 346.54, 346.58, 30/350; 117/93.3

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[57] **ABSTRACT**

The invention relates to razor blades and methods of manufacture thereof, the blades comprising a single crystal of alumina having a cutting edge thereon. The cutting edges can be formed by grinding of single crystals of alumina, preferably mounted to facilitate handling, in addition to or alternatively to dissolution or etching. The crystals are preferably grown in a shape approximating to the desired cross-section of blade to facilitate formation of the cutting edge. The alumina preferably has at the most a low content of impurities. Strengthening of the cutting edge can be effected by the implantation of large ions in and/or adjacent the cutting edge.

8 Claims, 3 Drawing Figures

FIG. 1.

FIG. 2.

FIG. 3.

ALUMINA RAZOR BLADES

This invention relates to razor blades and to methods of manufacture thereof.

The present invention provides a razor blade comprising a single crystal of alumina having a cutting edge thereon.

Further according to the invention there is provided a method of manufacturing a razor blade, which method comprises forming a cutting edge on a single crystal of alumina.

The term "single crystal of alumina" is used herein to refer to three dimensional crystalline bodies of alumina which can define at least one cutting edge and are substantially in the form of a single crystal.

Alumina, not in the form of single crystals, generally has a high strength and hardness, and is resistant to abrasion and chemical attack. However, such alumina generally has flaws in its structure which result, for example, in the strength being less than is theoretically possible. However, single crystal alumina generally has a higher strength than other forms of alumina due, for example, either to its having fewer flaws or to such flaws as are present being less serious or both. Furthermore, grain boundaries in forms of alumina other than single crystal alumina, can also reduce the strength of the alumina. Since single crystal alumina does not have grain boundaries, this cause of a reduction in strength is avoided. In theory, flaw-free alumina has an effective strength of 1.6×10^6 p.s.i. and a modulus of 57×10^6 p.s.i. compared with respective measured values of 3×10^5 p.s.i. and 30×10^6 p.s.i. for a conventional razor blade steel. The reduction of the flaws in single crystal alumina permits values nearer to the theoretical to be obtained in practice; strengths of up to 10^6 p.s.i. have been measured.

Satisfactory razor blades can be produced having at least one cutting edge of single crystal alumina, taking advantage of the physical characteristics associated with single crystal alumina, in particular the high strength resulting from the reduction of the flaws compared with other forms of alumina. The strength of the single crystal of alumina used for the cutting edges of razor blades is preferably greatest perpendicular to the cutting edge thereof. The crystal axes are therefore preferably arranged to give maximum strength to the cutting edge. However, the method of production of the single crystal alumina used may necessitate some less advantageous orientation of the crystal axes. For example, single crystals of α-alumina can readily be grown by known methods, preferably to produce single crystals of low porosity, and it has been found that single crystals grow particularly readily in the direction of the c-axis of the α-alumina unit cell. It may, therefore, be convenient to produce cutting edges substantially parallel to the c-axis of the unit cell but higher strength might be possible with some other orientation.

In order to provide a good adhesive bond between the alumina cutting edge and a polymer coating, it is generally preferred to use single crystal alumina containing at the most a low concentration of impurities such as, for example, mono- and di-valent metal ions. The total concentration of impurities should generally be less than 3×10^{-3} atomic percent and preferably less than 1×10^{-3} atomic percent. Examples of mono- and di-valent metals which may be present, for example in commercially available alumina used to form single

crystals of alumina, include alkali metals e.g. sodium and potassium, alkaline earth metals e.g. calcium and magnesium and certain transition metals e.g. copper and ferrous iron. These metals are advantageously absent or at the most they are preferably present in only a low concentration.

The single crystals of alumina for producing razor blades in accordance with the present invention can be produced, for example by growing from a melt, by growing from solution or by reacting the aluminum with oxygen to form single crystals. Growing of single crystals from a melt is generally preferred since the cross-section of the crystals formed can be made to approximate to the desired shape of single crystals having at least one cutting edge. Subsequent shaping of the single crystals to form the cutting edge can thereby be reduced.

Cutting edges on single crystals of alumina can be formed by any suitable method, for example, by methods used for forming cutting edges on metal razor blades.

Single crystals of alumina are generally comparatively expensive to produce and consequently it is preferred to form cutting edges on single crystals having a small cross-section. In such cases the crystals may be secured to a supporting mount of inexpensive material, for example of plastic or metal. Furthermore, by mounting the single crystals before forming the cutting edge, mechanical handling of the single crystals during the cutting edge shaping can be improved.

Single crystals of alumina, preferably produced to a shape approximating to the desired cutting edge shape can be processed to form the desired cutting edge, for example using an abrasive material. The method of shaping of the cutting edge ;using abrasion can, fora example, be analogous to the methods proposed for shaping the cutting edges of metal razor blades. The abrasive material may, for example, be bonded to a grinding wheel or to a strop, or a slurry of the abrasive may be used, for example in conjunction with means for providing the dessired abrasion of the single crystal. Diamond, for example, can be used as the abrasive material.

Single crystals of alumina may, if desired, be shaped by chemical methods, for example by dissolution or by etching. Either acidic or basic dissolving or etching agents can be used, due to the amphoteric nature of alumina. Adidic agents which may be used include, for example, halogen hydracids e.g. hydrogen fluoride or hydrogen chloride, preferably in concentrated aqueous solution, or sulphurous acid. Basic agents which may be used include, for example, inorganic or organic bases. Suitable inorganic bases include, for example, alkali metal hyroxides, e.g. sodium hydroxide or potassium hydroxide, preferably in aqueous solution e.g. containing up to 40% by weight of sodium hydroxide. Suitable organic bases include, for example, alkali metal alkoxides e.g. sodium and potassium alkoxides. The alkoxides, for example, the methoxides, ethoxides, propoxides and butoxides, are conveniently used in solution in the alkanol from which they are derived, for example methanol, ethanol, propanol or butanol.

The dissolution or etching may for example be effected by controlled immersion in the dissolving or etching agent. However, the dissolution or etching agent may be applied selectively to certain areas of the surface of the single crystals of alumina to incrrease the rate of dissolution or etching in those areas and thereby provide the crystals with the desired cross-section. The agents may be applied, for example, using wheels.

Alternatively, shaping of the single crystals of alumina to form cutting edges may be effected using melts of substances which dissolve or etch the surface of the crystals. For example, melts of alkali metal acidic fluorides e.g. KHF_2, ammonium fluoride, alkali metal hydroxides, e.g. sodium hydroxide, vanadium pentoxide, or mixtures of aluminim fluoride with fluorides of metals of Groups IA and IIA of the periodic table e.g. cryolite (Na_3AlF_6), can be used.

A combination of abrasive methods and chemical methods may be used to form the desired shape of cutting edge. The successive or simultaneous use of chemical methods and abrasive methods can be used to advantage, for example, when the chemical method produces a reaction product which is softer than the material of the single crystal which thereby may enable a softer abrasive to bed used. Furthermore, if the reaction product forms a protective layer which prevents further reaction, selective abrasion may be used to form a cutting edge of the desired profile.

The use of chemical methods in shaping cutting edges on single crystals of alumina can also be used to advantage by generally reducing the generation of flaws in the single crystals compared with mechanical methods. A similar low numbers of flaws can be obtained by annealing mechanically formed edges at temperatures of at least 1200°C.

Although it is possible to form a cutting edge on single crystals in one step, it is generally preferred to use two or more edge shaping steps, even if the single crystal is initially of a shape which generally conforms to the desired shape of cutting edge. When two or more edge shaping steps are used, the first shaping step is preferably arranged to remove more material from the single crystal than the second step. Furthermore, if a third or subsequent shaping step is used, the latter steps are preferably arranged to remove less material from the single crystals than the immediately preceding steps. In this way, an initial rapid removal of material may be achieved with the subsequent steps tending to give a progressively finer finish to the cutting edge.

One of the above described methods may be used to form the desired finished cutting edge. However, a final shaping and finishing can be provided, for example, by ion bombardment. Known methods of ion bombardment can be used, using an appropriately shaped ion beam, for example, a substantially flat beam or a substantially cylindrical or conical beam. In the case of cylindrical or conical beams, the beam of ions may, for example, be oscillated to form a wide beam. The desired shaping of the cutting edge using an ion beam may be effected, for example, by arranging the ion beam at a small angle of incidence to the surface of the single crystal, preferably with the beam of ions travelling from the source into the incidence with the surface of the single crystal and thence towards the cutting edge. The ions used are preferably inert gas ions, for example derived from argon. Ion energies of greater than 1 kiloelectron volt, for example 5 kiloelectron volts or more, will generally be used.

The present invention further provides a razor blade having at least one cutting edge formed on a single crystal of alumina and having large ions in and/or adjacent the surface thereof in an amount sufficient to strengthen the surface of the crystal at least in the vicinity of the cutting edge.

The term "large ions" is used herein to refer to ions having larger radii than that of aluminum. The large ions preferably have radii at least 50%, advantageously up to 100%, larger than that of aluminum. At least one type of large ion is used.

The large ions should in general be present in an amount, for example, of up to 3 atomic percent, preferably up to 1 atomic percent, in and/or adjacent the surface thereof. The large ions may be present, for example, to a depth of 100 to 1,000 Angstroms below the surface of the single crystal. The concentration of large ions in and/or adjacent the surface of the single crystals required to produce the desired degree of surface strengthening will depend, for example on the nature of the large ions and the size of the large ions in relation to the aluminum and oxygen ions forming the bulk of the single crystals.

Large ions which are used to strengthen the surface of the single crystal cutting edges should be compatible with the crystal structure of the bulk of the single crystals of alumina. The large ions may be selected, for example, from ions of metals in Group IIIA of the Periodic Table, e.g. scandium, yttrium and the rare earth elements, i.e. the elements having atomic numbers 57 to 71. Ions of other elements than those of Group IIIA which can give rise to tri-valent ions can also be used, for example chromium ions. However, since the ionic radius of chromium is only about 28% greater than the ionic radius of aluminum, larger concentrations of chromium ions are generally required than, for example, of ions of metals of Group IIIA of the Periodic Table, to obtain the same degree of surface strengthening.

The large ions can be introduced into preformed single crystals of alumina, for example by ion implantation methods using beams of high energy ions. Suitable ion energies for introducing large ions into the single crystals are, for example, in excess of 10^3 electron volts at the surface of the single crystals.

Alternatively, the large ions can be introduced into and/or adjacent the surface of the cutting edge of the single crystals by thermal methods. For example, the preformed single crystal cutting edges can be coated with a compound containing the appropriate large ions, or the element giving large ions, and the coating heated to effect migration of the desired ions into the single crystals. Suitable compounds include the appropriate oxides or nitrates of the metals giving rise to the large ions. Temperatures, for example, of from 300° to 900°C, preferably about 600°C, may be used to effect the migration of large ions from the coating into the single crystals. A similar effect can be obtained by reacting the surface with suitable compounds, for example, calcium oxide forming calcium aluminate, putting the surface under compressive stress, due to a volume expansion.

The present invention further provides a razor blade comprising a single crystal of alumina having a cutting edge thereon, and an alumina coating on and/or adjacent the cutting edge, the alumina coating containing a low concentration of impurities.

The alumina coating is preferably as described in application Ser. No. 349,269 of even date.

Satisfactory adherent coatings of polymers which improve the shaving characteristics of the blades can generally be formed on these alumina coatings.

The surface of the single crystals of alumina at least in the vicinity of the cutting edge may, if desired, be provided with a coating of a polymer which facilitates shaving with the razor blades, for example polytetrafluoroethylene or a copolymer of thiocarbonyl fluoride and tetrafluoroethylene.

The razor blades of the present invention may, if desired, be provided on the surface thereof, at least in the vicinity of the cutting edge, with one or more coatings, additional to any polymer or copolymer coating, for example of a material which strengthens the cutting edge of the blade. A coating of a metal e.g. chromium, an alloy e.g. a chromium alloy, or a compound of a metal may be provided. As used herein, the term "chromium alloy" is applied to alloys of chromium with at least one further metal, for example as defined in copending application Ser. No. 241,446, filed Apr. 5, 1972, and now U.S. Pat. No. 3,838,512. Coatings of compounds of metals may be selected, for example, from nitrided metals or nitrided alloys. Chromium alloys as defined in the aforesaid copending Application are examples of nitrided chromium alloys which may be used. Coatings of metals, alloys and compounds of metals may be produced by any appropriate method, for example by ion-sputtering.

Coatings other than the polymer or copolymer coatings are preferably from 50 to 450 Angstroms thick, advantageously not more than 300 Angstroms thick, the combined thickness of a plurality of such coatings preferably being not more than 500 Angstroms.

The present invention further provides razor blades having at least one cutting edge on a single crystal of alumina, the crystal having been mounted on a support prior to completing the formation of the razor blade.

In some cases, because of expense or physical properties, it may not be appropriate to use such materials for conventional razor blades. In such cases, a relatively narrow strip of the crystal material can be mounted on a support, prior to the completion of the formation of the razor blade, and preferably prior to sharpening of the cutting edge.

The support can be of any material to which a strip of the crystal material can be rigidly secured, the depth of the strip being determined by the cost of the crystal material and the need for adequate mechanical strength in the strip and support to permit the edge-forming processes to be carried out.

As an example, the crystal strip could be moulded into an epoxy or other resin, or bonded to the edge of a strip of metal or other material, or gripped between the sides of a channel section strip of metal or other material.

The invention is illustrated in the accompanying drawings in which:

FIG. 1 is a section through a blunt crystal strip moulded in a support,

FIG. 2 is a section through a wedge-shaped crystal strip moulded in a support; and

FIG. 3 is a section through a wedge-shaped crystal strip bonded to the edge of a support.

As indicated in FIG. 1, the crystal strip can be quite blunt when moulded into its support, so that the blade-edge grinding operation will remove both support material and crystal material.

Preferably as indicated in FIG. 2, the crystal strip is preshaped to triangular section or wedge-shape to assist the mechanical interlock with the support and to reduce the amount of crystal material to be removed to form the cutting edge.

A simple alternative is provided, as shown in FIG. 3, by bonding a wedge-shaped crystal strip to the edge of a support. Preferably the outer edge of the wedge-shaped strip, from which the cutting edge is formed, has an included angle of 20° ± 10°. The wedge-shaped strip of crystal can be symmetrical as shown, but clearly this is not essential.

Suitable materials in which the crystal strip could be moulded are synthetic resins, such as acrylonitrile/-butadiene/styrene copolymers,polycarbonates, polyphenylene oxide, polyethylene, polystyrene, polypropylene, polyacetal, cellulose esters, for example acetate and propionate, or polyamides.

Suitable materials for bonding a crystal strip to the edge of a support include, for example, epoxy resins and cementing mixtures for bonding ceramics, for example Cu/Cu_2O eutectic mixtures.

The moulding material and/or the bonding material should generally be selected to withstand any heating to which it may be subjected during processing of the single crystals after moulding or bonding, for example during sintering of a polymer coating.

The shape of the support will be such as to fit the blade holder in which it is to be mounted. In particular however, the support can be formed integrally with a guard bar in juxtaposition with the cutting edge so that in this case the holder will merely serve to grip the support and provide a handle.

I claim:

1. A razor blade comprising a single crystal of alumina having a cutting edge thereon, said single crystal having large ions in and/or adjacent the surface of the single crystal in an amount sufficient to strengthen the surface of the crystal at least in the vicinity of the cutting edge.

2. A razor blade according to claim 1, wherein the single crystal of alumina contains less than 3×10^{-3} atomic percent of impurities.

3. A razor blade according to claim 1, wherein the large ions have radii at least 50% larger than that of aluminum.

4. A razor blade according to claim 1, wherein the large ions are present in an amount of up to 3 atomic percent.

5. A razor blade according to claim 1, wherein the large ions are present to a depth of from 100 to 1,000 Angstroms below the said surface.

6. A razor blade according to claim 1, wherein the large ions are ions of metals in Group III A of the Periodic Table.

7. A razor blade according to claim 1, having at least one coating selected from the group consisting of alumina containing at the most a low concentration of impurities, metals, alloys and compounds of metals.

8. A razor blade according to claim 1, wherein the single crystal is mounted on a support.

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