Aug. 26, 1952 M. H. BARNES ET AL 2,608,031

FLAME GLOSSING ROD-SHAPED SINGLE CRYSTALS OF CORUNDUM

Filed April 16, 1946 2 SHEETS—SHEET 1

Fig. 1.

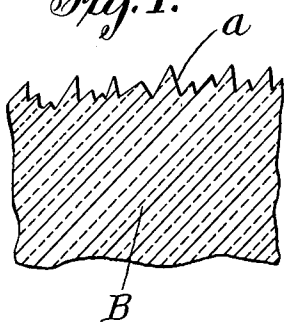


Fig. 2.

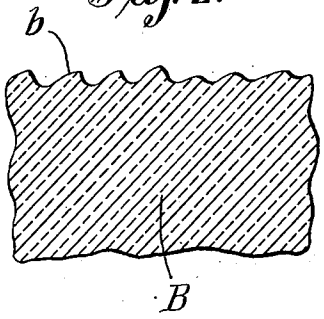


Fig. 3.

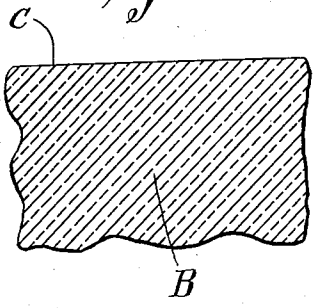
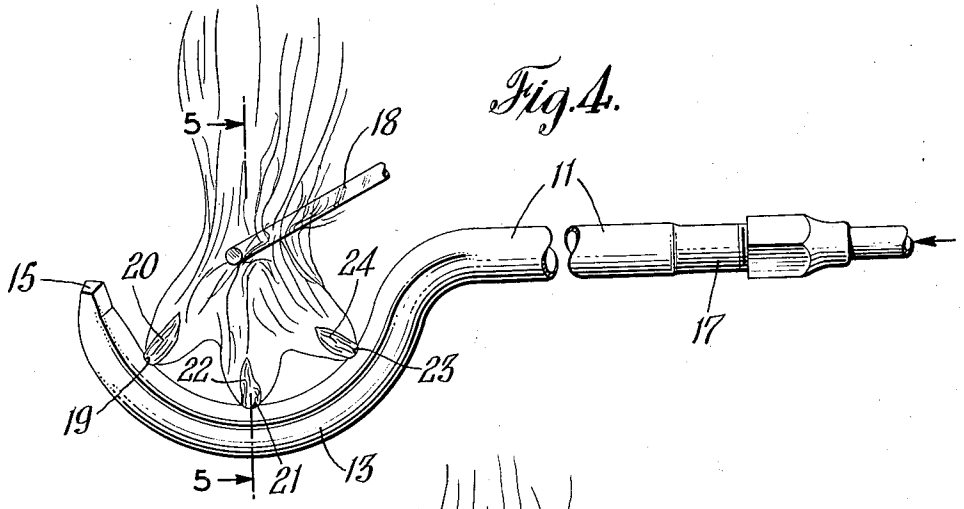


Fig. 4.



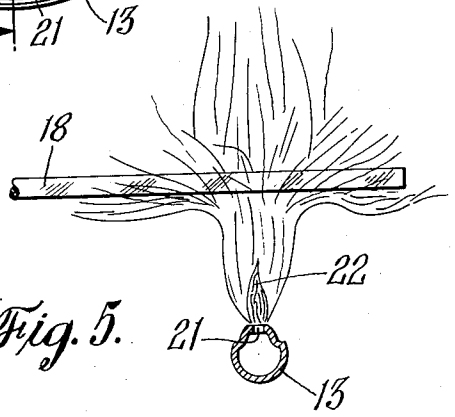


Fig. 5.

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Filed April 16, 1946 2 SHEETS—SHEET 2

Fig. 6

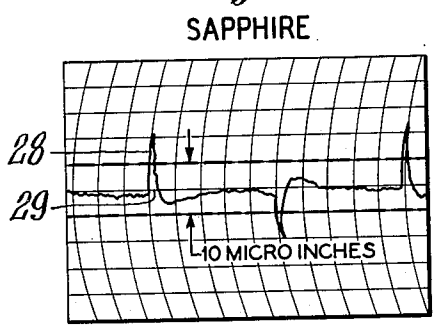
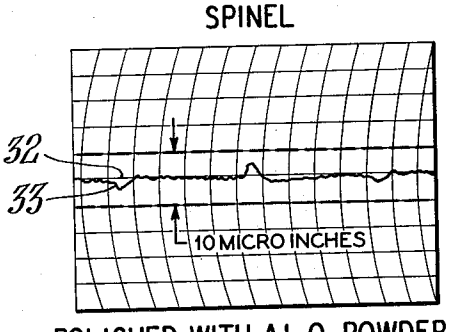


Fig. 8.



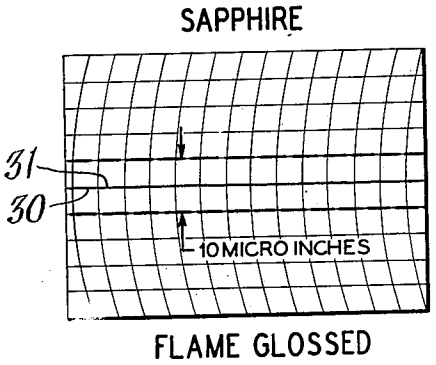


Fig. 7.

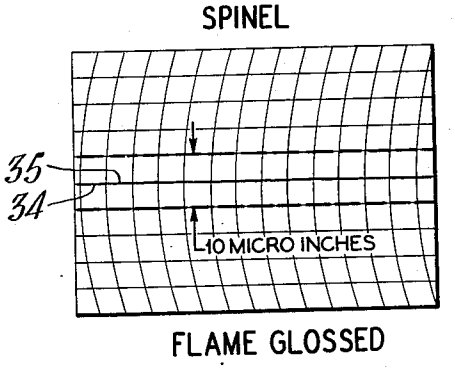


Fig. 9.

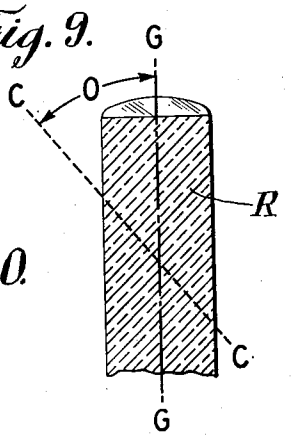


Fig. 10.

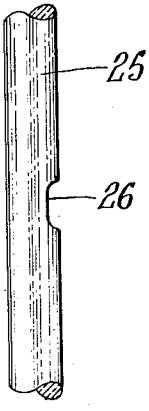


Fig. 8.

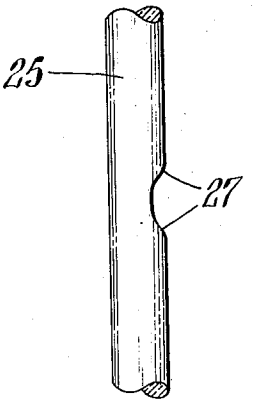


Fig. 9.

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UNITED STATES PATENT OFFICE

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FLAME GLOSSING ROD-SHAPED SINGLE CRYSTALS OF CORUNDUM

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Application April 16, 1946, Serial No. 662,454

2 Claims. (Cl. 49—77)

1

This invention is a process for providing glossy scratch-free surfaces on crystalline bodies of synthetic corundum. The invention also relates to crystalline corundum products having glossy scratch-free surfaces. This application is a continuation-in-part of our application 504,544 filed October 1, 1943, now abandoned.

Both natural and synthetic corundum crystals have been available for years in the form of clear sapphire (pure alumina) and ruby (alumina with a small percentage of chromium oxide). Such stones have rough surfaces when found in nature or when synthesized. For example, boules and thin rods of synthetic corundum, in the as-grown condition, have matte or frosted surfaces composed of many microscopic angular crystal projections or facets. Also, when such stones are sawed or ground, their surfaces are covered with scratches and projections produced by particles of abrasive material.

Before a hard body of corundum may be used as a jewel bearing, thread guide, or other low-friction wear-resistant device, or as a gem stone, it must be given a smooth and glossy surface, which has been done for generations by rubbing with successively smaller particles of diamond powder or like abrasive. While such mechanically polished surfaces may appear to be smooth and uniform to the naked eye, a microscope reveals the presence of many small scratches and pits produced by the small particles of abrasive. Furthermore, mechanical polishing is a slow, tedious, and expensive process.

The principal object of the present invention is the provision of a novel process for rapidly and inexpensively treating crystalline corundum bodies so as to give them glossy surfaces free from pits and scratches. Other objects are the provision of such a process whereby glossing is accomplished solely by heat; whereby the original shape of the body is retained; and whereby the character of the surface finish may be accurately controlled. Still another object is to impart utility to synthetic corundum rods of inferior quality. Other objects are the provision of: crystalline corundum bodies having glossy surfaces free from notches, pits and scratches; thin rods of synthetic corundum having substantially even and glossy surfaces free from pits and scratches; and such rods having glossy but wavy surfaces.

The above and other objects, and the novel features of the invention, will become apparent from the following description, having reference to the accompanying drawings, wherein:

2

Figs. 1, 2, and 3 are highly magnified schematic longitudinal sectional views of, respectively, a synthetic corundum rod in the as-grown condition, a similar rod partially glossed by the process of the invention, and a fully glossed similar rod;

Fig. 4 is a side elevational view, showing a heating torch suitable for performing the process of the invention;

Fig. 5 is a sectional view taken along line 5—5 in Fig. 4;

Figs. 6 and 7 are reproductions of two Brush analysis charts showing, respectively, the smoothness of a portion of the surface of a diamond-polished sapphire rod, and the smoothness of a sapphire rod glossed by the process of the invention;

Fig. 8 is an enlarged view of a synthetic corundum rod having a small cavity with sharp edges;

Fig. 9 is an enlarged view of the rod of Fig. 8 after being glossed by the process of the invention; and

Fig. 10 is an enlarged diagrammatic view illustrating the meaning of optic orientation in a corundum rod.

Our process for glossing a body of corundum essentially comprises fusing a thin layer including the surface of the body while retaining its interior in the solid condition, and then resolidifying the fused layer. When a smooth and even surface is desired, the rough surface is heated rapidly until the projections, such as sharp crystal facets, melt and the molten material coalesces and assumes an even and continuous surface, after which heating is stopped and the surface material cools and resolidifies. Heating may be accomplished in any way suitable for rapidly fusing a thin surface layer while retaining the interior solid and rigid, as by a gas flame, an electric arc, or a furnace. It is preferred, however, to heat the stone directly in a gas flame, such as an oxy-acetylene, oxy-hydrogen, or oxy-natural gas flame.

Heating in a gas flame is particularly applicable to long thin single crystals of synthetic corundum in the form of unicrystalline rods. Unicrystalline rods of corundum which have been grown in rod form and exceed three sixteenth inch in diameter tend to be unstable and easily fractured. For best results, therefor, corundum rods to be glossed should be three-sixteenth inch or less in diameter. The surface of such a rod may be glossed over its full circumference, and along its entire length or any part thereof, by holding it in a flame and rotat-

ing it on its longitudinal axis while effecting relative translational movement between the flame and the rod lengthwise of the rod. Successive circumferential zones of the surface are fused in this way, and, during the relative movement are progressively cooled and solidified as the flame passes away from the successive zones. Other shapes, such as slabs, also may be glossed in a gas flame.

A synthetic corundum rod B in the as-grown condition has a matte surface composed of many sharp projecting crystal facets, shown schematically at *a* in Fig. 1. When a partially glossed wavy surface free from scratches is desired, as shown schematically on a greatly enlarged scale at *b* in Fig. 2, the operator removes each portion of the rod from the flame to discontinue heating thereof as soon as the crystal facets have been fused superficially and rounded over, but before complete coalescence and the attainment of an even surface occurs. The surface obtained in this way is glossy but not quite so shiny and clear as a fully glossed surface.

Another and better way to form a wavy surface is by heating successive portions of the surface of the body completely to fusion with the flame, while maintaining the flame source sufficiently close to the surface that the dynamic action of the gases in the flame ripples the molten material, which then is allowed to solidify progressively into regular waves. A fully glossed, shiny and clear wavy surface results.

When a glossy, clear, scratch-free, and substantially even surface is desired, as shown schematically on a greatly enlarged scale at *c* in Fig. 3, the rough surface of the rod is heated in the flame until complete coalescence of the fused crystal facets occurs. By a substantially even surface is meant a surface which is practically without elevation or depression, as compared with a rough unglossed surface and a partially glossed surface. However, perfect evenness cannot always be obtained because the original rough stone may have variations in its surface which are carried over to the glossed product.

Although it is permissible to use a single small flame for flame glossing corundum bodies, it is usually more desirable to use a multi-jet flame wherein the jets intersect one another in such a way as to give a resultant soft broad flame. This is especially desirable for flame glossing a synthetic corundum rod by applying the flame progressively to successive zones along the length of the rod while it rotates on its longitudinal axis. A single flame jet sometimes produces a barely discernible threaded appearance on the surface of the rod under such conditions, but with a soft broad flame formed by a plurality of intersecting flame jets no such thread is obtained.

As shown in Figs. 4 and 5, one type of burner suitable for flame glossing is formed from a metal tube **11** bent into the shape of an arc or hook **13**. One end of the tube is sealed, as at **15**, and the other end comprises a shank **17** adapted to be connected to any suitable source of supply of a combustible gas, such as an oxy-natural gas mixture. Three spaced gas discharge ports **19**, **21** and **23** are drilled radially through the inside wall of the arc **13** in such a way that the three individual flame jets **20**, **22**, and **24** will intersect one another approximately at the center of curvature of the arc to provide a soft high temperature flame which spreads transversely of the arc **13** and heats a substantial length of rod **18**.

Often it is desirable, prior to heat glossing the surface, to shape a corundum body by mechanical cutting or grinding with a conventional cutting or grinding wheel having diamond or other abrasive particles embedded therein, thereby making pits, scratches or other undesirable marks. For example, synthetic unicrystalline corundum rods are usually ground to uniform diameter with abrasive diamond powder in a centerless grinder, after which the ground slightly rough surfaces are heat glossed.

Some synthetic corundum rods include subsurface bubbles which require their classification as of inferior quality. When such inferior quality rod **25** is centerless ground to a uniform diameter, the bubbles near the surface are exposed as open cavities, as shown at **26** in Fig. 8. The edges of such cavities are so sharp that they cannot be used successfully where a smooth surface is required, as in guiding threads. However, when such a rod is flame glossed after centerless grinding, the sharp edges of the exposed bubbles become rounded and smooth, as shown at **27** in Fig. 9, and the rest of the surface becomes glossy and free from scratches.

Sometimes flame glossed corundum rods may become worn and cut after they have been in service for some time, for example as thread guides. Such rough, worn and cut rods can be reglossed by applying a flame thereto in the manner described previously herein, and a smooth and glossy scratch-free surface comparable in quality to the original flame-glossed surface is again obtained.

The glossing of a corundum body in a flame is believed to proceed by heating a thin layer, including the surface, so rapidly that the layer fuses while the interior of the body is retained below the fusion temperature and remains solid and rigid. Consequently, the original shape of such a body is retained without auxiliary support during flame glossing. It is thought that the force of surface tension acting on the fused material on the surface of the body levels out irregularities, in spite of the counteracting force which tends to make the material recrystallize into a definite angular shape, as would be expected from its crystal habit.

It has not been possible to measure accurately the temperatures of corundum surfaces during a flame glossing operation, but tests which have been conducted by exposing thin corundum rods to various carefully controlled temperatures in a furnace have indicated that the surface must be heated to fusion if satisfactory glossing is to be obtained. For example, a sapphire rod was heated at 1900° C. in a furnace, but the rod after heating was only about 75% glossed, having a satin finish rather than a completely glossy finish. Since the melting point of corundum is about 2050° C., it is apparent that the material must be heated superficially to a temperature higher than 1900° C. to obtain successful glossing. Even though the surface is heated to such a high temperature, corundum single crystals have such a low thermal conductivity that it is possible to hold the ends of a thin rod in the hands while heating the middle in the flame.

For completely successful results in flame glossing synthetic corundum single crystals, it is important to consider the optic orientation of the crystal. Corundum crystallizes in the hexagonal system and has a single principal optic or C-axis, represented on the rod R in Fig. 10 by the line C—C, which extends in the direction in which light may be passed through the crystal without

being doubly refracted. The optic orientation of a corundum boule or rod is defined by the angle O included between the C-axis C—C' and the longitudinal or growth axis G—G, as shown in Fig. 10. When centerless ground synthetic clear sapphire rods, wherein the optic orientation O is between zero and 70 degrees, are selected for flame glossing, successful results are almost invariably obtained. However, when a centerless ground clear sapphire rod is selected wherein the optic orientation is between 70 degrees and 90 degrees it is found that during the flame glossing operation a series of small notches forms along two sides of the rod. Therefore, it is important to select for flame glossing only those clear sapphire rods having an optic orientation between zero and 70 degrees. Synthetic ruby rods exhibit the notching phenomenon during flame glossing if the optic orientation exceeds 65 degrees. Therefore, the most inclusive range for flame glossing the various forms of synthetic corundum rods is zero to 65 degrees.

Synthetic unicrystalline corundum rods centerless ground and then heat glossed by the process of the invention had an average tensile strength of 102,000 lbs./sq. in., compared with 67,000 lbs./sq. in. for corundum rod in the as-grown condition. This superior strength of flame glossed rods is believed traceable to the elimination of a notch effect, which exists in the as-grown and diamond-polished rods.

Examination of heat-glossed synthetic corundum rods with an electron microscope at a magnification of 2500X, has shown that the surfaces of such rods are free from scratches, pits, and striations. Rods which have been polished with fine diamond powder, on the other hand, show many scratches at 2500X magnification. Furthermore, the superior smoothness of flame polished corundum and spinel has been shown in Brush analysis tests with a Brush surface analyzer comprising a diamond point so mounted that when it rides on a surface the movement of the diamond point in a direction normal to the surface is transmitted through a piezo-electric crystal and an amplifier to a recording oscillograph. In the Brush analysis records shown in Figs. 6 and 7 magnification in the vertical direction is 40,000 and in the horizontal direction is 16. The displacement of the traced line **28** with respect to the datum line **29** in Fig. 6 definitely shows that surface irregularities occur at regular intervals on the surface of a centerless ground sapphire rod polished with diamond powder of between 2 and 4 microns size, whereas in Fig. 7 the traced line **31** coincides with the datum line **30**, showing that the surface of a centerless ground and flame-glossed sapphire rod is perfectly smooth and even.

The glossy, clear, and scratch free surfaces on hard crystalline corundum bodies treated by the process of the invention make them useful for many purposes. For example, fully heat-glossed unicrystalline synthetic corundum bodies are useful as gemstones, jewel bearings, thread guides and tension posts, and as micrometer gauge contact points. Flame-glossed sapphire gauge contact points do not scratch work of a relatively soft nature, such as high lead content bearings, whereas diamond polished points do tend to scratch such work because of the minute scratches formed on the surface by the particles of diamond. Flame-glossed sapphire thread guides outwear diamond-polished sapphire guides. Partially glossed synthetic corundum rods, having a wavy surface, are advantageous as thread guides and tension posts because many threads can be run in parallel over such a guide without interfering with one another.

The process and products of the invention have been described specifically by way of illustration only. It is apparent, however, that variations in procedure and in the products may be made within the spirit and scope of the invention, as defined in the claims.

We claim:

1. A process for glossing a unicrystalline thin rod of corundum comprising selecting such a rod wherein the angle between the longitudinal and optic axes thereof is between zero and 65 degrees, fusing a thin layer of such rod including the surface thereof by applying flame laterally against said rod and heating said surface therewith to a temperature of about 2050° C. while retaining the interior of said rod in a solid condition, and then resolidifying said layer to form a smooth glossy notchless surface.

2. A unicrystalline synthetic corundum rod grown in rod form and not exceeding three sixteenth inch in diameter, said rod having an optic orientation between zero and 65 degrees and having a smooth, glossy, clear, notchless heat glossed surface over its full circumference and extending along at least the major portion of its length, said surface appearing to be completely scratch-free at a magnification of 2500X.

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