

Aug. 6, 1957

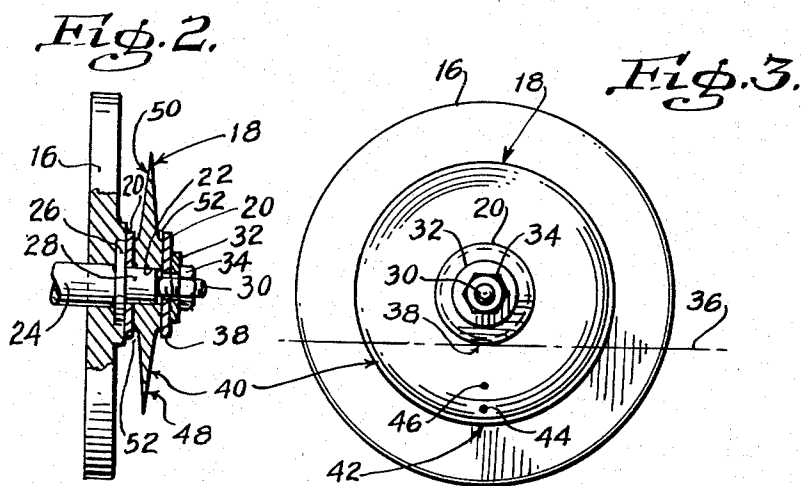
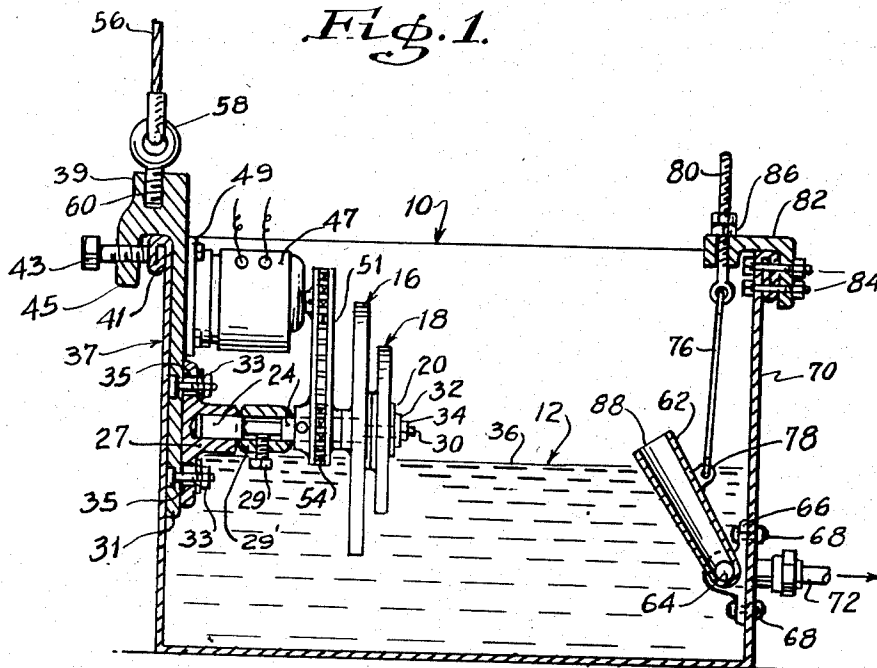
F. C. HIRDLER, JR

2,801,909

METHOD FOR REMOVING METAL FROM THE SURFACE OF A METAL OBJECT

Filed Oct. 12, 1954

3 Sheets-Sheet 1



INVENTOR.
FAIRBANKS C. HIRDLER, JR.
BY *Philip Lubow*
ATTORNEY

Aug. 6, 1957

F. C. HIRDLER, JR

2,801,909

METHOD FOR REMOVING METAL FROM THE SURFACE OF A METAL OBJECT

Filed Oct. 12, 1954

3 Sheets-Sheet 2

Fig. 4.

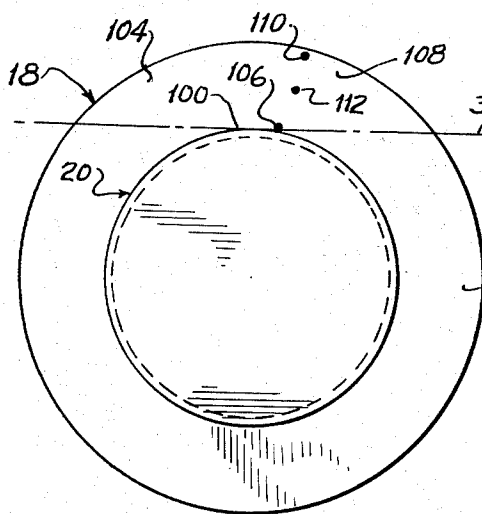


Fig. 5. Fig. 6.

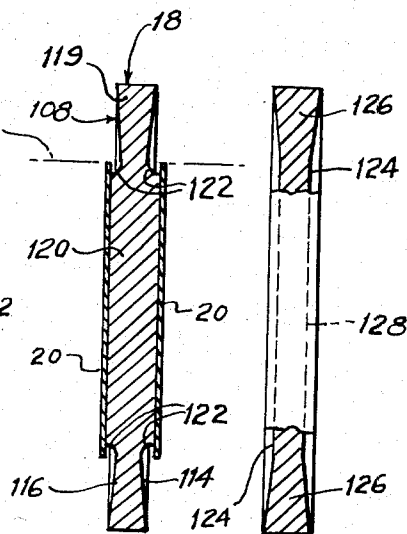


Fig. 7.

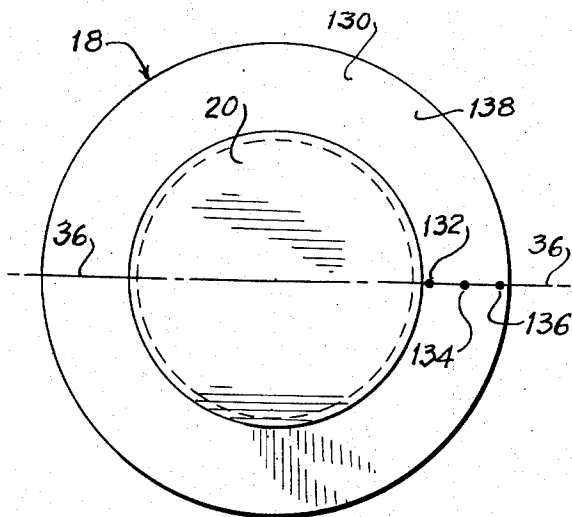
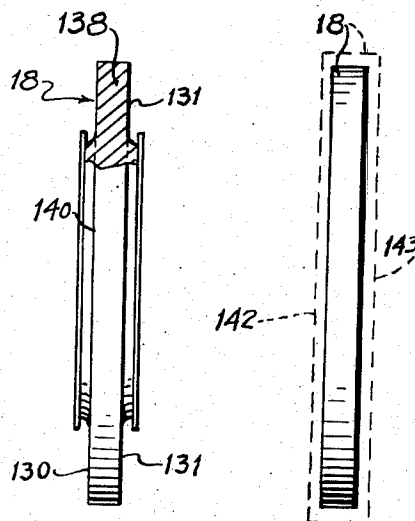


Fig. 8. Fig. 9.



INVENTOR.
FAIRBANKS C. HIRDLER, JR.

By *Philip S. Suber*
ATTORNEY.

Aug. 6, 1957

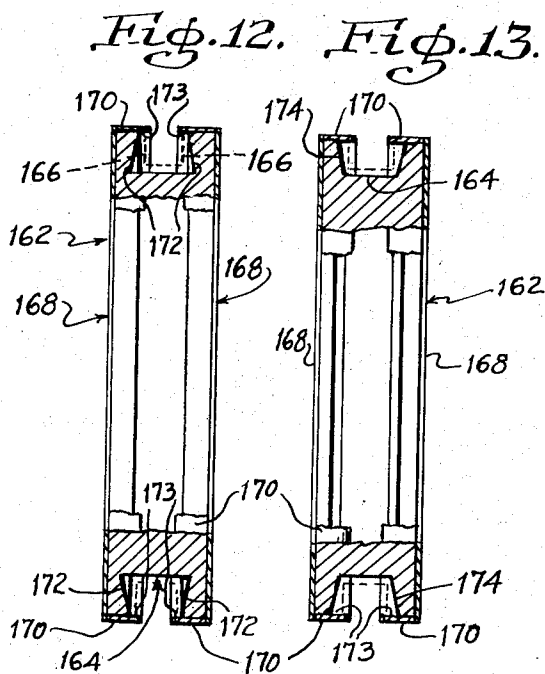
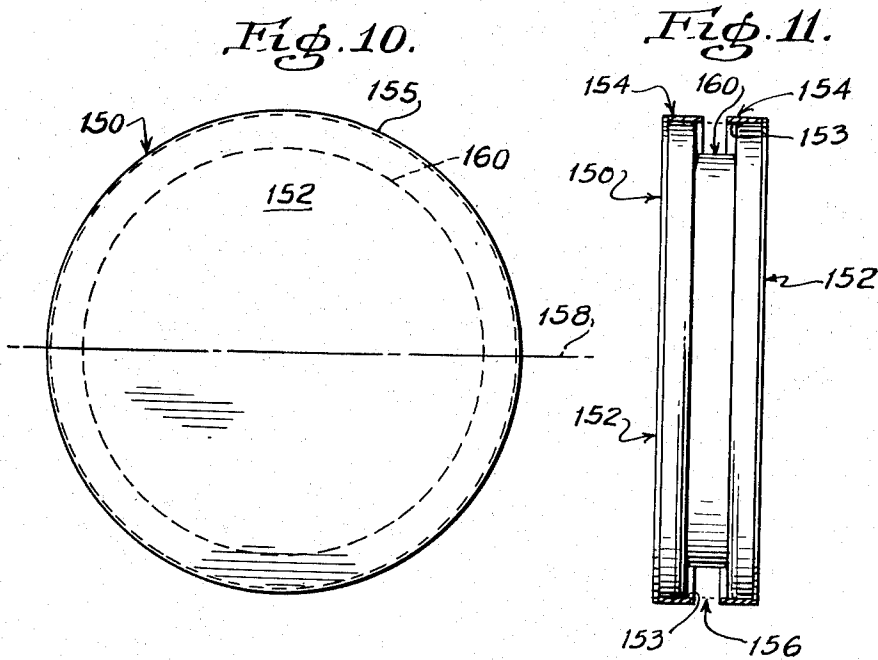
F. C. HIRDLER, JR

2,801,909

METHOD FOR REMOVING METAL FROM THE SURFACE OF A METAL OBJECT

Filed Oct. 12, 1954

3 Sheets-Sheet 3



INVENTOR.
FAIRBANKS C. HIRDLER, JR.
By *John S. Suber*
ATTORNEY.

2,801,909

METHOD FOR REMOVING METAL FROM THE SURFACE OF A METAL OBJECT

Fairbanks C. Hirdler, Jr., Los Angeles, Calif., assignor to Turco Products, Inc., Los Angeles, Calif., a corporation of California

Application October 12, 1954, Serial No. 461,804

7 Claims. (Cl. 41—43)

This invention relates to the etching or the removal of metal from the surface of a metal object, e. g., one composed of iron, nickel, magnesium, zinc, titanium, aluminum or their alloys. More particularly, the invention is concerned with novel procedure for this purpose, especially for the treatment of aluminum and its alloys.

This application is a continuation-in-part of my co-pending application Serial No. 460,075, filed October 4, 1954.

It is known to etch acid soluble metals such as magnesium, zinc, titanium and their alloys with an acid solution such as aqueous nitric acid or hydrofluoric acid, or their mixtures. It is also known to etch alkali soluble metals such as aluminum and its alloys with a solution having a solvent action on the aluminum or alloy surface, such as a hot aqueous alkali solution, e. g., one containing sodium hydroxide. One method of carrying out the etching process employing acids is to immerse the metal part to be etched in the etching bath, while another is to splash the solution contained in a bath against the work, the surface of which is to be etched or dissolved away. The prior art method for etching alkali soluble metals such as aluminum or its alloys is by immersion. However, the use of the conventional immersion or splash methods for etching metal parts often produces non-uniform etching, is difficult to control, and is time consuming. One of the drawbacks of such conventional procedures is that it has been heretofore difficult to produce metal parts having certain shapes or contours, e. g. tapered plates, by such prior art etching procedures.

Further, during the etching of aluminum or its alloys, the sodium hydroxide and certain other ingredients of the etching bath react with aluminum and aluminum alloys, forming hydrogen gas, sodium aluminate, aluminum oxide, and aluminum hydroxide. Since the hydrogen gas is much lighter than air, and considerably lighter than the etching solution, it rapidly rises to the surface of the solution. Since the metal dissolving or etching liquid tends to undercut the surface of the metal adjacent and beneath the edges of the mask or resist which is applied to the metal work piece in order to produce a specific etch pattern, there is a tendency for entrapment of some of the hydrogen gas behind the mask. This causes what is known as "gas masking," resulting in non-uniform and substantial undercutting, which is undesirable.

One object of this invention is to devise novel procedure for readily dissolving or removing metal in a controllable manner from the surface of a metal object, e. g., iron, nickel, titanium, aluminum, magnesium, zinc, and the like, or their alloys.

Another object is to provide procedure for the controlled etching of a metal part.

Another object is to design novel procedure particularly adapted for the uniform, controlled etching or removal of metal from the surface of a work piece composed of aluminum or its alloys.

Still another object is to provide procedure to produce a graduated amount of etching of the surface of a work

piece, such as aluminum or an alloy thereof, e. g. to form a part having a tapered section, wherein one portion of the etched part has a deeper etch than an adjacent portion.

A still further object of the invention is the provision of novel procedure for the efficient etching or removal of metal from the surface of a metal work piece with only a relatively small amount of substantially even undercutting, if any, of the surface of the metal below the edges of a mask which may be placed over the surface of the metal work piece to produce a desired etch pattern.

A still further object is the provision of etching procedure for the removal of reaction gas and precipitated solids from the surface of the work piece, especially adjacent and beneath the edges of a mask placed thereon.

Other objects and advantages will become apparent from the following description of the invention.

According to the invention for producing the desired contouring of a metal work piece, e. g. to form a part having a tapered section, the part to be etched to the desired shape is only partially immersed in the etching solution. This part is then rotated in the solution so that a uniformly varying depth of etch is produced in the surface of the part. For this purpose the part or the surface thereof to be etched should be located on an axis disposed at an angle to the horizontal axis of the etching tank, and preferably parallel to the vertical axis thereof. That portion of the part immersed in the solution may be located below or may extend above the axis of rotation of the part during the etching operation or period of rotation, that is, the axis of rotation of the part may be located either below or above the surface of the etching liquid.

Where, according to a preferred embodiment, only the lower portion of the work piece below the axis of rotation is at any time immersed in the etching bath, it will be seen that as the work piece rotates, the solution etches the surface of the work piece unevenly, the depth of etch graduating from a maximum at the outer periphery of the part which is immersed to the greatest depth in the solution, to a minimum about a circle defining an inner periphery of the part. With the surface of the etch bath tangent to such inner circular periphery during rotation of the part in the bath, the portion of the part between such inner periphery and the center or axis of rotation of the part is at all times above the solution, and hence is not etched thereby during rotation of the part.

Gas formed by the above etching procedure during such rotational etching of an acid soluble metal such as magnesium, titanium, zinc, nickel, or iron, or its alloys, or an alkali soluble metal such as aluminum or its alloys, is constantly removed from the metal work piece or part undergoing treatment as the etched portion of the work piece is rotated out of the solution, so that there will be no gas masking or entrapment of gas below and behind the edges of a mask which may be placed on the work piece. Most desirably, the work piece is positioned vertically in the tank and rotated about substantially the horizontal axis of the tank. In this way, all portions of the part being etched will, at one time or another, be at the top, sides, and bottom as the part rotates around this axis, and hence, the gas normally tending to become trapped will be continuously released from the work piece by the above described rotation thereof.

According to the invention, rotation of the work piece or part need not be at any particular speed but may be varied as desired. For instance, a rotational speed of twenty or thirty revolutions per minute may be sufficient to produce the desired results. However, the speed of rotation could be slower or faster than that

above indicated, depending on the size of the part being etched, the nature of the etch pattern, etc.

Another advantage of such rotation is that it permits the continuous circulation of solution by virtue of the movement of the part so that fresh solution will constantly reach the portions of the part adjacent the mask where used, as well as in the more exposed portions of the etch cavity. Continuous movement of the etching liquid over the surface of the metal work piece thus facilitates attack thereof by the solution in the selected, e. g. unmasked areas, of the work piece, and also has a scouring effect on such surface. So-called smut, often formed on the surface of a metal work piece during etching, is materially reduced by this scouring action. This is noted particularly where the work piece being processed is aluminum or an alloy thereof, in which case such scouring action also aids in the removal of any aluminum compounds such as the oxide or hydroxide, which may adhere to the surface of the work piece. Smut appears on surfaces of aluminum alloys, particularly when aluminum is alloyed with elements, such as for example, copper, iron and silicon, etc. Such aluminum alloys when etched with caustic soda, produce a film which is black and highly adherent to the surface. These smuts are insoluble in water and most acids. They are soluble in HNO_3 , mixtures of HNO_3 and H_2SO_4 , and in mixtures of chromic and sulfuric acids.

The solvent solution, after making contact with the rotating work pieces, is conducted away, carrying with it the aforementioned solids and gaseous foam. By rotation of the work piece according to the invention, there will be substantially no accumulation of solids in any crevices of the part, or in the undercuts adjacent the mask where one is used, since there will be no dead air spaces behind the mask. This also promotes uniform etching and the adherence of the etch to the design requirements.

The invention will be more clearly understood by reference to the following description of a preferred embodiment taken in connection with the accompanying drawings wherein:

Fig. 1 is a cross section of the device, shown partly in full for clarity;

Fig. 2 shows an enlarged section of the support for a work piece and the work piece thereon following tapering thereof according to the invention;

Fig. 3 is a plan view of the assembly of Fig. 2;

Fig. 4 is a plan view of a work piece or plate similar to Fig. 3;

Fig. 5 is a section of the plate of Fig. 4 after being subjected to the action of an etching bath according to one mode of procedure;

Fig. 6 is an end view partly in section of a plate like that of Fig. 4 after being subjected to the action of an etching bath according to another mode of procedure;

Fig. 7 is a plan view of a plate similar to Fig. 4;

Fig. 8 is an end view partly in section of the plate of Fig. 7 after being subjected to the action of an etching bath according to one mode of procedure;

Fig. 9 is an end view of the plate of Fig. 7 after being subjected to the action of an etching bath according to another mode of procedure;

Fig. 10 is a plan view of a plate similar to Fig. 7;

Fig. 11 is an end view of the plate of Fig. 10 after being subjected to one mode of etching procedure;

Fig. 12 is an end view partly in section of the plate of Fig. 10 after being subjected to another mode of etching procedure; and

Fig. 13 is an end view partly in section of the plate of Fig. 10 after being subjected to still another mode of etching procedure.

Referring particularly to Fig. 1 of the drawing showing apparatus for carrying out the invention procedure to form an etch pattern or tapered etch, i. e. one of gradually varying thickness, numeral 10 represents a tank

containing a body of metal dissolving liquid 12, e. g., hot sodium hydroxide solution. Mounted vertically in the tank for rotation substantially about a horizontal axis is a turntable 16. A work piece 18 is supported in vertical position against the turntable 16 in a manner more fully described below.

As seen particularly in Figs. 2 and 3, work piece 18 has a centrally positioned mask 20, e. g., in the form of a resist disposed on both sides of the work piece, there being a centrally located aperture 22 through the work piece and masks 20. Turntable 16 is rotated by a centrally positioned horizontal shaft 24 having a collar 26. A reduced portion 28 at the end of shaft 24 has a screw 30 connected thereto, and portion 28 and such screw are received in aperture 22 of the work piece, which is secured to the turntable by a clamp 32 held in position by a nut 34 threadably engaging screw 30.

Shaft 24 for rotation of turntable 16 and work piece 18 is journaled in a bracket 27 and prevented from removal therefrom by means of set screw 29 mounted in a sleeve 29'. Bracket 27 is mounted for vertically adjustable movement on a plate 31 by means of bolt and nut assemblies 33, the bolts passing through vertical slots 35 in the bracket 27. Plate 31 is a flat elongated member which is positioned in contact with the inner surface of a wall 37 of tank 10, and is supported thereagainst by an upper flange 39 resting on the upper lip 41 of the tank, the plate 31 being held firmly in position by means of a bolt 43 passing through a downwardly extending member 45 integrally connected to flange 39, the end of the bolt 43 frictionally engaging the outer surface of lip 41.

A motor 47 positioned on a bracket 49 suitably connected to the upper end of plate 31, drives shaft 24 for rotation of turntable 16, by means of a chain 51 meshing with a sprocket 54 on the shaft 24. Plate 31 and the entire assembly connected thereto, including the turntable 16 and motor 47, may be withdrawn from the tank 10 by a cable 56 passing through a ring 58, in turn connected through a screw 60 to flange 39; the cable being attached at its other end to a crane or other hoisting mechanism (not shown).

To adjust the level 36 of liquid 12 in tank 10, a nozzle 62 is provided, the nozzle being pivotally supported on a hollow trunnion 64 mounted on a bracket 66 which is connected by rivets 68 to wall 70 of the tank. Hollow trunnion 64 communicating with the interior of the nozzle 62 is connected to a pipe 72 for removal of liquid from the nozzle. Nozzle 62 is supported by an arm 76 pivotally connected at one end to a bracket 78 on the outer wall of the nozzle, the other end of arm 76 being pivotally retained in the head of a vertically adjustable screw 80 received in the end of an overhanging flange 82 connected to the top of the tank by means of bolts 84. A nut 86 on screw 80 can be adjusted so as to impart to nozzle 62 the desired degree of inclination thereof to place the outer end 88 of the nozzle at a selected position relative to the level of liquid 12 in tank 10. Contact of the nut 86 with the upper surface of flange 82 maintains the nozzle 62 in a fixed position.

The turntable 16 and work piece 18 thereon are positioned in the etch tank so that the liquid etchant level 36 is below shaft 24 and is approximately tangent to the lowermost peripheral edge 38 of the masks 20, as seen in Figs. 2 and 3. It is thus seen that as the work piece 18 rotates, only the lower portion 40 thereof is at any time immersed in the etchant fluid. Further, it is noted that a point 42 on the outer periphery of such portion 40 remains in the body of solution longer than any other point, e. g. 44, on the surface of the lower portion 40, since point 42 travels through an arc of greater radius than any other such point. Also, for the same reason, point 44, which is closer to the outer periphery of the work piece 18 than point 46 on the surface of lower portion 40,

remains in the body of etchant solution longer than point 46.

Hence, as work piece 18 rotates, the solution etches the surface of the work piece unevenly, the depth of etch on the opposite surfaces of such metal part graduating from a maximum at the outer periphery of the part to a minimum about the inner periphery of the work piece adjacent the outer edges of the masks 20, as clearly indicated in Fig. 2. Thus, for example, when the work piece is etched on both sides, the cross section of the etched portion of the work piece will be wedge shaped, as seen in Fig. 2, and tapering in the direction of the outer periphery of the part. The work piece 18 will also be shortened radially from its original radius due to the etching action of the solution along the outer peripheral edges of the work piece. The etched surfaces 48 and 50 thus obtained on opposite sides of work piece 18 are of uniform taper, and a minimum amount of even undercutting indicated at 52 is also produced in the metal part adjacent the outer edges of masks 20 and the etched surfaces 48 and 50. It is noted in this embodiment that any hydrogen gas trapped in the undercuts 52 adjacent the edges of the masks 20, will be removed on rotation of the immersed portion 40 of the work piece to its uppermost position out of the solution, and that sludge tending to lodge in such undercuts adjacent the masks will be removed during rotation of the work piece.

If desired, the masks 20 may be omitted, since the surfaces of the work piece 18 covered thereby are above the liquid level 36 and hence are free from contact with the main body of etching solution. However, the masks protect the surfaces of the plate 18 which are not to be etched from any etching liquid which may be splashed thereagainst during rotation of the plate in the bath. Further, where there is turbulence of the surface of the etching solution, the mask, e. g. masks 20 in Fig. 1, may be of such a diameter that the outer portions thereof dip into the solution as the work piece rotates. In this manner, etching is facilitated for production of a smooth taper without any irregularity etched sections being formed on the work piece adjacent the inner end of the taper.

In the embodiment shown in Figs. 1 to 3, the turntable 16 and work pieces or plate 18 thereon is positioned in the etch tank so that the etching liquid surface 36 is below the shaft 24 and hence below the axis of rotation of the work piece. If, however, the turntable and work piece 18 thereon are positioned in the bath with the shaft 24 located below the surface 36 of the etching liquid, a different taper configuration may be obtained from that shown in Fig. 2.

Thus, for example, if plate 18 with the masks 20 thereon be partially immersed in the etch bath so that the liquid etchant level 36 is approximately tangent to point 100 on the uppermost peripheral edge of the masks 20, as seen in Figs. 4 and 5, it is seen that as the work plate rotates, the portion 102 of the plate below point 100 and including the masks 20 will be at all times immersed in the solution, while that portion 104 above point 100 will remain above and unexposed to attack by the etching solution. It is noted in this embodiment that a point 106 on the inner periphery of the uncovered or unmasked outer surface area 108 of plate 18 adjacent the edge of mask 20 would remain in the body of solution longer than any other point on surface 108 which is further from the center of plate 18, e. g. 110 located near the outer periphery of the exposed portion of plate 18; also, point 112, which lies closer to the inner periphery of the exposed area 108 of plate 18 than point 110, would remain in the body of etchant solution longer than point 110.

Hence as work piece 18 rotates in the solution according to the embodiment of Figs. 4 and 5, the solution will etch the unmasked area 108 of the work piece unevenly, the depth of etch on the opposite unmasked surfaces 108

of the metal part graduating from a maximum at the inner periphery of the uncovered portions of the surfaces 108 to a minimum at the outer periphery of the work piece, as clearly indicated in Fig. 5. The work piece thus may be etched on both faces, the cross section of the etched portion 119 of the work piece being wedge shaped and tapering in a direction from the outer periphery of the part to the inner periphery thereof adjacent masks 20, as noted in Fig. 5.

The etched surfaces 114 and 116 thus obtainable on opposite sides of work piece 18 will be of uniform taper and the work piece will also be shortened radially due to the etching action of the solution on the outer peripheral edges of the work piece. The center section 120 of the work piece 18 will have its original thickness since it is covered by the masks 20 as in the case of the embodiment of Fig. 2. In the instant embodiment also, a minimum of even undercutting indicated at 122 may be produced in the metal adjacent the outer edges of masks 20, and as the work piece is rotated in the solution, gas and sludge tending to become lodged in such undercuts will be removed in the manner previously described.

Further, if a work piece 124 similar to 18, but without any masks on the surface thereof, be partially immersed in the etching solution to the same extent as in the case of work piece 18 in Figs. 4 and 5, i. e. with its axis of rotation below the surface of the solution, and the work piece rotated during etching, the same peripheral wedge shaped configuration 126 may be produced as the peripheral wedge 119 of Fig. 5. However, the center portion 128, which is not covered on its outer surface by masks and which is at all times completely immersed in the solution, may be etched down uniformly across its surface to a greater depth than any portion of the outer surface of the peripheral taper 126.

On the other hand, as seen in Figs. 7 and 8, if the part 18 having the masks 20 on both sides thereof be rotated on an axis in the plane of the surface 36 of the solution, all portions of the outer unmasked opposite surfaces 130 and 131 may be etched uniformly because all points on each radius of the part, e. g. points 132, 134 and 136 will enter and leave the solution at the same time. Hence a part as shown in Fig. 8 having a uniformly etched outer peripheral portion 138 may be formed. The resulting part will also have a center portion 140 of a thickness equal to that of the original part since this center portion is covered by masks 20 and is hence immune from attack by the solution. If no masks were used in this embodiment, the entire area of both sides 142 and 143 of part 18 would be subjected to attack, and hence the part would be uniformly reduced in thickness throughout its entire cross section from that shown in dotted lines in Fig. 9 to the full line representation thereof. The diameter of the part 18 in Figs. 8 and 9 will also be reduced due to radial etching. It is seen that the embodiments of Figs. 7 to 9, wherein the part is rotated on an axis at the level of the solution, do not form tapered sections, but form uniformly etched sections similar to those which would be formed if the part were entirely immersed, as described and claimed in my above copending application.

Figs. 10, 11, 12 and 13 illustrate still other embodiments of the invention. Here a part in the form of a circular plate 150 has a mask 152 applied over the entire area of the outer opposite faces of the plate, and a mask 154 is also applied to the periphery 155 of the plate, leaving a center circular portion 156 above the periphery uncovered by this mask. The disc or plate 150 may then be placed in the etching solution and rotated on an axis at a level with the surface 153 of the solution. Rotation of the plate 150 on this axis would form a central peripheral notch 160 between the mask portions 154 on the periphery. It will be noted that as the depth of the notch increases, the width thereof will also increase. In this manner I may form a part in the shape of a grooved pulley according to the invention. It is seen in Fig. 11

that the solution will tend to undercut the mask as at 153 during etching.

If the disc 150 is rotated on an axis below the level of the solution, the lower portions of the notch radially nearer the center traverse the solution for a greater length of time than the portions of the notch radially farther from the center. Since at all times while the part 150 is thus immersed in the solution, the solution undercuts the mask at a rate substantially equal to the rate at which it deepens the notch, by controlling the position of the axis of rotation with respect to the surface of the solution, and the rate of rotation as well as the temperature and concentration of the solution, the rate of etching radially may be maintained uniform and substantially at a constant ratio to the rate at which the mask is undercut, e. g., at an equal rate, and thus to produce a notch having a substantially perpendicular wall such as shown in Fig. 11. If, however, the rate of etching is not controlled in this manner to obtain a notch having a perpendicular wall, a tapered notch may be obtained. Such, for example, may be the case where the disc 150 is rotated on a level above the surface of the solution, in which case the portions of the notch near the periphery of the disc and farther from the center of rotation will be in the solution longer than those portions of the notch closer to the center of rotation, thus tending to form an inverted notch where the sides of the notch 160 tend to taper inwardly as at 170 in Fig. 13.

Referring to Fig. 12, a disc 162 has a peripheral notch 164 (shown in dotted lines) formed therein, similar to notch 160 in plate 150, the notch 162 having parallel sides 166 which are perpendicular to the bottom of the notch. A mask 168 is applied to opposite faces of plate 162, and a peripheral mask 170 is applied to the periphery of plate 162 on both sides of notch 164. If plate 162 be partially immersed in an etching solution with its axis below the level of the solution and the plate rotated on such axis, as in the case of the plate in Figs. 4 to 6, the etching solution will tend to attack the inner surfaces of the notch 164 in such a manner as to form an inverted notch having outwardly tapering sides 172, since the inner peripheral portion of notch 164 is subjected to the action of the solution for a greater period than the outer peripheral portion of the notch. Also, the depth of notch 164 will tend to increase during the etching period and the mask 170 will be undercut at 173 adjacent the outer periphery of the notch.

Further, as shown in Fig. 13, if the plate 162 having masks 168 and 170 applied to the outer surfaces thereof, and a notch 164, be partially immersed in the solution with the axis of the plate disposed above the level of the solution, as in the case of the embodiment shown in Figs. 1 to 3, and the plate rotated on such axis, the etching solution will attack the inner surface of the notch 164 so as to tend to produce a notch having inwardly tapering sides 174. This is due to the fact that the outer periphery of the notch will be subjected to a greater period of etching than the inner periphery of the notch.

If desired, the above described procedures may be combined to produce a part having a plurality of tapered or etched surfaces. Thus, the peripheral portion of a part may be tapered by etching as shown in Fig. 6, a notch then formed in the outer periphery thereof as in the case of Fig. 11, and the sides of the notch tapered in one direction or the other as in Fig. 12 or Fig. 13. This illustrates the versatility of the invention procedure in producing parts of various shapes.

The above etching procedures, especially for producing work pieces or plates having tapered sections, may be applied to circular, square, rectangular, etc., parts as long as they are symmetrical with the axis of rotation. For example, a square billet could be turned on its longitudinal axis to round off the sharp edges as well as to produce other effects with or without masking. During rotation of the part, the exposed portion thereof, i. e.

above the surface of the bath, may be sprayed with water, so that the residual chemical or etchant thereon will not continue to etch that portion of the part which is at any time disposed above the solution level.

While in the preferred embodiments, the work piece is shown as mounted vertically in the tank and rotated on a horizontal axis, the work piece may be inclined at an angle to the vertical and rotated on an axis inclined to the horizontal, so long as successive portions of the work piece move continuously from a lower to a higher position in the body of etching solution according to the invention principles. Thus, for example, if the plate 18 in Fig. 1 as inclined at say a 45° angle to the vertical, and shaft 24 disposed at a 45° angle to the horizontal for rotation of the plate, a tapered plate having a non-uniform taper on its opposite sides may be formed.

Where the work piece is aluminum or an alloy thereof and the tanks are heated by coils, the precipitate of aluminum hydroxide and/or aluminum oxides in the solvent or etching bath resulting from the etching reaction forms deposits on such coils and also on the surface of the etching tank. In order to prevent or reduce the formation of hard adherent scale, there may be added to the alkaline etching solution, agents which keep the precipitate flocculent.

If it is desired to remove precipitated solids continuously from the etch tank 10 without resorting to periodic shutdowns for removal of such sludge, the procedure and equipment disclosed in application Serial No. 449,994 of Emmette R. Holman, filed August 16, 1954, may be employed.

According to the preferred embodiment of the invention for etching or removing metal from an aluminum or aluminum alloy material, which is alkali soluble, a hot aqueous solution is generally employed containing an alkali such as sodium or potassium hydroxide, trisodium phosphate, soda ash or the like, or mixtures thereof. Preferably, a sodium hydroxide solution is used. Temperature is generally maintained in a range, say from 100° F. to about boiling during treatment, although lower temperatures may be used. Generally, the alkali concentration employed in such solutions ranges from 0.1 to 10 normal.

While the invention has been described particularly in connection with the etching of aluminum or an alloy thereof by means of an alkali solution, it is of course understood that acid soluble metals such as magnesium, iron, nickel, titanium and zinc can also be effectively etched by the procedure herein, employing acid etchants such as aqueous nitric acid, hydrofluoric acid, or mixtures thereof depending on the nature of the metal. Further, it is noted that aluminum may also be etched by means of an acid etching solution such as hydrochloric acid or salts such as ferric sulfate.

Of course, it will be understood that the apparatus described herein should be constructed of materials which are substantially inert to attack by the etchant solutions employed and those skilled in this art will know how to select such materials.

While I have described a particular embodiment of my invention for the purpose of illustration, it should be understood that various modifications and adaptations thereof may be made within the spirit of the invention as set forth in the appended claims.

I claim:

1. A process for forming a plate having a tapered cross section adjacent the outer periphery thereof which comprises applying a mask to a surface of a plate centrally thereof to prevent attack of the surface of said plate beneath said mask, leaving uncovered an outer surface portion adjacent said mask, partially immersing said plate in a body of etching solution contained in a tank, said uncovered surface portion being positioned substantially parallel to the vertical axis of said tank, rotating said plate on an axis disposed substantially parallel to a hori-

zontal axis of said tank, and differentially etching said uncovered surface portion to produce a varying depth of etch thereon.

2. A process for forming a tapered notch in the outer peripheral edge of a disc by etching, which comprises applying a mask to said peripheral edge, leaving a portion of said edge extending about the entire periphery of said disc uncovered, said mask preventing attack by an etching solution of the surface of said disc covered by said mask, partially immersing said disc in an etching solution contained in a tank, a surface of said disc being positioned substantially parallel to the vertical axis of said tank, and rotating said disc on an axis disposed substantially parallel to a horizontal axis of said tank and perpendicular to said surface of the disc, so that adjacent radially disposed portions of said surface of the disc located on a radius about said axis of rotation traverse the solution for varying periods of time depending on the respective distances of said surface portions of the disc from the axis of rotation, and differentially etching said uncovered peripheral portion of said disc.

3. A process of etching a surface of a metal work piece, comprising immersing a portion of said surface in a metal dissolving solution with the remaining portion of said surface outside said dissolving solution, and with said surface oriented at a substantial angle to the surface of said dissolving solution, and rotating said work piece to continually immerse and withdraw sections of said work piece surface in and from said dissolving solution, said work piece surface being further oriented relative to said solution to provide for different sections of said surface being immersed in said dissolving solution for different total periods of time, whereby varying degrees of etching are had over said surface.

4. A process of etching a surface of a metal work piece, comprising immersing a portion of said surface in

a metal dissolving solution with the remaining portion of said surface outside said dissolving solution, and with said surface oriented at a substantial angle to the surface of said dissolving solution, and rotating said work piece about an axis transverse to said work piece surface to continually immerse and withdraw sections of said work piece surface in and from said dissolving solution, the intersection of said axis and said work piece surface being displaced from said surface of said solution, whereby adjacent portions of said work piece surface relatively displaced radially from said axis traverse the solution for different periods of time to provide varying degrees of etching over said work piece surface.

5. A process as defined in claim 4, wherein said axis is substantially parallel with said surface of said solution and is located above said surface of said solution.

6. A process as defined in claim 4, wherein said axis is substantially parallel with said surface of said solution and is located beneath said surface of said solution.

7. A process as defined in claim 4, wherein said axis is substantially parallel with said surface of said solution and is substantially perpendicular to said work piece surface.

References Cited in the file of this patent

UNITED STATES PATENTS

1,001,031	Hilliard	Aug. 22, 1911
1,276,599	Weeks	Aug. 20, 1918
1,918,627	Ballard	July 18, 1933
2,155,392	Ballard	Apr. 25, 1939
2,509,848	Ulasich	May 30, 1950
2,662,002	Sunderhauf et al.	Dec. 8, 1953

FOREIGN PATENTS

122,433	Great Britain	June 19, 1918
205,182	Switzerland	June 15, 1939