United States Patent

Blossick et al.

[15] **3,668,029**

[45] **June 6, 1972**

[54] CHEMICAL MACHINING PROCESS

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[73] Assignee: **Armstrong Cork Company,** Lancaster, Pa.

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[52] **U.S. Cl.**..................................**156/11,** 96/36.3, 117/113, 156/14

[51] **Int. Cl.**..**C23f 1/02**

[58] **Field of Search**.................156/11, 12, 13, 14, 18; 96/36, 96/44, 36.3, 36.4; 117/49, 113

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Primary Examiner—William A. Powell
Attorney—Barry E. Harverstick

[57] **ABSTRACT**

A process for chemically machining metals, particularly steels and steel alloys, to depths greater than 0.010 inches by using a chemical etching solution. The metal is coated with an etch-resist, exposed to an energy source to harden and bond a predetermined area of the resist to the metal and then developed to remove the unhardened and unbonded resist. The metal is then recoated with resist, again exposed to an energy source to harden and bond the second resist layer to the first resist layer at the aforesaid predetermined area and then developed to remove the unhardened and unbonded resist. The metal is then passed through a chemical etching solution to chemically machine those areas of the metal unprotected by the double layer of resist.

1 Claim, 8 Drawing Figures

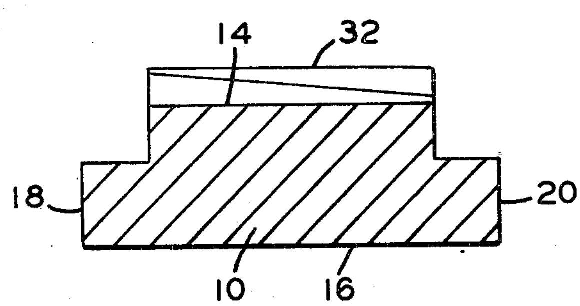


Fig. 1

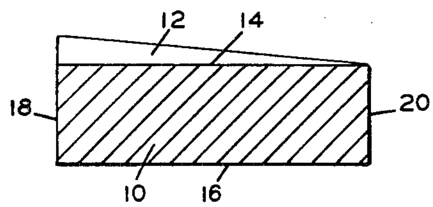


Fig. 2

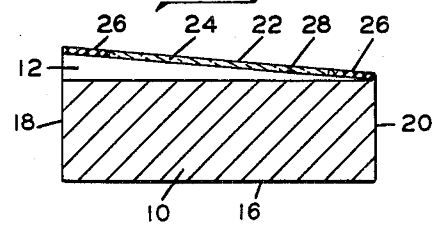


Fig. 3

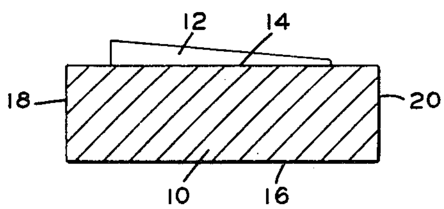


Fig. 4

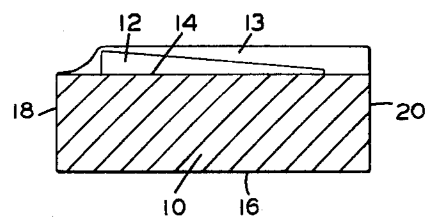


Fig. 5

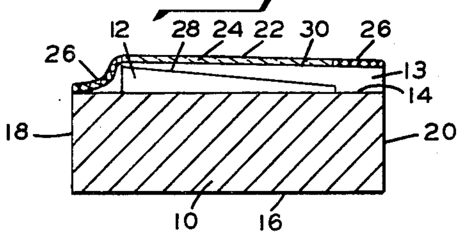


Fig. 6

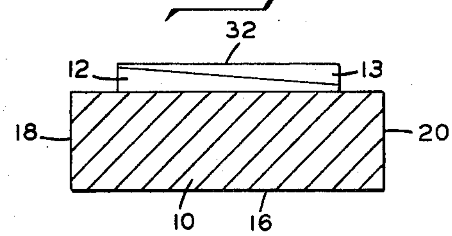


Fig. 7

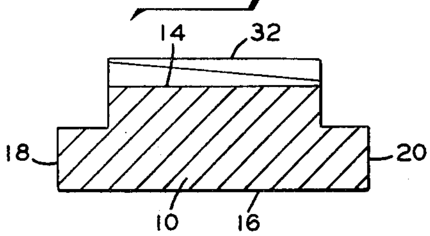
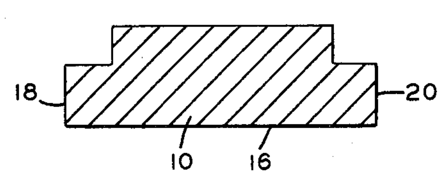


Fig. 8



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CHEMICAL MACHINING PROCESS

BACKGROUND OF THE INVENTION

1. Field of the Invention

This invention relates to the process for chemically machining metals. More particularly, the invention relates to the process for chemically machining hard-to-etch metals such as steels and steel alloys, to depths greater than 0.010 inch.

2. Description of the Prior Art

The Giangualano et al. U.S. Pat. No. 3,376,138, issued Apr. 2, 1968 teaches a method of chemically machining thin metal sheets such as 0.0014-inch-thick copper for use as a printed circuit board. Such a process can also be used to etch micro parts from thin metal sheets where depth of etch, and hence, resist breakdown, is not a problem.

U. S. Pat. No. 3,257,251 issued June 21, 1966, to Lewis et al. sets forth a method of chemically machining a pattern on an embossing roll using a repeat coating and etching process to achieve a desired depth. In this repeat process it is necessary to recoat the entire pattern area with a coating of resist before the embossing roll can be etched a second time. In the improved method of chemically machining disclosed herein, it is unnecessary to repeat the resist coating step after each pass through the etching apparatus. It is only necessary in using this improved method, to pass the metal through the etching machine as many times as is required to attain the desired depth of etch.

The Young U.S. Pat. No. 3,386,901, which issued on June 4, 1968, discloses a method of etching metal plates such as steel, to make embossing dies. Although this patent relates to an electrolytic method of etching metal, it does disclose the conventional process and materials used, both of which are old in the art, to prepare the metal for the first etching step which electrolytically achieves an etching depth of approximately 0.005 inch. To achieve an etched depth of about 0.025 inch, it is necessary to follow a rather intricate process of recoating the raised pattern and its sidewalls with a protective coating before the second etching step which again achieves an etching depth of about 0.005 inch. These steps are repeated until the desired depth of etch is attained.

Using the chemical machining process disclosed herein, it is not necessary to repeat any coating step between the etching steps in order to achieve a desired depth of etch. The method of this disclosure has been used to etch embossing dies and plates to a depth of about 0.036 inch without the need to repeat the resist coating step after the metal has been initially prepared using this method. Using this method, a steel plate bench model has been etched to a depth of 0.250 inch without breakdown of the resist which necessitated any recoating steps, and all the while maintaining good definition of the original shape of the design figure. The process described herein can also be used to etch other metals as well as steel, which is one of the most difficult metals to etch because of its slow etch rate, whenever it is necessary to hold fine detail, good definition and close tolerances over a large area, such as would be the case for a large area, repeat pattern embossing plate. The fine detail, good definition and close tolerances are especially very important when embossing a repeat pattern in register with a certain design area of the pattern.

SUMMARY OF THE INVENTION

The main object of this invention is to present a method of chemcially machining metals, and particularly zinc, steels and steel alloys, to depths greater than 0.010 inch, while maintaining fine detail, good definition and close tolerances, without utilizing any etch resist recoating step between etching steps.

The invention is directed to a method of chemically machining metal embossing plates or dies and metal stencils. The method includes the steps of cleaning the surface of the metal, coating the cleaned metal surface with a layer of etch resist and then drying this resist layer. Next, a photographic film having a desired design pattern thereon is positioned on the resist layer and the resist layer is exposed through said film to an energy source to harden and bond certain areas of the resist to the metal plate. The photographic film is then removed from the metal plate and the resist coating which has not been exposed to the energy source is developed off said plate.

At this point in the process, the metal plate is recoated with a second layer of etch resist and allowed to dry. The same photographic film is again positioned on the plate and the second layer of resist is exposed to an energy source to harden and bond this second layer of resist to the first layer of resist. The photographic film is then removed and the second layer of the etch resist which has not been exposed to the energy source is developed off the metal plate.

After completion of the above-described steps, the metal plate has a double layer of hardened and bonded etch resist thereon in predetermined areas. This metal plate is then chemically machined by passing said plate through an apparatus containing a chemical etching solution as many times as is necessary to etch the metal to a desired depth. As can be seen from the preceding brief description of this chemical machining method, there is no need to repeat the resist coating or any other protective coating steps after the metal plate has been prepared by this method and is ready to be passed through the chemical etching apparatus.

BRIEF DESCRIPTION OF THE DRAWING

FIG. 1 is a cross-sectional view of a metal plate having a first layer of etch resist deposited thereon by dip coating.

FIG. 2 is a cross-sectional view of a metal plate having a dried first layer of etch resist deposited thereon and having a photographic film negative positioned over said resist for exposure of said resist to a light source through said film.

FIG. 3 is a cross-sectional view of a metal plate having a hardened and bonded etch resist remaining thereon after the photographic film negative has been removed and the unexposed etch resist developed off.

FIG. 4 is a cross-sectional view of a metal plate having a hardened and bonded first layer of etch resist remaining thereon and having a second layer of etch resist deposited thereon by a second dip coating after the metal plate has been inverted.

FIG. 5 is a cross-sectional view of a metal plate having a hardened and bonded first layer of etch resist, having a dried second layer of etch resist deposited thereon and having the photographic film negative of FIG. 2 positioned over said second resist layer for exposing said second layer of resist to a light source through said film.

FIG. 6 is a cross-sectional view of a metal plate, having a hardened and bonded first layer of etch resist on said metal plate and having a hardened and bonded second layer of etch resist covering said first layer of etch resist after the photographic film negative has been removed and the unexposed second layer of etch resist developed off.

FIG. 7 is a cross-sectional view of a metal plate which has been chemically machined in those areas which are not covered by the double layer of hardened and bonded etch resist.

FIG. 8 is a cross-sectional view of a chemically machined metal plate after the double layer of hardened and bonded etch resist has been stripped off said metal plate.

DESCRIPTION OF THE PREFERRED EMBODIMENT

The first step in the process of chemically machining a steel embossing plate or die is that of cleaning the surface of the steel. This is accomplished by first degreasing the surface to be chemically machined with a commercially available chemical degreasing fluid such as Oakite 33. This degreasing fluid is, in turn, washed off the surface of the steel with a spray of demineralized water. The surface to be chemically machined is then thoroughly scrubbed with a slurry of pumice powder and water after which it is rinsed with a spray of demineralized water. The entire steel plate is then immersed in a tank of heated phosphoric acid to lightly phosphatize its surface and prepare it for coating with a metal etch resist such as K.M.E.R., a commercially available metal etch resist. The plate is then removed from the tank of phosphoric acid, again rinsed with demineralized water while wiping the surface with an absorbent cotton such as Photex manufactured by the Kendall Company to remove the smut formed thereon by the chemical reaction of the phosphoric acid with the steel and then blown dry with filtered compressed air which thus completes the first step of cleaning the surface of the steel plate which is to be chemically machined.

The next step is that of dip coating the steel plate into a tank of metal etch resist such as K.M.E.R. referred to above. The resist comprises 50 parts of K.M.E.R. and 50 parts of a commercially available thinner. FIG. 1 shows a steel plate **10** after it has been dip coated into a tank of metal etch resist. The metal etch resist **12** is shown only on one surface, surface **14** of steel plate **10** in FIG. 1. The metal etch resist **12** would also cover surface **16** of steel plate **10** when using a dip coating process such as is used in this embodiment. However, all of the drawings, FIGS. 1 through 8 inclusive are used to illustrate the chemical machining of one surface of steel plate **10** to produce an embossing plate or die. An alternative application would be to describe the steps heretofore described and those hereafter to be described for both sides **14** and **16** of steel plate **10** so that both sides of the plate could be chemically machined. This application could be used to produce a stencil for a particular design pattern. It should be noted that relative thicknesses of the elements of the drawings have been exaggerated to clearly show the different layers. Steel plate **10** is dip coated into the tank of metal etch resist, with end **18** entering the tank first. As the plate is removed from the tank, end **20** first, the resist **12** drains off sides **14** and **16** and dries thereon in a pyramid form of increasing thickness from end **20** to end **18** as shown in FIG. 1.

The metal etch resist **12** is then allowed to air-dry on side **14** of steel plate **10** while said plate is standing on end **18**. The time necessary to accomplish this air-drying step is dependent on several variables such as ambient temperature, relative humidity and the material being coated. For 1010 Low Carbon Steel, with an ambient room temperature of about 72° F. and about 30 percent relative humidity, an air-drying time of about 30 minutes is required.

After the resist **12** has sufficiently air-dryed, the plate **10** is heated in an oven within a temperature range of about 200° to 260° F. for a time in the range of about 15 to 45 minutes. After a sufficient time in the oven, the plate is removed and allowed to air-cool to ambient room temperature.

The air-cooled plate **10** is then placed on the lower member of a glass vacuum frame with the resist coated surface **14** which is to be chemically machined facing upward. As shown in FIG. 2, the photographic film negative **22** having clear area **24** and dark areas **26**, is positioned on surface **28** of resist layer **12** with the emulsion side of the film being in contact with said surface. Said film negative **22** has dark areas **26** masking those areas of resist **12** and the metal thereunder which eventually is to be chemically machined. Clear area **24** of film **22** overlays the area of resist **12** and the metal thereunder which is not to be chemically machined. The upper member of the vacuum frame is lowered into contact with the lower member of the vacuum frame so that a vacuum can be drawn therebetween. This vacuum causes the photographic film negative **22** to come into good contact with the surface **28** of resist **12** so that there is no space therebetween for diffused light when being exposed to a light source.

While the resist coated steel plate **10** and the overlying and contacting film **22** are still in the vacuum frame with the vacuum drawn, the etch resist **12** is exposed to a high power ultraviolet light source, such as a Xenon 8,000-watt arc box lamp. The resist **12** is exposed through film **22** to said light source for a time in the range of about 4 to 20 minutes. The metal etch resist **12** is photosensitive, and upon exposure to said light source, hardens and increases the bond of the resist to the surface **14** of plate **10** through a polymerizing and cross-linking action within said resist. Therefore, in FIG. 2, the resist **12** under the clear area **24** of film **22** becomes hardened and more thoroughly bonded to the metal, while those areas of resist **12** under areas **26** of film **22** which are not exposed to the light source do not become hardened and more thoroughly bonded to the metal surface **14**.

After being exposed to the light source the requisite amount of time, the light source is removed, the vacuum within the vacuum frame is relieved, and the lower and upper members of the vacuum frame are separated. The plate **10** is then removed from the vacuum frame and the photographic film negative **22** removed from the surface **28** of resist **12**.

Next, the steel plate **10**, having both exposed and unexposed areas of resist **12**, is immersed in a tank of developing fluid, such as a mixture of xylene and mineral spirits, to dissolve, and hence, to develop off the unexposed areas of resist **12** which had not become hardened and more thoroughly bonded to the plate by the light source. The plate remains immersed in the developing solution for a time in the range of about 15 seconds to 2.5 minutes.

Plate **10** is then removed from the development tank and rinsed with water to wash off any dissolved resist in sludge form which still remains on the surfaces **14** and **16** of the plate. Since the process is being described for a steel embossing plate, surface **16** of plate **10** was never exposed to the light source, and hence, the etch resist on this surface was completely developed off as was the etch resist on those areas of surface **14** of plate **10** which were under the dark areas **26** of film **22** and which were not exposed to the light source. After being rinsed with water, the plate is heated in an oven for about 10 to 20 minutes at a temperature in the range of about 200° to 260° F. to dry. After the plate has been heated for a sufficient length of time, it is removed from the oven and allowed to air-cool to ambient room temperature.

FIG. 3 illustrates the hardened and bonded resist **12** on plate **10** in that area which is not to be chemically machined. As can be seen in this figure, the resist **12** varies in increasing thickness from end **20** of plate **10** to end **18** thereof. If this were a large embossing plate or die of 5 feet or 6 feet between ends **18** and **20** and the plate were chemically machined at this point in the process, the resist **12** near end **20** would start to break down before the resist at end **18**. Therefore, there would be more undercutting of plate **10** at end **20** than there would be at end **18**. This, in turn, would mean a loss in fine detail and definition of the design pattern. Even if the distance between ends **20** and **18** were only about 1 foot, this loss of detail and definition would still be noticeable if chemically machined at this time. At end **20** where the resist is thinnest, there is also the possibility of the resist itself breaking down at surface **14** so as to give a pinhole or sandblasted effect to the area which should be smooth. Hence, to overcome these problems, several additional steps are performed on plate **10** before it is chemically machined in an etching solution.

The next step is the inverting of steel plate **10**, end for end, before re-dip coating it in the tank of K.M.E.R. metal etch resist described above, so that end **20** enters the tank first. Then, plate **10** is re-dip coated in the tank of K.M.E.R. As the plate **10** is removed from the tank of resist, there is an increasing buildup and pyramiding of the second resist coating **13** from the upper end **18** of plate **10** to the bottom and lower end **20** of plate **10**. However, since the first resist layer **12**, having a thickness decreasing from end **18** to end **20** was on the surface **14** of plate **10** at the time it was re-dip coated, the effect of the second resist layer **13** in combination with the already existing resist layer **12** is to give an even distribution and thickness of resist over approximately the entire surface **14** of plate **10**, and particularly, an even distribution of resist on that portion of surface **14** under the existing first resist layer **12**. The steel plate **10** having the combination of the hardened and bonded first resist layer **12** and the newly applied second resist layer **13** thereon is illustrated in FIG. 4.

After the re-dip coating step, the steel plate is removed from the tank of etch resist and allowed to air-dry. It should be noted that since the first resist layer 12 has been hardened and more thoroughly bonded to the surface 14 because of the exposure to the light source, the solvents of the commercial thinner which is mixed with the K.M.E.R. do not soften the first resist layer 12 or weaken its bond to surface 14 of steel plate 10.

The recoated plate is then heated in an oven having a temperature in the range of about 200° to 260° F. for a time in the range of about 20 to 40 minutes to more thoroughly dry the second resist layer 13. After the second resist layer has sufficiently dried, it is removed from the oven and allowed to air-cool to ambient room temperature.

The steel plate is then placed on the lower member of the glass vacuum frame. As illustrated in FIG. 5, the same photographic film negative 22 shown in FIG. 2 and having clear area 24 and dark areas 26 is positioned on surface 30 of the second resist layer 13. The upper member of the glass vacuum frame is then lowered into contact with the lower member of the vacuum frame, and a vacuum is drawn therebetween. The second resist layer 13 is then exposed to the high power light source as described above through photographic film negative 22. The second resist layer under the clear area 24 of film 22, having been exposed to said light source, has become hardened and more thoroughly bonded to the surface 28 of the first resist layer 12. The areas of second resist layer 13 under the dark areas 26 of film 22, not having been exposed to said light source, have not become hardened and more thoroughly bonded to the surface 14 of steel plate 10.

After the second layer of resist has been exposed to the light source for a sufficient length of time, the vacuum between the lower and upper members of the vacuum frame is relieved; the upper member of the vacuum frame is raised out of contact with the lower member of the vacuum frame; and the plate 10 is removed from the lower member of the vacuum frame. At this point, the photographic film negative 22 is removed from the surface 30 of the second resist layer 13. The plate is then placed in the tank of developing solution as described above for the first developing step, to develop off those areas of the second resist layer 13 which were under the dark areas 26 of film 22 and were not exposed to the light source, and hence, were not hardened or more thoroughly bonded to metal surface 14.

After the steel plate 10 has been immersed in the developing tank for sufficient time to develop off those unhardened and less thoroughly bonded areas of the second resist layer 13, the plate is removed from said tank and rinsed with water to wash off any dissolved resist in sludge form which may still remain on the surfaces of plate 10. As illustrated in FIG. 6, the resultant hardened and bonded metal etch resist layer 32 comprising the combination of the first resist layer 12 and the second resist layer 13 which overlies said first resist layer, has an even distribution throughout its entire area and the required thickness to prevent rapid undercutting and breakdown of the resist during the chemical machining of the steel plate 10. After rinsing with water, the plate having the double layer of hardened and bonded resists thereon is placed in an oven having a temperature in the range of about 200° to 260° F. for a time in the range of approximately 10 to 20 minutes to thoroughly dry. After the steel plate has sufficiently dried, it is removed from the oven and allowed to air-cool to ambient room temperature.

The next step after air-cooling to ambient room temperature is to adhesively tape a plastic sheet film such as Du Pont's Mylar, which is resistant to the corrosive action of the chemical etching solution, such as ferric chloride for steel, onto the surface 16 of the steel plate 10 which surface is not to be chemically machined. An electroplating tape such as 3M Company's pressure sensitive tape No. 470 which is also resistant to the corrosive action of the chemical etching solution is used to fasten said film to the steel plate 10.

Next, the steel plate 10, with the surface 14 which is to be chemically machined facing downward, is passed through the etching chamber of a conventional stray-type etching machine to start the chemical machining of the metal. After the first pass through the etching chamber is completed, a second, third, fourth and as many additional passes as are necessary to achieve a desired depth of etch are made through the etching chamber of the chemical etching machine. In this manner, the desired depth of etch is achieved while maintaining fine detail, good definition and close tolerances for the pattern of the design figure without the need for any recoating steps between the consecutive passes through the etching chamber of the chemical etching machine.

When the desired depth of etch, such as 0.036 inch, has been attained for a particular design figure in the embossing plate or die, the chemical machining for this particular design figure is stopped. This is illustrated in FIG. 7 where the ends 18 and 20 of the steel embossing plate or die 10 have been chemically machined to a desired depth for a particular design figure while the metal under the resultant resist layer 32 has been protected by said resist layer, and hence, has not been chemically machined.

After the steel plate 10 has been chemically machined to a desired depth of etch, the acid resistant film and tape on the side of the plate which was not being chemically machined is removed from the plate. The plate 10 is then immersed in a tank of a commercially available stripping solution such as Oakite, Stripper SA which strips the resultant hardened and bonded metal etch resist layer 32 off surface 14 of steel plate 10. After being immersed for a sufficient time to strip off the resist layer 32, the plate is removed from the stripping tank, rinsed with high pressure water, and blown dry with compressed air. Any of the etch resist layer 32 which is still adhering to surface 14 of steel plate 10 after the preceding stripping operation is removed by hand. The finished chemically machined steel embossing plate or die 10 having the desired depth of etch at ends 18 and 20 is illustrated in FIG. 8. As noted previously, the above-described chemical machining process, which has been described and illustrated for only one surface of a steel plate to produce an embossing plate or die, can very easily be adapted to produce stencils by utilizing the above-described process on both sides of a metal plate and cutting completely through the plate.

What is claimed is:

1. A method of chemically machining a metal comprising the steps of cleaning the metal, coating the metal with a layer of resist, drying said resist layer, positioning a film having at least one clear and one opaque area on the surface of the resist-coated metal to be chemically machined, exposing the film-covered resist layer to an energy source to harden and increase the bond of a predetermined area of the resist coating to the metal, developing off the resist coating from that area of the metal which has not been exposed to said energy source, recoating the metal and at least one area of hardened and bonded resist remaining thereon with a second layer of resist, drying said second resist layer, repositioning said film on the surface of said second resist layer, exposing this film-covered second resist layer to an energy source to harden said second resist layer adhered to said first resist layer, developing off the second layer of resist coating from that area of the metal which has not been exposed to said energy source and thereby leaving at least one area of metal having a double layer of hardened and bonded resist thereon, then chemically machining said metal area not coated with resist using a chemical etching solution, the steps of coating with a resist are accomplished by dipping the metal endwise into a resist, and between the first dip coating step and the second dip coating step, the metal is inverted end for end so that the double coating of resist has an even distribution over the surface of the metal.

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