Jan. 13, 1959 F. A. MONAHAN 2,867,929

METHOD AND APPARATUS FOR CHEMICALLY BORING METALLIC MATERIAL

Filed Dec. 20, 1956

FIG. 1

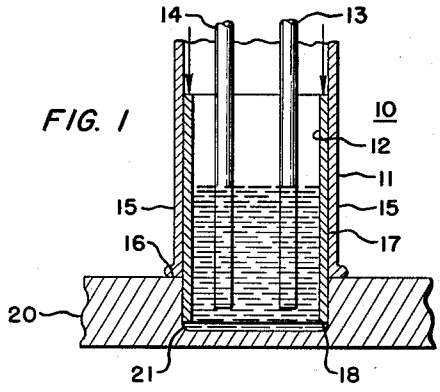


FIG. 2

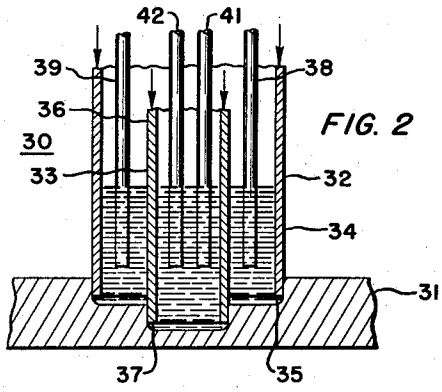


FIG. 3

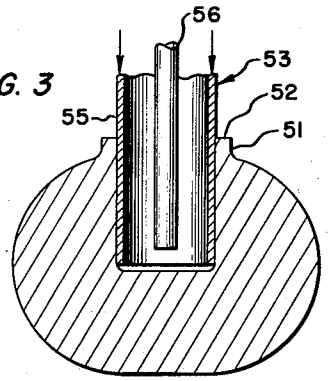


FIG. 4

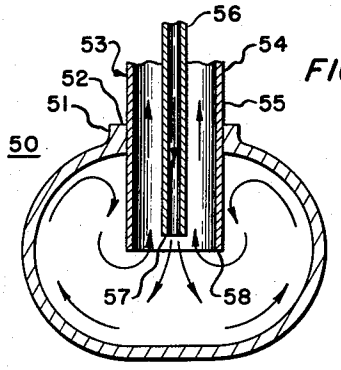


FIG. 5

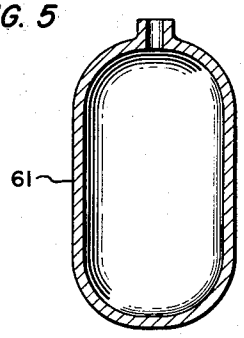


FIG. 6

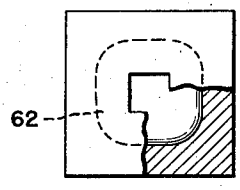
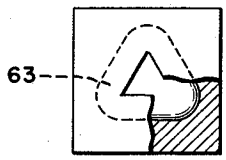


FIG. 7



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2,867,929

Patented Jan. 13, 1959

2,867,929

METHOD AND APPARATUS FOR CHEMICALLY BORING METALLIC MATERIAL

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Application December 20, 1956, Serial No. 629,598

8 Claims. (Cl. 41—9)

The present invention relates generally to the chemical etching of metallic material and more particularly to a novel method and apparatus for chemically boring or forming holes, recesses, apertures, cavities or other openings in a metallic work-piece.

An object of the present invention is to provide an improved method and apparatus for confining and directing a chemical agent to a desired area of a metallic work-piece for the formation of an opening therein.

Another object of this invention is to provide novel means for limiting the action of a chemical etchant to a particular area of a work-piece for the formation of an opening of a desired configuration and size therein, the depth of which opening may be controlled.

Another object of this invention is to provide improved means for mechanically outlining a desired area of a metallic work-piece which is to be subject to the action of a chemical etchant for forming an opening at such area.

Another object of this invention resides in providing a novel chemical etchant boring device within which a chemical etchant is circulated in the formation of a bore in a metallic body.

Another object of this invention lies in providing a boring device of the character above which is adapted to form enlarged cavities of desired configurations in a metallic body and which works through an opening of relatively small size in the metallic body.

Another object of this invention is to provide a chemical etchant boring device of unique construction which is capable of performing a plurality of operations at a desired area of a work-piece such as boring and counterboring at the same time.

Other objects and features of the present invention will be readily apparent to those skilled in the art from the following specification and appended drawings wherein is illustrated a preferred form of the inveniton, and in which:

Figure 1 is a cross-sectional view of a hole-forming apparatus embodying the present invention and shown in operative position on a work-piece for forming a hole therein through the action of a chemical agent.

Figure 2 is a cross-sectional view of a modification of this invention which serves to chemically bore and counterbore a work-piece in a single operation.

Figure 3 is a cross-sectional view of a form of chemical etchant boring device embodying the present invention and shown in connection with a solid metallic body within which the boring device has formed an axial bore as the first step in providing an enlarged cavity within the metallic body.

Figure 4 is a cross-sectional view similar to Figure 3 but illustrating an enlarged cavity formed by the boring device within the metallic body; and

Figures 5, 6 and 7 are illustrations of typical configurations which may be achieved with the use of the present invention.

Referring now to Figure 1 of the drawings, there is shown a boring or hole forming device, indicated generally in its entirety by the numeral **10**, which is an example of apparatus intended by the present invention. Boring device **10** comprises an outer sleeve or guide member **11** within which a hollow shield member **12** is telescopically positioned for slidable movement relative to sleeve **11**. A supply conduit **13** and an exhaust conduit **14** extend into and communicate with the interior of shield member **12** to provide a circulating supply of chemical etchant within shield member **12**. A usual etchant reservoir and suitable pumping means, not shown, are associated with the conduits **13** and **14** for effecting continuous circulation of a chemical etchant to and from the shield **12** and thus assuring uniformity in etchant solution strength and stabilizing the rate of advance of shield **12** in a boring operation.

Sleeve **11** and shield **12** conform in cross-sectional outline one to the other to permit the free movement of shield **12** within sleeve **11**. Sleeve **11** comprises defining walls **15** having lower edge surfaces **16** and shield **12** comprises defining walls **17** having lower edge surfaces **18**, the function of which edge surfaces will be discussed hereinafter.

Sleeve **11** and shield **12** are made of any suitable material which is resistant to the action of the chemical etchant. Such material may be molded rubber or plastic or metal which has been treated with an etchant resistant coating such as a resistant lacquer or an impervious plastic or any other commercially available masking material.

The etchant employed in the present invention may be any suitable etchant. The particular etchant employed will, of course, be that which is adapted for etching the particular metal to be chemically bored. If the metal is aluminum, for example, then a caustic such as sodium hydroxide may be used. The present invention is not concerned with the particular composition of the etchant which might be employed and contemplates the use of any etchant available which will effect the desired result. Also the present invention is intended for use with any of the metals which are adapted to be etched, such as aluminum, magnesium, steel or titanium.

As shown in Figure 1, the boring device **10** has been applied to a metallic work-piece, indicated by the numeral **20**, and has formed a cavity therein. To effect a boring operation, the respective edge surfaces **16** and **18** of the lower ends of sleeve **11** and shield **12** must be of a shape to adapt them to be placed in intimate contact with the surface of the work-piece within which a cavity or opening is to be formed. If, for example, the surface of the work-piece is flat, as is the surface of work-piece **20** shown in Figure 1, then edge surfaces **16** and **18** of sleeve **11** and shield **12** are also flat. If the work-piece is of curved configuration then the edge surfaces **16** and **18** which will bear on the work-piece will be so formed that intimate contact is obtained. Affording an intimate contact of edge surfaces **16** and **18** with the work-piece prevents leakage of the etchant and assures that the etching action will be in the proper direction.

After the boring device **10** has been applied to the surface of work-piece **20** at the area which is to be bored sleeve **11** is held in place by any suitable clamping means, not shown, and the chemical etchant is introduced into hollow shield member **12** and circulation of the etchant begun. Simultaneously with the introduction of the chemical etchant into shield **12** pressure is evenly applied to shield member **12** at its upper end through the agency of any suitable pressure apparatus, not shown, which apparatus may be of pneumatic, hydraulic, spring or other usual character. The particular construction of the pres-

sure apparatus does not form a part of the present invention since any usual, suitable pressure device or arrangement is contemplated.

The etchant confined in shield **12** by the intimate contact of surfaces **16** and **18** acts through the lower open end of the shield upon the surface of the work-piece **20** in the area outlined by the defining walls **17** of shield **12** and undercuts the material of the work-piece immediately below the flat edge surfaces **18** of shield **12** as at **21**. Under the suitable pressure applied to shield **12** it advances downwardly into the undercut at a rate equivalent to the chemical eroding action of the etchant on the work-piece **20**. It is apparent that the advance of shield **12** into work-piece **20** results in the formation of a smooth surfaced bore or cavity **21** since the vertical walls of the shield **12** protect and shield the surfaces already etched from further attack by the etchant.

Any desired depth of cavity **21** may be formed in work-piece **20** since merely by stopping the flow of etchant to the shield and pumping out the etchant already present therein any further chemical boring operation is halted. At the bottom of the cavity which is formed in the work-piece there will be a slight fillet formed by the undercutting action of the etchant. This fillet, it is found, will have a radius equal to that of the undercut and the undercut will be equal to the thickness of the shield walls at the lower surfaces **18**. It is apparent that if different radii fillets are desired it is a matter only of selecting a proper thickness for the walls of shield **12** at their lower edge surfaces. If it is desired to completely pierce the work-piece such may be done by permitting the etchant to erode through the undersurface of the work-piece and providing a container to accept the etchant as it breaks through.

It is apparent that the outline configuration of the cavity formed in the work-piece by the chemical etchant is the same as the peripheral outline of shield **12** along its bottom edges **17**. Thus if a circular cavity is to be bored in the work-piece then a shield is used whose bottom edges define a circle. If the opening is to be square in cross-section then the bottom edges must define a square. Accordingly, being aware of the cross-sectional configuration desired for a cavity it is necessary only to provide a shield which has its peripheral edges shaped into the same configuration and to provide an outer sleeve **11** which is also appropriately shaped to accept the shield **12** for relative movement therebetween. If desired, sleeve **11** could be omitted and reliance placed entirely on the intimate contact of edge surface **18** with the work-piece to prevent leakage of the etchant. Sleeve **11** serves primarily as a guide to make it easier to obtain proper downward movement of shield **12**, it adds stability particularly when small bored shields **12** are used for boring small cavities but it does not assist the etchant in the actual boring of a cavity.

Figure 2 illustrates an embodiment of the invention for effecting a plurality of boring operations, the particular operations here being the forming of a bore and a counterbore. The boring device of this embodiment is indicated in its entirety generally by the numeral **30** and is shown in operative position on a work-piece **31**. Boring device **30** comprises two shields **32** and **33** each of which acts to effect a boring operation. Shield **32**, as shown, is of larger width than is shield **33** and comprises defining walls **34** having lower edge surfaces **35** adapted to bear on the surface of a work-piece. Shield **33** fits within shield **32** and has its defining walls **36** spaced from the defining walls **34** of shield **32**. Shield **33** similarly to shield **32** has lower edge surfaces **37** which are adapted to act upon the work-piece. Lower edge surfaces **35** and **37**, it is understood will conform in shape to the work-piece surface to which they are applied to effect intimate contact therewith just as in the case of edge surfaces **18** of shield **12** of the first embodiment.

As with shield **12** of the first embodiment shields **32** and **33** will bore cavities of any desired configurations, it being merely a matter of forming the shields so that their peripheral edge surfaces **35** and **37** have outlines conforming to the required configurations of the cavities to be formed.

Shield **33** may be axially or eccentrically positioned relative to shield **32** as dictated by the desired relative locations of the counterbore and the bore to be formed; the location of shield **33** within shield **32** will not impede or interfere with the boring operation of either.

Associated with shield **32** are a pair of conduits **38** and **39** leading from suitable pumping apparatus and an etchant reservoir, not shown, and associated with shield **33** are a pair of conduits **41** and **42** which are also connected by suitable pumping apparatus to the etchant reservoir. The conduits **38** and **39** provide the chemical etchant which is circulated within shield **32** in the area thereof between the inner surfaces of its walls **34** and the outer surfaces of walls **36** of shield **33**. Conduits **41** and **42** provide a circulating supply of the chemical etchant within shield **33** in the interior space defined by its walls **36**.

Suitable pressure means are associated with each of the shields **32** and **33** and provide pressure to such shields during the time that etchant is confined within these shields.

In the operation of boring device **30** etchant may be introduced first into inner shield **33** and pressure applied thereto to bore a cavity conforming in cross-section to the outline configuration of lower edge surfaces **37** thereof. The boring operation here is the same as that described in connection with the shield **12** of the first embodiment. As the etchant undercuts the material of the work-piece **31** beneath the edge surfaces **37** shield **33** moves downwardly under the pressure applied thereto and effects a smooth sided cavity. After shield **33** has been in operation a predetermined length of time in accordance with the requirements of the specific job to be performed, etchant is circulated within outer shield **32** and pressure applied thereto to urge it into the bore effected by the eroding action of the etchant. Both shields **32** and **33** will remain in operation for such time as is required to effect the desired depth dimensions of the bore and counterbore. With proper control of the solution strength of the etchants in shields **32** and **33** and control of the exposure time of the etchants on the outlined areas of the work-piece accurate depth dimensions of both bore and counterbore are readily achieved.

If desired, both shields **32** and **33** could be placed into operation at the same time with a higher strength solution of chemical etchant being circulated in the inner shield **33** whereby shields **32** and **33** will bore their respective cavities at different rates. As each shield effects the desired depth of bore the etchant supply thereto is shut off and the etchant pumped therefrom to stop any further boring operation. Also, if desired, both shields **32** and **33** could be operated at the same time and with the same strength etchant therein but the supply to outer shield **32** will be shut off first when the proper depth of bore is effected. Circulation of etchant is continued in inner shield **33** until the desired depth of counterbore is obtained and thereafter the etchant supply is removed.

Figures 3 and 4 illustrate a form of the present invention for hollowing a solid metallic body. As an example of the typical body which may be worked by the present invention a solid body substantially in the form of a sphere is selected, which is indicated generally by the numeral **50** in Figure 4. Sphere **50** has a generally cylindrical projection **51** thereon having a flat surface **52**. The boring device for hollowing sphere **50** is indicated by the numeral **53** and comprises an outer cylindrical shield **54** having positioned within its defining walls **55** a tubular member **56** generally axially disposed relative thereto. The lower end of the walls **55** of outer shield **54** have edge surfaces **58** conforming in shape to surface **52** of sphere **50** for intimate contact therewith. The

lower end **57** of tubular member **56**, as shown, is spaced inwardly from the plane of the lower end of outer shield **54**. Etchant is supplied to tubular member **56** from a reservoir by suitable pumping apparatus conveniently connected thereto, not shown, and withdrawn from the boring device **53** by way of the outer shield **54** which is also suitably connected to pumping apparatus to return the etchant to the reservoir. The particular pumping apparatus and the particular connecting conduits from the shield **54** and tubular member **56** form no part of this invention. Any suitable arrangement for effecting movement of etchant into boring device **53** and withdrawal therefrom is contemplated for use.

In operation the boring device **53** is positioned on sphere **50** with the lower edge surfaces **58** thereof in intimate contact with surface **52** of the sphere **50**. As with the other boring devices above described, pressure from any suitable device conveniently associated with boring device **53** is applied to the boring device as etchant is circulated within the device. The etchant fed to device **53** works on the material of the sphere underlying the open end of shield **54** and undercuts beneath edge surfaces **58** whereby boring device **53** moves downwardly under the pressure applied thereto to form a bore within the sphere conforming in outline to the outline of the boring device **53**. Thus the boring operation here is the same as the boring operations of the two boring devices above described.

This boring operation is continued until a smooth-sided vertical bore is formed in the sphere to a depth substantially equal to one-half the diameter of the cavity desired in the sphere. Upon reaching the desired depth, boring device **53** is suitably restrained in a static position but the circulation of the chemical etchant is continued. The etchant is permitted to continue its attack on the material of the sphere until such time as a spherical concavity, as shown in Figure 4, of the desired dimensions has been eroded. The supply of etchant is cut off and the boring device **53** is then withdrawn and the chemical etchant which may be present is suitably evacuated and the cavity flushed with a suitable neutralizing fluid to prevent further chemical attack. Knowing the strength of the chemical etchant and the etching rate, the operator can readily effect internal cavities of desired dimensions within the sphere.

It is apparent that with boring device **53** various shaped concavities may be formed within a solid body. it is merely a matter of selecting a desired outline for the boring device, properly advancing the device by a boring operation into a body to a desired depth then holding it for the appropriate time to complete a desired cavity formation. It is here also noted that if desired the solid metallic body may be first provided with a bore formed to a desired depth by the use of conventional machinery and thereafter the boring device **53** inserted and etchant circulated to complete the operation.

Figure 5 illustrates a flask-type body **61** which may be effected by use of the boring device **53**. Figure 6 shows a cavity **62** of generally square outline which can be produced by use of a boring device **53** which is square in cross-section. Figure 7 illustrates a generally triangular in cross-section cavity **63** which may be formed by use of a boring device **53** which has a triangular cross-sectional outline. Thus with appropriate selections of the outline configuration of boring device **53** and by use of etchants whose etching rate is known an operator can effectively and accurately form cavities of desired configurations and dimensions in any solid metallic body.

The present invention affords a ready and efficient method for boring cavities in metallic work-pieces and in forming cavities of desired configurations within solid bodies. Tasks can be performed which would be very difficult and expensive to accomplish with the use of conventional milling machinery. Further, with conventional methods it is necessary to employ extremely skilled machinists to achieve concavities which are simple to obtain with the invention herein described. The present invention is well adapted to production work since the boring device may be used over and over again. Also if a number of similar openings, bores, or cavities are required to be formed in a single member then a gang of boring devices may be assembled and operated in unison.

Boring operations with the present apparatus are simple to carry out. Having knowledge of the solution strength and the etching rate of the etchants being used an operator with an appropriately shaped boring device can readily produce openings, bores, or cavities of desired depth, size, and/or configuration and with a minimum of time devoted to surveillance.

While certain preferred embodiments of the present invention have been shown and described, variations will be readily apparent to those skilled in the art and the invention is to be given its broadest possible interpretation within the terms of the following claims:

What I claim is:

1. Apparatus for forming an opening in a metallic work-piece by the use of a chemical etchant, said apparatus comprising a container having an opening through its lower end, said container having wall members and edge surfaces on said wall members defining said opening and arranged in a desired configuration, said edge surfaces adapted to be pressed upon the surface of a work-piece to outline an area of said surface to be subject to the action of a chemical etchant, said edge surfaces conforming in contour to the contour of the surface where pressed thereagainst for intimate contact between said edge surfaces and said work-piece surface, and conduit means projecting into said container for affording a circulating supply of chemical etchant within said container, said chemical etchant adapted to operate through said opening in said container to erode the surface of the work-piece outlined by said edge surfaces and to undercut material of the work-piece in the areas beneath said edge surfaces to permit progressive movement of said container wall members into said undercut areas.

2. A device for forming openings in a metallic work-piece by the use of a chemical etchant, said device comprising a first bodily movable member, a second bodily movable member positioned within said first bodily movable member, each of said bodily movable members having a chamber therewithin and having wall portions arranged to define openings of predetermined configurations at like ends of said members, said wall portions at said openings terminating in peripheral edge surfaces adapted to be pressed upon the surface of a work-piece to outline areas of said surface to be subject to the action of a chemical etchant, said peripheral edge surfaces of said first and second movable members conforming in contour to the contour of the surface where such edge surfaces are pressed thereagainst for intimate contact therebetween, and conduit means leading to said first and second movable members for affording a supply of chemical etchant within each of said movable members, said chemical etchant adapted to operate through said openings in said movable members to erode the areas of the work-piece surface outlined by the peripheral edge surfaces of said movable members and to undercut material of the work-piece in the areas beneath said edge surfaces to permit progressive movements of the wall members of said first and second movable members into said undercut areas.

3. A device for forming openings in a metallic work-piece by the use of a chemical etchant, said device comprising a first bodily movable member, a second bodily movable member co-axially positioned within said first bodily movable member, each of said bodily movable members formed of material impervious to a chemical etchant and each having a chamber therewithin and having wall portions arranged to define openings of prede-

termined configurations at like ends of said members, the wall portions of said second movable member being radially spaced from the wall portions of said first movable member, said wall portions at said openings terminating in peripheral edge surfaces adapted to be pressed upon the surface of a work-piece to outline areas of said surface to be subject to the action of a chemical etchant, said peripheral edge surfaces of said first and second movable members conforming in contour to the contour of the surface where such edge surfaces are pressed thereagainst for intimate contact therebetween, and conduit means extending within the chambers of said first and second movable members for affording a circulating supply of chemical etchant within each of said movable members, said chemical etchant adapted to operate through said openings in said movable members to erode the areas of the work-piece surface outlined by the peripheral edge surfaces of said movable members and to undercut material of the work-piece in the areas beneath said edge surfaces to permit individual progressive movements of the wall members of said first and second movable members into said undercut areas.

4. Apparatus for use in forming a cavity in a metallic work-piece with a chemical etchant, said apparatus comprising a bodily movable member formed of material impervious to a chemical etchant, said movable member having a chamber therein and comprising wall portions arranged to define an opening of desired configuration, said wall portions terminating in peripheral edge surfaces arranged to define an end opening of desired configuration, said edge surfaces adapted to be placed in intimate contact with the surface of a work-piece to outline an area of said surface to be subject to the action of a chemical etchant, and a conduit projecting into said movable member for supplying chemical etchant to said movable member which chemical etchant is movable into and through the chamber thereof, said chemical etchant adapted for eroding action upon the area of work-piece surface underlying said end opening of said movable member and for undercutting the material of said work-piece beneath said peripheral edge surfaces, said movable member serving as a conduit for withdrawal of said etchant.

5. Apparatus for use in forming a cavity in a metallic work-piece with a chemical etchant, said apparatus comprising a bodily movable hollow cylindrical member formed of material impervious to a chemical etchant, said cylindrical member having an annular open end and edge surfaces surrounding said annular open end adapted to be placed in intimate contact with the surface of a work-piece to outline a circular area of said surface to be subject to the action of a chemical etchant, and a tubular member projecting within said cylindrical member and spaced from the inner wall surfaces thereof for supplying chemical etchant into said cylindrical member for passage therethrough, said chemical etchant adapted for eroding action upon the area of work-piece surface underlying said open end of said cylindrical member and for undercutting the material of said work-piece beneath said edge surfaces of said cylindrical member, said cylindrical member serving as a conduit for withdrawal of said etchant.

6. The method of chemically forming a cavity within a solid metallic body comprising the providing of a boring device having a chamber therewithin and an end opening with peripheral edge surfaces in surrounding relationship thereto, placing said boring device upon said metallic body with the edge surfaces thereof in intimate contact with said metallic body, circulating a supply of chemical etchant through said boring device for eroding action through the end opening thereof upon the surface area of the metallic body positioned beneath said boring device, applying pressure to said boring device to progressively advance it into a bore formed beneath the boring device by the eroding action of the chemical etchant, withdrawing pressure from said boring device and halting movement thereof after a bore of predetermined depth has been formed, holding said boring device in its halted position, and continuing circulation of said chemical etchant to continue the eroding action thereof within said solid body until a cavity of desired dimensions is formed.

7. The method of forming a cavity internally of a solid metallic body by the use of a chemical etchant comprising the providing of a hollow movable body having an opening of desired configuration at one end and peripheral edge surfaces in surrounding relationship to said opening, placing said movable body upon said solid metallic body with the edge surfaces thereof in intimate contact with said solid metallic body, circulating a supply of chemical etchant through said movable body for eroding action through the end opening thereof upon the surface area of the metallic body positioned beneath said movable body, applying pressure to said movable body to progressively advance it into an etched opening having an outline configuration conforming to the configuration of said end opening of the movable body, withdrawing pressure from said boring device and halting movement thereof after a predetermined depth of opening has been formed, holding said movable body in its halted position, and continuing circulation of said chemical etchant to form a cavity within said solid body having a configuration substantially conforming to the configuration of the etched opening.

8. The method of forming a cavity within a solid metallic body by the use of a chemical etchant comprising the providing of a movable body of desired configuration with a chamber therein and with an opening at one end and peripheral edge surfaces in surrounding relationship to said opening, placing said movable body with its edge surfaces resting within an opening in said solid body of desired depth and conforming to the outline of said movable body, circulating a supply of chemical etchant through said movable body for eroding action through the end opening thereof upon the material of the solid body positioned beneath said end opening, and continuing circulation of said chemical action for a predetermined period of time to form a cavity of desired dimensions and having an outline configuration conforming substantially to the outline configuration of the movable body.

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