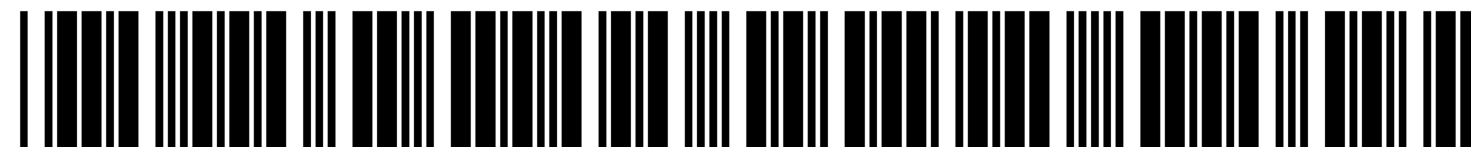
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(54) **STAMPING TOOL, CASTING MOLD AND METHODS FOR STRUCTURING A SURFACE OF A WORK PIECE**

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**Related U.S. Patent Documents**

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USPC .......................................... **428/141**; 428/156

(58) **Field of Classification Search**
USPC ................................ 428/141, 156, 167, 172
See application file for complete search history.

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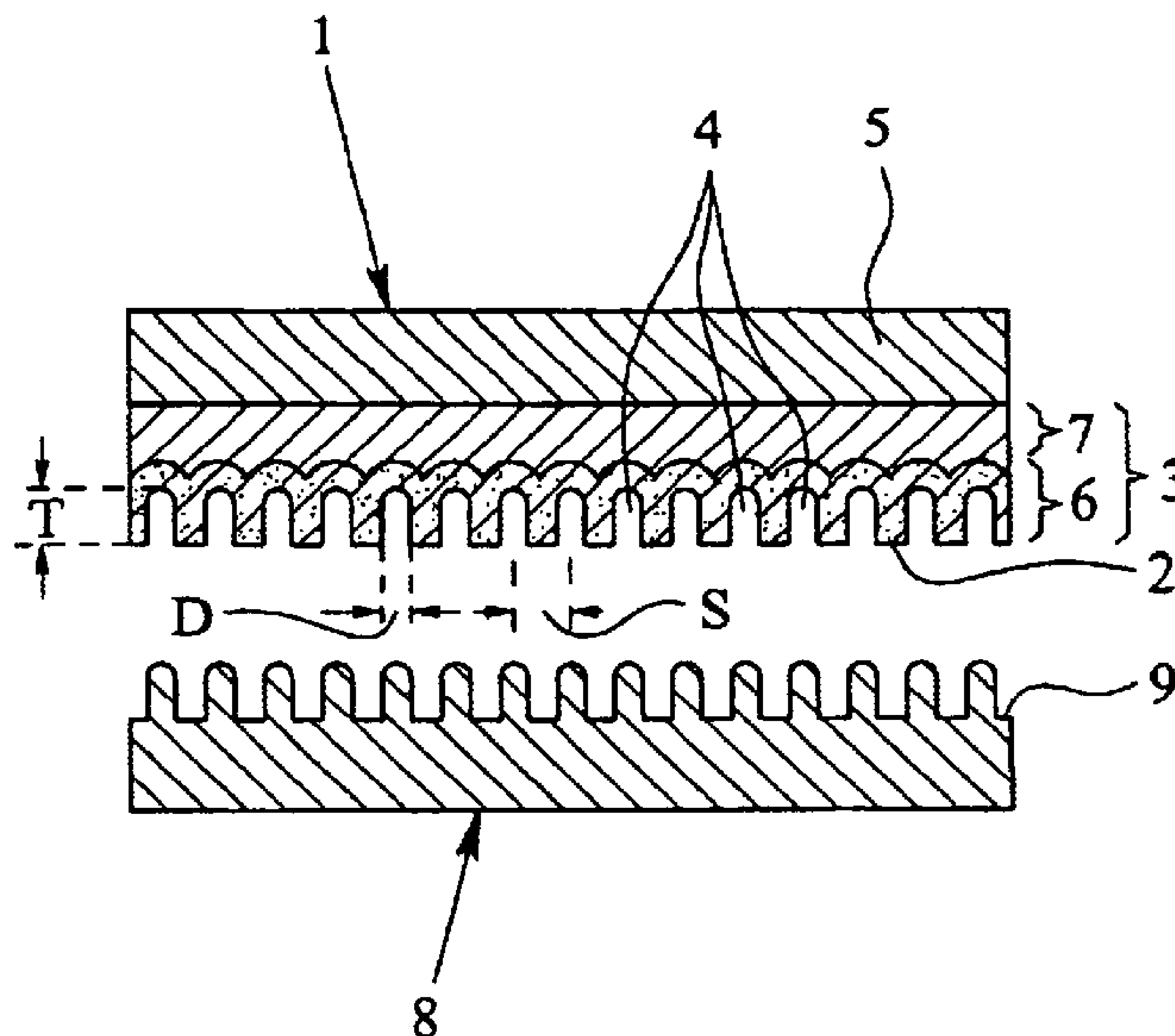
(57) **ABSTRACT**

A simple, cost-effective stamping or molding in the nanometer range is enabled using a stamping surface or molding face with a surface layer having hollow chambers that have been formed by anodic oxidation.

**33 Claims, 2 Drawing Sheets**



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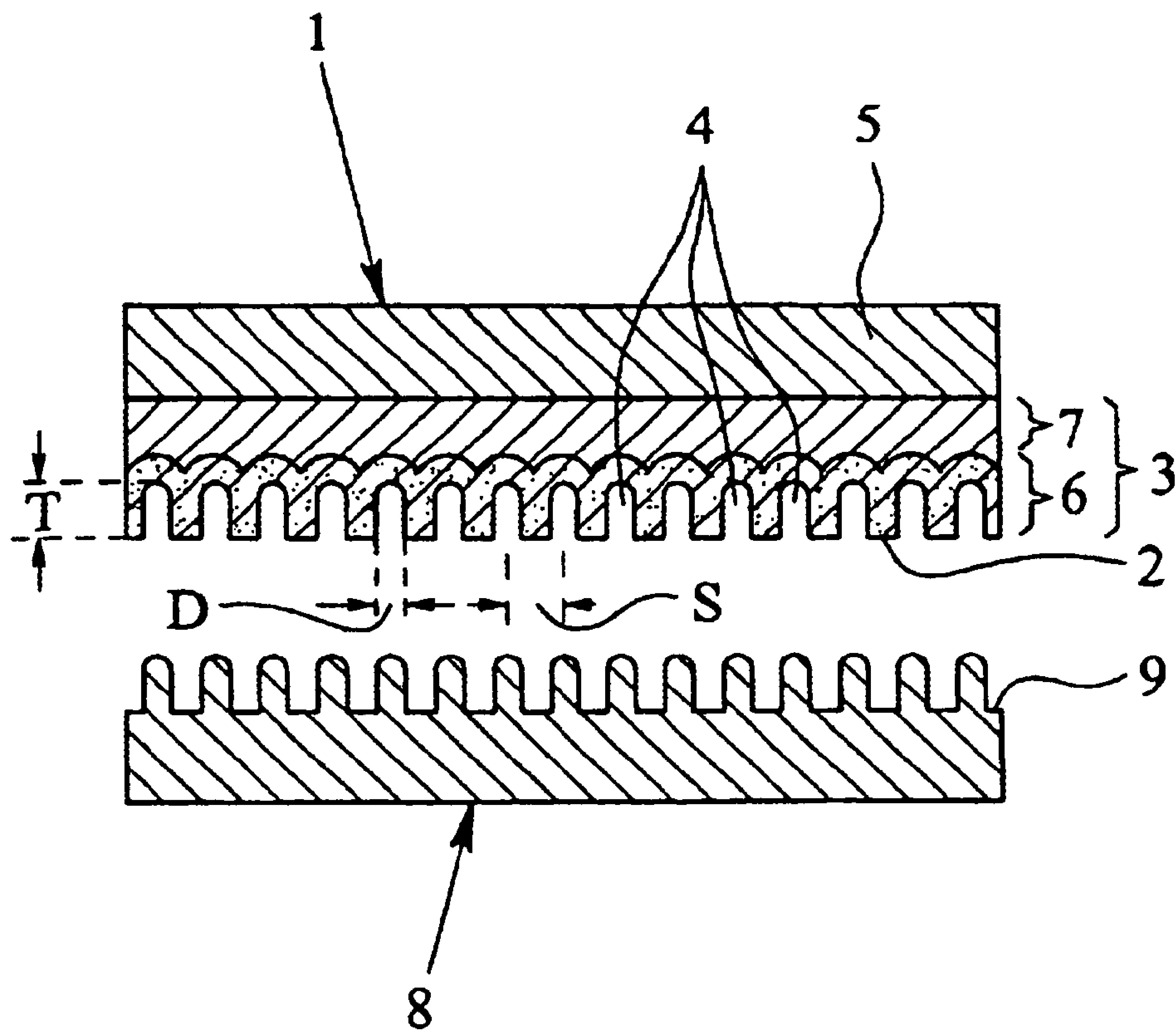



Fig. 1

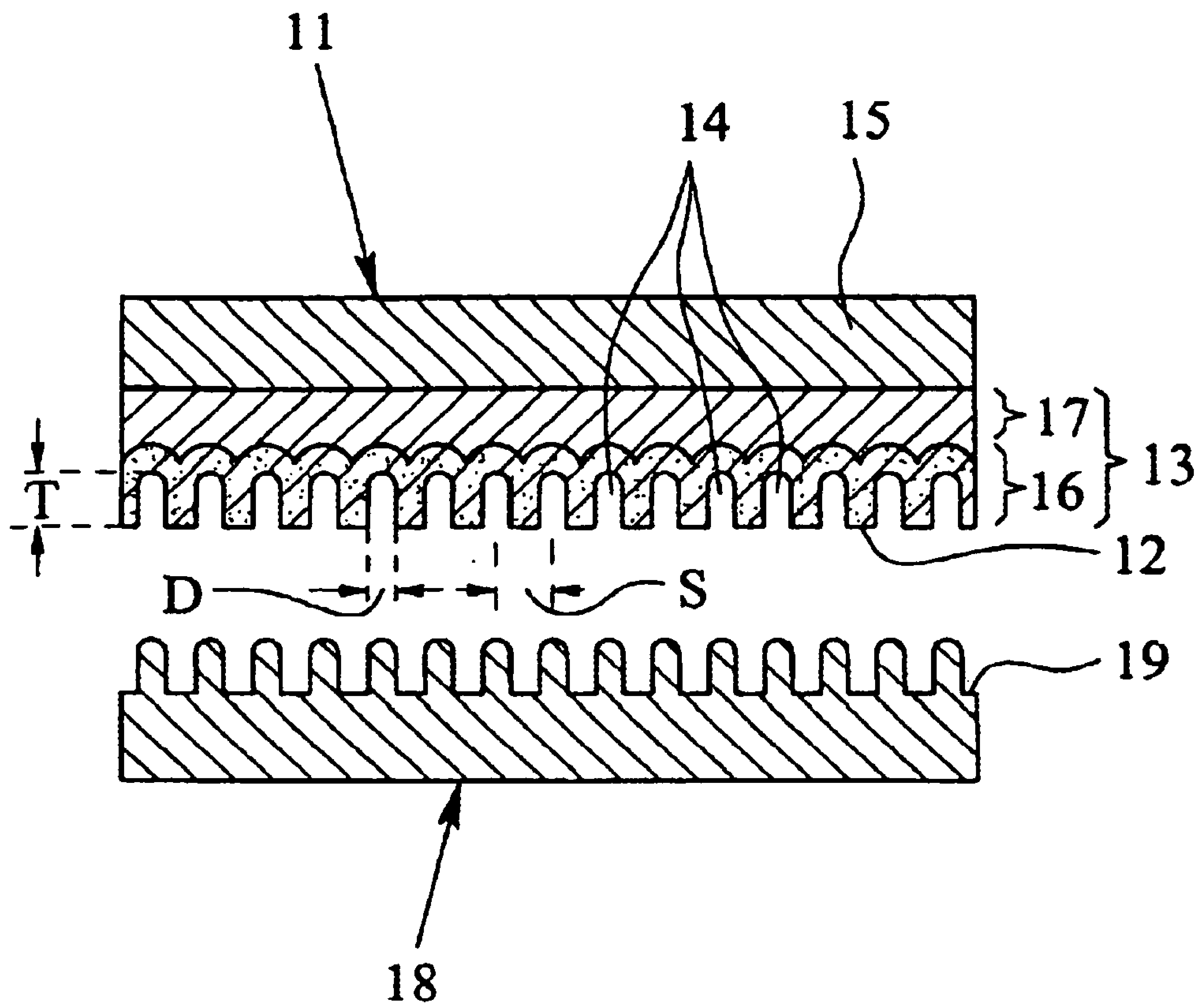



Fig. 2

# STAMPING TOOL, CASTING MOLD AND METHODS FOR STRUCTURING A SURFACE OF A WORK PIECE

**Matter enclosed in heavy brackets [ ] appears in the original patent but forms no part of this reissue specification; matter printed in italics indicates the additions made by reissue.**

*Notice: This application is a reissue divisional of application Ser. No. 12/213,990, which is an application for reissue of U.S. Pat. No. 7,066,234. More than one reissue application has been filed for the reissue of U.S. Pat. No. 7,066,234. In particular, three applications for reissue of U.S. Pat. No. 7,066,234 have been filed. The reissue applications are application Ser. No. 12/213,990 filed on Jun. 26, 2008 and a divisional reissue of the broadening reissue of U.S. Pat. No. 7,066,234 (Ser. No. 12/213,990) filed on Apr. 28, 2010 (the present application), and a continuation reissue of the broadening reissue of U.S. Pat. No. 7,066,234 (Ser. No. 12/213,990) filed on Apr. 28, 2010 (the serial number of which is unknown).*

## CROSS-REFERENCE TO RELATED APPLICATIONS

This application is a continuation-in-part of International Patent Application No. PCT/EP02/07240 filed Jul. 1, 2002, which designated the United States and of International Patent Application No. PCT/EP01/04650 Apr. 25, 2001 which designated the United States.

## BACKGROUND OF THE INVENTION

1. Field of the Invention

The present invention relates to a stamping tool having a structured stamping surface, a casting mold, a method for producing a stamping tool or a casting mold having a structured stamping surface, and methods for structuring a surface of a work piece.

2. Description of Related Art

Stamping constitutes a non-cutting manufacturing method for producing a relief-like or structured surface on a work piece. A stamping tool with a profiled or structured stamping surface is used for this. The stamping surface is pressed with such a stamping force onto the surface to be structured of the work piece or rolled on it, so that the work piece becomes plastic and flows into depressions in the stamping tool or the stamping surface. Due to the considerable stamping forces employed, the stamping tool and the stamping surface are usually made of metal.

Further, molding is known. A casting mold with a structured molding face can be used for producing a cast work piece with a structured surface by casting.

In the present invention, nanometer range is understood to mean profiling or structuring with structural widths of less than 1000 nm, especially of less than 500 nm. The structural width designates the dimension by which individual structural elements, such as bumps, are repeated, that is, for example, the average distance of adjacent bumps from one another or of depressions from one another.

It is very expensive to manufacture a stamping tool with a very finely structured or profiled stamping surface. To create a so-called "moth eye structure"—evenly arranged, egg carton-like bumps—or fine grooves in the nanometer range, it is



known from practice to use a lighting pattern with periodic intensity modulation for illuminating photosensitive material via two interfering laser beams. After the illuminated material develops, a periodic surface structure results, which is molded into other materials using various replication methods and finally into nickel, for example, by electroforming. This type of manufacturing is very expensive and is suited only for structuring even surfaces.

In the nanometer range, lithographic methods for structuring a stamping surface of a stamping tool can still only be used in a limited way. It should be noted here that the wavelength of the visible light alone is already 400 to 750 nm. In each case, lithographic methods are very costly.

German Patent DE 197 27 132 C2 discloses the manufacturing of a stamping tool by means of electrolytic machining. During electrolytic machining, a metallic stamping surface of the stamping tool is treated electrolytically, wherein, being an anode in a fast-flowing electrolyte, the metal of the stamping surface is located at a minimal distance opposite a cathode and is dissolved in surface terms. The metal or the stamping surface contains the structure determined by the form of the cathode, and the cathode thus forms a recipient vessel that is shaped electrochemically. German Patent DE 197 27 132 C2 also provides the use of a cylindrical rotation electrode, whose covering surface presents a negative form of the desired stamping structure. Here, too, there is considerable expense involved and structuring in the nanometre range is at least only partly possible.

The use of anodally oxidized surface layers made of aluminum or magnesium in casting molds to increase resistance is known from Swiss Patent CH 251 451. However, the forming of hollow chambers by oxidation for structuring a molded article in the nanometer range is not disclosed.

Forming hollow chambers by anodic oxidation of aluminum is described in published European Patent Application EP 0 931 859 A1, for example.

However, the related art does not provide a cost-effective solution to production of a work piece, like a stamped piece, or casting with a surface structured in the nanometer range.

Consequently, there is a need for a stamping tool, a casting mold, a method for manufacturing a stamping tool or a casting mold, a method for structuring a surface of a work piece and a method for using a surface layer provided with open hollow chambers, wherein structuring in the nanometer range is enabled in a simple and cost-effective manner.

## SUMMARY OF INVENTION

A primary object of the present invention is to provide a stamping tool, a casting mold, a method for manufacturing a stamping tool or a casting mold, a method for structuring a surface of a work piece and a method for using a surface layer provided with open hollow chambers, wherein structuring in the nanometer range is enabled in a simple and cost-effective manner.

One aspect of the present invention is to use a porous oxide layer, and especially a surface layer, formed via anodic oxidation and provided with open hollow chambers, as stamping surface of a stamping tool. This leads to several advantages.

First, an oxide layer, especially the preferably provided aluminum oxide, is relatively hard. With respect to the often very high stamping forces, this is an advantage for being able to stamp work pieces of various materials and for achieving a long tool life of the stamping tool.

Second, model-free oxidation is very easy and cost-effective to carry out. In particular, producing hollow chambers is (quasi) independent of the form and configuration of the

cathodes employed, so a model or negative form is not required, as in electrolytic machining.

Third, the provided model-free forming of open hollow chambers via anodic oxidation enables structures to be manufactured in the nanometer range very easily and cost-effectively. In particular, structural widths of 500 nm and less, even 100 nm and less are possible.

Fourth, depending on choice of procedural conditions the configuration—regular or irregular—and the surface density of the hollow chambers can be varied as required.

Fifth, likewise, by simply varying the procedural conditions—especially by variation of the voltage during anodizing—the form of the hollow chambers, and thus, the structure of the stamping surface, can be adjusted and varied.

Sixth, the anodally oxidized surface layer can be used directly, thus without further molding, as the stamping surface of a stamping tool.

A further aspect of the present invention is to use a porous oxide layer, and especially a surface layer with open hollow chambers, formed by anodic oxidation directly or model-free, thus independent of a cathode form, as molding face or inner face of a casting mold. This has a number of advantages.

First, an oxide layer, especially the preferably provided aluminum oxide, is relatively hard. With respect to the often very high forces utilized in casting or molding, this is an advantage for being able to produce work pieces of various materials and for achieving a long shelf life of the casting mold.

Second, the model-free oxidation is very easy and cost-effective to carry out. Producing hollow chambers is (quasi) independent on the form and configuration of the cathodes used, and a model or negative form is therefore not required.

Third, the model-free forming of open hollow chambers as provided via anodic oxidation enables structures to be manufactured in the nanometer range very easily and cost-effectively. In particular, structural widths of 500 nm and less, even 100 nm and less are possible.

Fourth, depending on choice of procedural conditions the configuration—regular or irregular—and the surface density of the hollow chambers can be varied as required.

Fifth, likewise, by simply varying the procedural conditions—especially by variation of the voltage during anodizing—the form of the hollow chambers, and thus, the structure of the surface can be adjusted and varied.

Sixth, the anodally oxidized surface layer can be used directly, thus without further molding, as the surface of a casting mold.

Further advantages, properties, features and goals of the present invention will emerge from the following description of preferred embodiments with reference to the drawings.

## BRIEF DESCRIPTION OF THE DRAWINGS

FIG. **1** is a very schematic sectional elevation of a stamping tool and a work piece structured therewith according to a first embodiment; and

FIG. **2** is a very schematic sectional elevation of a proposed casting mold and a work piece structured therewith according to an second embodiment.

## DETAILED DESCRIPTION OF THE INVENTION

In a highly simplified sectional elevation, FIG. **1** shows a proposed stamping tool **1** with a structured, i.e., profiled or relief-like, stamping surface **2**. The stamping surface **2** is formed by a side of a surface layer **3** which is provided with open hollow chambers **4** produced by anodic oxidation or an originally flat surface.

In the illustrative example, the surface layer is applied to a support **5** of the stamping tool **1**. For example, the surface layer **3** is applied to the support **5** by plasma coating. However, the surface layer **3** can also be formed directly by the support **5**, and thus can be a surface area of the support **5**.

It is understood that the surface layer **3** can also be deposited on the support **5** using other methods.

In the illustrative example, the surface layer **3** preferably is made of aluminum which is applied to the support **5**, especially via plasma coating, and adheres well to the support **5**, which is preferably made of metal, especially iron or steel.

The surface layer **3** is at least partially anodally oxidized in the illustrative example, to the depth of a covering layer **6**, whereby the hollow chambers **4** are formed in the surface layer **3**. The hollow chambers **4** are formed immediately and/or without any model or pattern, i.e., the arrangement, distribution, form and the like of the hollow chambers **4**—as opposed to electrolytic machining—is, thus, at least essentially independent of the surface shape and the proximity of the cathode (not shown) used in oxidation. Moreover, according to the invention, the "valve effect," namely the occurring, independent formation of hollow chambers **4** during oxidation or anodization of the surface layer **3**—at least in particular in the so-called valve metals—is used. This immediate or undefined formation of the hollow chambers **4** does not preclude an additional (before or after) formation or structuring of the stamping surface **2** or the hollow chambers **4** by means of a negative form.

Depending on how completely or how deeply the surface layer **3** is oxidized, or whether the surface layer **3** is formed directly by the support **5**, the surface layer **3** can correspond to the oxidized covering layer **6**. In this case, for example, the intermediate layer **7**, which is comprised of aluminum in the illustrative example, and which promotes very good adhesion between the covering layer **6** and the support **5**, can be omitted.

For example, according to an alternative embodiment, the uncoated support **5** can be oxidized anodally on its surface forming the stamping surface **2** by formation of a porous oxide layer or hollow chambers **4**. This is possible, for example, for a support **5** made of iron or steel, especially stainless steel. In this case, the surface layer **3** then corresponds to the covering layer **6**, i.e., the oxidized layer.

Aluminum and iron or steel, especially stainless steel, have already been named as particularly preferred materials, used at least substantially for forming the anodally oxidized surface layer **3** or the covering layer **6**. However, silicon and titanium as well as other valve metals, for example, can also be used.

In the illustrative example, the proportions in size are not presented true to scale. The stamping tool **1** or its stamping surface **2** preferably has a structural width S in the nanometer range, especially from 30 to 600 nm and preferably from 50 to 200 nm.

The hollow chambers **4** or their openings have an average diameter D of essentially 10 to 500 nm, preferably 15 to 200 nm and especially 20 to 100 nm.

In the illustrative example, the hollow chambers **4** are designed essentially lengthwise, wherein their depth T is preferably at least approximately 0.5 times the above-mentioned, average diameter D and especially approximately 1.0 to 10 times the diameter D.

Here, the hollow chambers **4** are designed at least substantially similarly in shape. In particular, the hollow chambers **4**

are designed substantially cylindrically. However, the hollow chambers **4** can also present a form deviating therefrom, for example, they can be designed substantially conically.

In general, the hollow chambers **4** can also have a cross-section varying in its depth T, form and/or diameter. In addition to this, the hollow chambers **4** can be designed substantially conically as a rough structure, for example, and can be provided along their walls with many fine depressions (small hollow chambers) to fonts a fine structure in each case.

The hollow chambers **4** are preferably distributed at least substantially uniformly over the surface of the surface layer **3** or over the stamping surface **2**. However, uneven distribution is also feasible.

The hollow chambers or their openings are preferably distributed over the stamping surface **2** with a surface density of $10^9$ to $10^{11}/cm^2$. In the illustrative example, the surface density is substantially constant over the stamping surface **2**. However, the surface density can also vary partially on the stamping surface **2** as required.

The area of the openings of the hollow chambers **4** is, at the most, preferably 50% of the extension area of the stamping surface **2**. A sufficiently high stability or carrying capacity of the stamping surface **2** or the surface layer **3**/covering layer **6** is hereby achieved with respect to the high stresses arising during the stamping.

In general, the form, configuration, surface density and the like of the hollow chambers **4** can be controlled by corresponding choice of the procedural conditions during anodic oxidation. For example, with oxidation of aluminium under potentiostatic conditions—with at least substantially constant voltage—an at least substantially even cross-section of the hollow chambers **4** is achieved over their depth T, i.e., an at least substantially cylindrical form. Accordingly, the form of the hollow chambers **4** can be influenced by varying the voltage. For example, galvanostatic oxidation—i.e., at an at least substantially constant current—leads to a somewhat conical or hill-like form of the hollow chambers **4**, so that a type of "moth eye structure" or the like can be formed in this way. The surface density of the hollow chambers **4**, i.e., the number of hollow chambers **4** per surface unit of the stamping surface **2**, depends inter alia on the voltage and the current during anodizing.

As required, the hollow chambers **4** can vary in their form, depth and/or surface density over the stamping surface **2**, especially partially, and/or be designed only partly on the stamping surface **2**.

If required, the stamping surface **2** can also be modified before and/or after oxidation—creation of the hollow chambers **4**—for example, via a lithographic process, etching and/or other, preferably material-stripping methods, for example, to create a rough structure in the form of paths, ridges, areas with or without hollow chambers **4**, large-surface bumps or depressions and the like on the stamping surface **2**.

Chemical sizing, especially by partial etching of oxide material, can also be carried out to modify the stamping surface **2** or the hollow chambers **4**. In this way, the surface ratio of the opening surfaces of the hollow chambers **4** to the extension area of the stamping surface **2** can be varied or increased. It is understood that other modifications of the stamping surface **2** or of the hollow chambers **4** can also be made, depending on reaction time and intensity.

A particular advantage of the proposed solution is that the stamping surface **2** can also be designed in a curved manner, for example, cylindrically, bulged, lenticular, or hemispherical. In particular, the stamping surface **2** can have practically any shape at all. Compared to the prior art, it is thus not necessary that the stamping surface **2** or the surface of the surface layer **3**/covering layer **6** is at least substantially even.



The figure also shows a work piece **8**, likewise in a highly simplified, not true-to-scale, sectional diagram, in the already stamped state, i.e., with a surface **9** already structured by the stamping tool **1**. Stamping takes places especially by the stamping tool **1** being pressed with a corresponding stamping force onto the surface **9** of the work piece **8** to be structured, so that the material of the work piece **8** flows at least partially into the hollow chambers **4**. Here, it is not necessary that the work piece **8**, as illustrated diagrammatically in the figure, is designed in a monobloc manner. Instead, the work piece **8** can also present another type of surface layer or surface coating or the like, not illustrated here, which forms the surface **9** and is structured or designed in a relief-like manner by means of the stamping tool **1**.

Instead of the stamp-like embossing, the stamping tool **1** can be unrolled with corresponding shaping/form of the to stamping surface **2** and/or the surface **9** to be structured. By way of example, the stamping surface **2** and/or the surface **9** to be structured can be designed in a curved manner—for example, cylindrically—or in a bulged manner, to enable reciprocal unrolling for structuring the surface **9**.

Both a die stamping process and also a rolling stamp process can be realized with the proposed solution.

Furthermore, the proposed solution can be used for embossing as well as closed-die coining or coining. A corresponding abutment for the work piece **8** or a corresponding countertool is not illustrated for clarification purposes.

The proposed stamping tool **1** allows very fine structuring of the work piece **8** or its surface **9**. If needed, the work piece **8** or the surface **9** can also be profiled or structured repeatedly, first with a rough structured stamping tool—optionally manufactured also in customary fashion—and then with the finer structured stamping tool **1** proposed here. A lower stamping force is employed, especially during the second stamping procedure using the finer stamping tool **1** and/or, in an intermediate step, the surface **9** is hardened in order not to fully neutralize the rough structure produced at first stamping, but to achieve superposition from the rough structure and the fine structure of both stamping tools. Thus, it is possible, for example, to create on the surface **9** relatively large bumps of the order of 0.1 to 50 μm, each with several, relatively small protrusions, for example, of the order of 10 to 400 nm, on the surface **9** of the work piece **8**.

The proposed solution very easily and cost-effectively enables very fine structuring of the surface **9**. Accordingly, there is a very broad area of application. For example, such especially very fine structuring can be utilized in anti-reflex layers, for altering radiation emission of structured surfaces, in sensory analysis, in catalysis, in self-cleaning surfaces, in improving surface wettability and the like. In particular, the proposed solution also extends to the use of work pieces **8** with structured surfaces **9** that have been structured by use of the proposed stamping tool **1** for the purposes mentioned hereinabove.

In particular, the proposed solution is suited for stamping synthetic materials—for example, PMMA (polymethyl methacrylates), Teflon or the like, metals—for example, gold, silver, platinum, lead, indium, cadmium, zinc or the like, polymer coatings—for example, paints, dyes or the like, and inorganic coating systems etc.

Expressed in general terms, an essential aspect of the present invention according to the first embodiment is using a surface layer with hollow chambers formed by anodic oxidation as a bottom die or upper die, to enable surface structuring in the nanometer range.

Now, the second embodiment of the present invention is discussed with reference to FIG. **2**.

In a highly simplified partial sectional elevation, FIG. **2** shows a proposed casting mold **11** with an at least partially structured, thus profiled or relief-like inner face or molding face **12**. The face **12** is formed by a top or flat side of a surface layer **13** that is provided with open hollow chambers **14** produced by anodic oxidation.

In the illustrative example, the surface layer **13** is applied to a support **15** of the casting mold **11**. For example, the surface layer **13** is applied to the support **15** by plasma coating. However, the surface layer **13** can also be formed directly by the support **15**, and thus can be a surface area of the support **15**.

It is understood that the surface layer **13** can also be deposited on the support **15** using other methods.

In the illustrative example, the surface layer **13** preferably comprises aluminum, which is applied to the support **15** especially via plasma coating, and adheres well to the support **15** that is preferably made of metal, especially iron or steel.

The surface layer **13** is at least partially anodally oxidized, in the illustrative example, to the depth of a covering layer **16**, by means of which the hollow chambers **14** are formed in the surface layer **13** or covering layer **16**. The hollow chambers **14** are formed directly or model-free, that is, the configuration, distribution, form and the like of the hollow chambers **14** is, compared to electrolytic machining, therefore at least substantially dependent on the surface shape and proximity of the cathodes (not illustrated here) used during oxidation. Rather, the 'valve effect' is made use of here, as per the invention, namely the automatic development of the hollow chambers **14** occurring during oxidation or anodizing of the surface layer **13**, at least especially with so-called valve metals. Such direct and model-free production of the hollow chambers **14** does not exclude additional (prior or subsequent) forming or structuring of the face **12** or of the hollow chambers **14** by a negative form.

Depending on how completely or how deeply the surface layer **13** is oxidized, or whether the surface layer **13** is formed directly by the support **15**, the surface layer **13** can correspond to the oxidized covering layer **16**. In the illustrative example, in this case, for example, the intermediate layer **17**, which is comprised of aluminum and which promotes very good adhesion between the covering layer **16** and the support **15**, can be omitted.

For example, according to a design alternative the uncoated support **15** can be oxidized anodally on its surface forming the face **12** by formation of a porous oxide layer or hollow chambers **14**. This is possible for example, for a support **15** made of iron or steel, especially stainless steel. In this case the surface layer **13** then corresponds to the covering layer **16**, i.e., the oxidized layer.

Aluminum and iron or steel, especially stainless steel, have already been named as particularly preferred materials, used at least substantially for forming the anodally oxidized surface layer **13** or the covering layer **16**. However, silicon and titanium as well as other valve metals for example, can also be used.

In the illustrative example, the proportions in size are not presented true to scale. The face **12** preferably has a structural width S in the nanometer range, especially of 130 to 600 nm and preferably of 50 to 200 nm. The hollow chambers **14** or their openings have an average diameter D of essentially 10 to 500 nm, preferably 15 to 200 nm and especially 20 to 100 nm.

In the illustrative example, the hollow chambers **14** are designed essentially lengthwise, wherein their depth T is preferably at least approximately 0.5 times the above-mentioned, average diameter D and especially approximately 1.0 to 10 times the diameter D.

The hollow chambers **14** are designed, here, at least substantially identically. In particular, the hollow chambers **14** are designed substantially cylindrically. However, the hollow chambers **14** can also present a form deviating therefrom, for example, they can be designed substantially conically.

In general the hollow chambers **14** can also have a cross-section varying in its depth T in form and/or diameter. In addition to this, the hollow chambers **14** can be designed substantially conically as a rough structure, for example, and can be provided with many fine depressions (small hollow chambers) along their walls to form a fine structure in each case.

The hollow chambers **14** are preferably distributed at least substantially uniformly over the surface of the surface layer **13** or over the face **12**. However, uneven distribution is also feasible.

The hollow chambers or their openings are preferably distributed with a surface density of $10^9$ to $10^{11}$/cm. In the illustrative example, the surface density is substantially constant over the face **12**. However, the surface density can also vary selectively on the surface **12** as required.

The area of the openings of the hollow chambers **14** is at the most preferably 50% of the extension area of the face **12**. A sufficiently high stability or carrying capacity of the face **12** or the surface layer **13**/covering layer **16** is thereby achieved with respect to the high stresses arising partially from molding or casting.

In general, the form, configuration, surface density and the like of the hollow chambers **14** can be controlled by corresponding choice of the procedural conditions during anodic oxidation. For example, with oxidation of aluminium under potentiostatic conditions—i.e., at least at substantially constant voltage—an at least substantially uniform cross-section of the hollow chambers **14** is achieved over their depth T, i.e., an at least substantially cylindrical form. Accordingly, the form of the hollow chambers **14** can be influenced by varying the voltage. For example, galvanostatic oxidation, i.e., at an at least substantially constant current, leads to a somewhat conical or hill-like form of the hollow chambers **14**, so that a type of "moth eye structure" or the like can be formed in this way. The area density of the hollow chambers **14**, i.e., the number of hollow chambers **14** per area unit on the face **2**, depends inter alia on the voltage and the current during anodizing.

As required, the hollow chambers **14** can vary in their form, depth and/or surface density over the face **2**, especially partially, and/or be designed only partially on the face **12**.

And, if required, the face **12** can also be modified before and/or after oxidation—thus, creation of the hollow chambers **14**—for example, via a lithographic process, etching and/or other, preferably material-stripping methods, for example, to create a rough structure in the form of paths, ridges, areas with or without hollow chambers **14**, large-surface bumps or depressions and the like on the face **12**.

Mechanical processing and/or chemical sizing, especially by partial etching of oxide material, can also be carried out to modify the face **12** or the hollow chambers **14**. In this way, the area ratio of the opening areas of the hollow chambers **14** to the extension area of the face **12** can be varied or increased. It is understood that other modifications of the face **12** or of the hollow chambers **14** can also be made, depending on reaction time and intensity.

A particular advantage of the proposed solution is that the face **12** can also be designed in practically any shape at all.

The figure also shows a molded article or work piece **18**, likewise in a highly simplified, not true-to-scale, sectional diagram, in the already finished state, i.e., with a surface **19** already structured by the casting mold **11** after casting.

The proposed casting mold **11** allows very fine structuring of the work piece **18** or its surface **19**. It is possible, for example, to create relatively large bumps of the order of 0.1 to 50 μm each with several, relatively small projections on the surface **19**, for example, of the order of 10 to 400 nm, on the surface **19** of the work piece **18**.

The proposed solution very easily and cost-effectively enables very fine structuring of the surface **19**. Accordingly, there is a very broad area of application. For example, such especially very fine structuring can be utilized in anti-reflex layers, for altering radiation emission of structured surfaces, in sensory analysis, in catalysis, in self-cleaning surfaces, in improving surface wettability and the like.

Expressed in general terms, an essential aspect of the present invention is casting or molding a surface layer with hollow chambers formed directly or model-free by anodic oxidation, to enable surface structuring in the nanometer range.

The present invention is especially not limited to a casting mold **11** in the narrower sense. Rather, the surface layer **13** or covering layer **16** is to be understood as model for a general structuring of a surface, a tool, a work piece or the like in the nanometer range. In particular, the model may be molded in any way at all. In particular, no reshaping is required when molding. For example, with the work piece **18** to be manufactured having a structured surface **19**, this can be a cast article, wherein the surface **19** is structured by casting or decanting or any molding of the mold **11**.

In general, the present invention enables a simple, cost-effective stamping or molding in the nanometer range by a surface layer with hollow chambers formed by anodic oxidation being used as matrix or as casting mold.

## TECHNICAL APPLICABILITY

The proposed solution very easily and cost-effectively enables very fine structuring of the surface. Accordingly, there is a very broad area of application. For example, such especially very fine structuring can be utilized in anti-reflex layers, for altering radiation emission of structured surfaces, in sensory analysis, in catalysis, in self-cleaning surfaces, in improving surface wettability and the like. In particular, the proposed solution also extends to the use of work pieces with structured surfaces that have been structured by use of the proposed stamping tool for the purposes mentioned hereinabove. Further, the proposed solution can be used for casting with practically any material, since aluminum oxide especially is highly resistant mechanically, thermally and/or chemically.

What is claimed is:

[**1**. Method for producing a stamping tool with a structured stamping surface, comprising the steps of:

oxidizing a surface or covering layer of the stamping tool for forming the stamping surface at least partially anodally and forming open hollow chambers that are at least essentially uniformly shaped and at least essentially evenly distributed over the surface or surface area of the stamping surface without the use of a model.]

[**2**. Method according to claim **1**, wherein the surface or covering layer is oxidized potentiostatically.]

[**3**. Method according to claim **1**, wherein the surface layer or covering layer is oxidized with varying voltage.]

[**4**. Method according to claim **3**, wherein the surface or covering layer is oxidized galvanostatically.]

[**5**. Method according to claim **1**, wherein the surface or covering layer that is oxidized is formed of a material selected from the group consisting of aluminum, silicon, iron, steel and titanium.]

[**6**. Method according to claim **1**, comprising the additional step of modifying the stamping surface at least one of before and after said oxidizing step for producing a rough structure.]

[**7**. Method for structuring a surface of a work piece in a nanometer range by means of a stamping tool with a structured stamping surface, comprising at least one of pressing and rolling a stamping surface, formed of an anodally oxidized surface or covering layer with open hollow chambers which have diameters in a nanometer range that have been created model-free by anodic oxidation, onto the surface to be structured.]

[**8**. Method according to claim **7**, wherein the surface is first roughly structured in a first step by means of a first stamping tool and then is finely structured by means of a second stamping tool in a second step.]

[**9**. Method according to claim **8**, wherein the surface is finely structured by means of said second stamping tool in said second step with a stamping force that is reduced relative to that applied with said first stamping tool.]

[**10**. Method according to claim **8**, wherein the surface is finely structured by means of said second stamping tool in said second step after hardening of the surface structured by said first step.]

[**11**. Method for at least partially structuring a surface of a cast work piece, comprising the steps of: casting the work piece using a casting mold with a structured molding face having an anodally oxidized surface or covering layer with open hollow chambers created model-free by anodic oxidation.]

[**12**. Method according to claim **11**, wherein the surface or covering layer is formed at least substantially of a material selected from the group consisting of aluminum oxide, silicon oxide, iron oxide, oxidized steel, and titanium oxide.]

*13. An anti-reflection surface, comprising:*

*a surface including at least one of projections of diameters in a nanometer range, and hollow chambers including diameters in a nanometer range, wherein the at least one of projections and hollow chambers on the anti-reflection surface are irregularly distributed, and wherein groups of the projections form larger projections of an order ranging from 0.1-50 micrometers, the larger projections including a surface having additional projections of 10-400 nm.*

*14. The anti-reflection surface according to claim 13, wherein the surface comprises an anodically oxidized material selected from the group consisting of aluminum, silicon, iron, steel and titanium.*

*15. The anti-reflection surface of claim 13, wherein the hollow chambers include diameters ranging from 10-500 nanometers.*

*16. The anti-reflection surface of claim 15, wherein the hollow chambers include diameters ranging from 15-200 nanometers.*

*17. The anti-reflection surface of claim 16, wherein the hollow chambers include diameters ranging from 20-100 nanometers.*

*18. The anti-reflection surface of claim 13, wherein the projections include diameters ranging from 10-400 nanometers.*

*19. A device, comprising the anti-reflection surface of claim 13.*

*20. A workpiece, comprising the anti-reflection surface of claim 13.*

*21. A device, comprising a workpiece, wherein the anti-reflection surface of claim 13 is a surface of the workpiece.*

*22. The anti-reflection surface of claim 13, wherein the projections include irregularly shaped projections.*

*23. The anti-reflection surface of claim 13, wherein the projections are of a somewhat conical shape.*

*24. The anti-reflection surface of claim 13, wherein the hollow chambers are irregularly shaped hollow chambers.*

*25. The anti-reflection surface of claim 13, wherein the hollow chambers are of a somewhat conical shape.*

*26. The anti-reflection surface of claim 13, wherein the anti-reflection surface is formed from an acrylic resin.*

*27. The anti-reflection surface of claim 26, wherein the acrylic resin is PMMA.*

*28. The anti-reflection surface of claim 13, wherein the hollow chambers include structural widths ranging from 30-600 nanometers.*

*29. An anti-reflection surface, comprising:*

*a surface including at least one of projections and hollow chambers distributed over the surface at a density of* $10^9$ *to* $10^{11}/cm^2$*, wherein the at least one of projections and hollow chambers have a substantially conical shape.*

*30. The anti-reflection surface according to claim 29, wherein the anti-reflection surface is formed of an anodically oxidized material selected from the group consisting of aluminum, silicon, iron, steel and titanium.*

*31. The anti-reflection surface of claim 29, wherein the hollow chambers of the anti-reflection surface includes diameters ranging from 10-500 nanometers.*

*32. The anti-reflection surface of claim 31, wherein the hollow chambers include diameters ranging from 15-200 nanometers.*

*33. The anti-reflection surface of claim 32, wherein the hollow chambers include diameters ranging from 20-100 nanometers.*

*34. The anti-reflection surface of claim 29, wherein the projections include diameters ranging from 10-400 nanometers.*

*35. The anti-reflection surface of claim 34, wherein groups of the projections form larger projections of an order ranging from 0.1-50 micrometers.*

*36. A device, comprising the anti-reflection surface of claim 29.*

*37. A workpiece, comprising the anti-reflection surface of claim 29.*

*38. A device, comprising a workpiece, wherein the anti-reflection surface of claim 29 is a surface of the workpiece.*

*39. The anti-reflection surface of claim 29, wherein the hollow chambers of the anti-reflection surface includes irregularly distributed hollow chambers.*

*40. The anti-reflection surface of claim 29, wherein the anti-reflection surface includes irregularly shaped hollow chambers.*

*41. The anti-reflection surface of claim 29, wherein the anti-reflection surface includes irregularly distributed projections.*

*42. The anti-reflection surface of claim 29, wherein the anti-reflection surface includes irregularly shaped projections.*

*43. The anti-reflection surface of claim 29, wherein the anti-reflection surface is formed from an acrylic resin.*

*44. The anti-reflection surface of claim 43, wherein the acrylic resin is PMMA.*

*45. The anti-reflection surface of claim 29, wherein the anti-reflection surface includes hollow chambers with structural widths ranging from 30-600 nanometers.*

* * * * *

# UNITED STATES PATENT AND TRADEMARK OFFICE
# CERTIFICATE OF CORRECTION



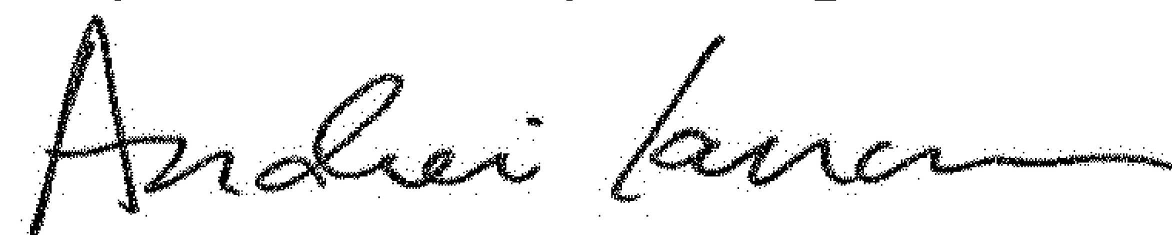
PATENT NO. : RE44,830 E
APPLICATION NO. : 12/662682
DATED : April 8, 2014
INVENTOR(S) : Sawitowski

It is certified that error appears in the above-identified patent and that said Letters Patent is hereby corrected as shown below:

In the Specification

At Column 1, replace Lines 12-28 (approx.) in their entirety and the portion of Line 29 (approx.) that includes the words "This application," with the following:
--*CROSS-REFERENCE TO RELATED APPLICATIONS*
*NOTICE: More than one reissue application has been filed for the reissue of U.S. Patent No. 7,066,234 B2. The reissue applications are U.S. Reissue Patent Application Serial Nos. 12/662,683 and 12/662,682 (the present application), each filed on April 28, 2010, now U.S. Reissue Patent Nos. RE46,606 E and RE 44,830 E, respectively, issued November 14, 2017 and April 8, 2014, respectively, which are a continuation reissue application and a divisional reissue application, respectively, of U.S. Reissue Patent Application Serial No. 12/213,990, filed on June 26, 2008, now U.S. Reissue Patent No. RE43,694 E, issued October 2, 2012, which is a reissue application of U.S. Patent Application No. 10/281,376, filed October 28, 2002, now U.S. Patent No. 7,066,234 B2, issued June 27, 2006, which*--

Signed and Sealed this
Twenty-second Day of September, 2020



Andrei Iancu
*Director of the United States Patent and Trademark Office*