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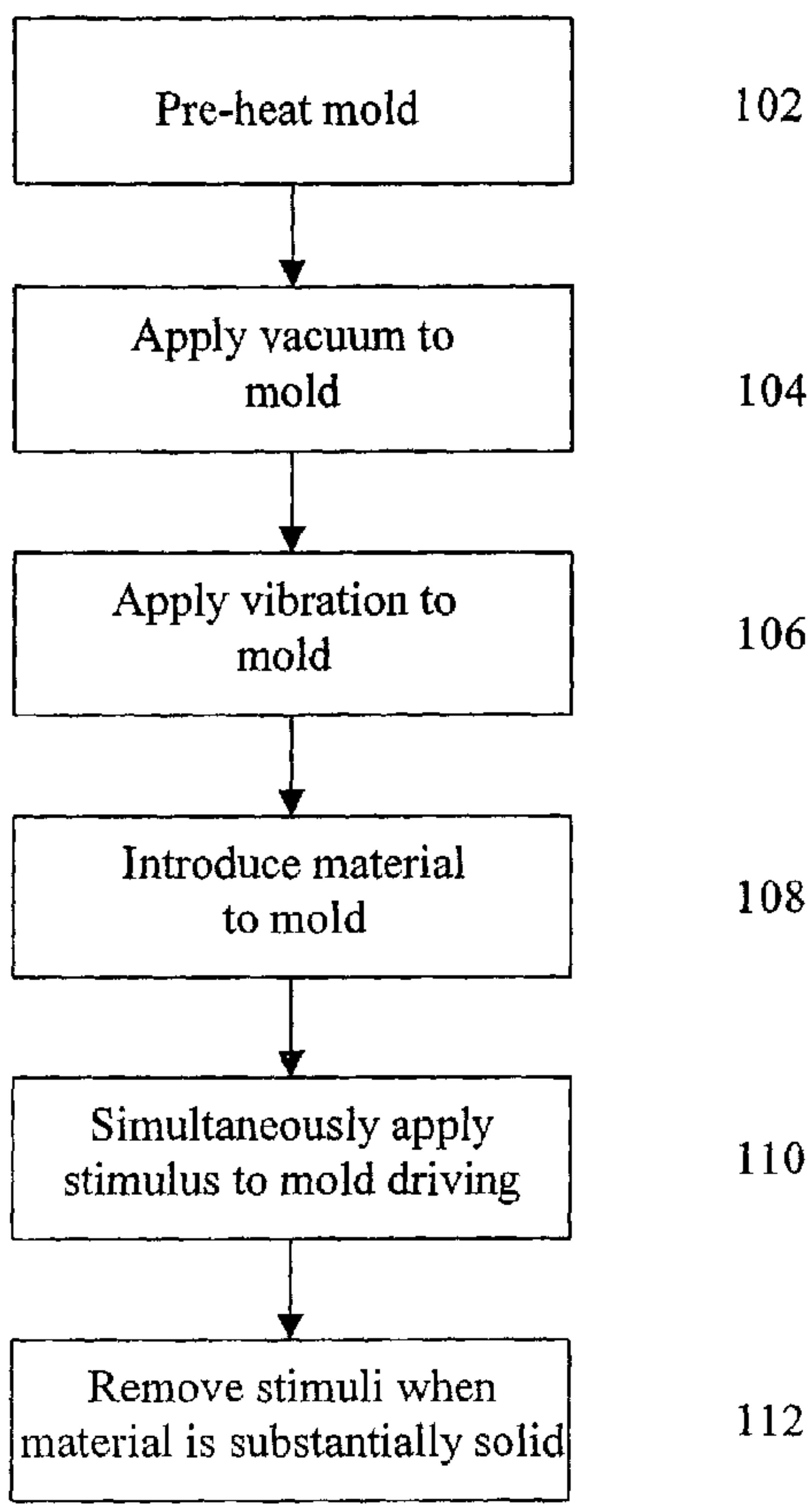
(54) Titre : COLLIMATEUR DE COULEE ET SON PROCEDE DE FABRICATION
(54) Title: CAST COLLIMATOR AND METHOD FOR MAKING SAME



(57) Abrégé/Abstract:
There is a method of manufacturing a cast collimator that includes pre-heating a mold (102), filling the mold with material in a liquid phase (110), and simultaneously applying vacuum (104), heat and vibration (106) to the mold until the material reaches a substantially solid phase.

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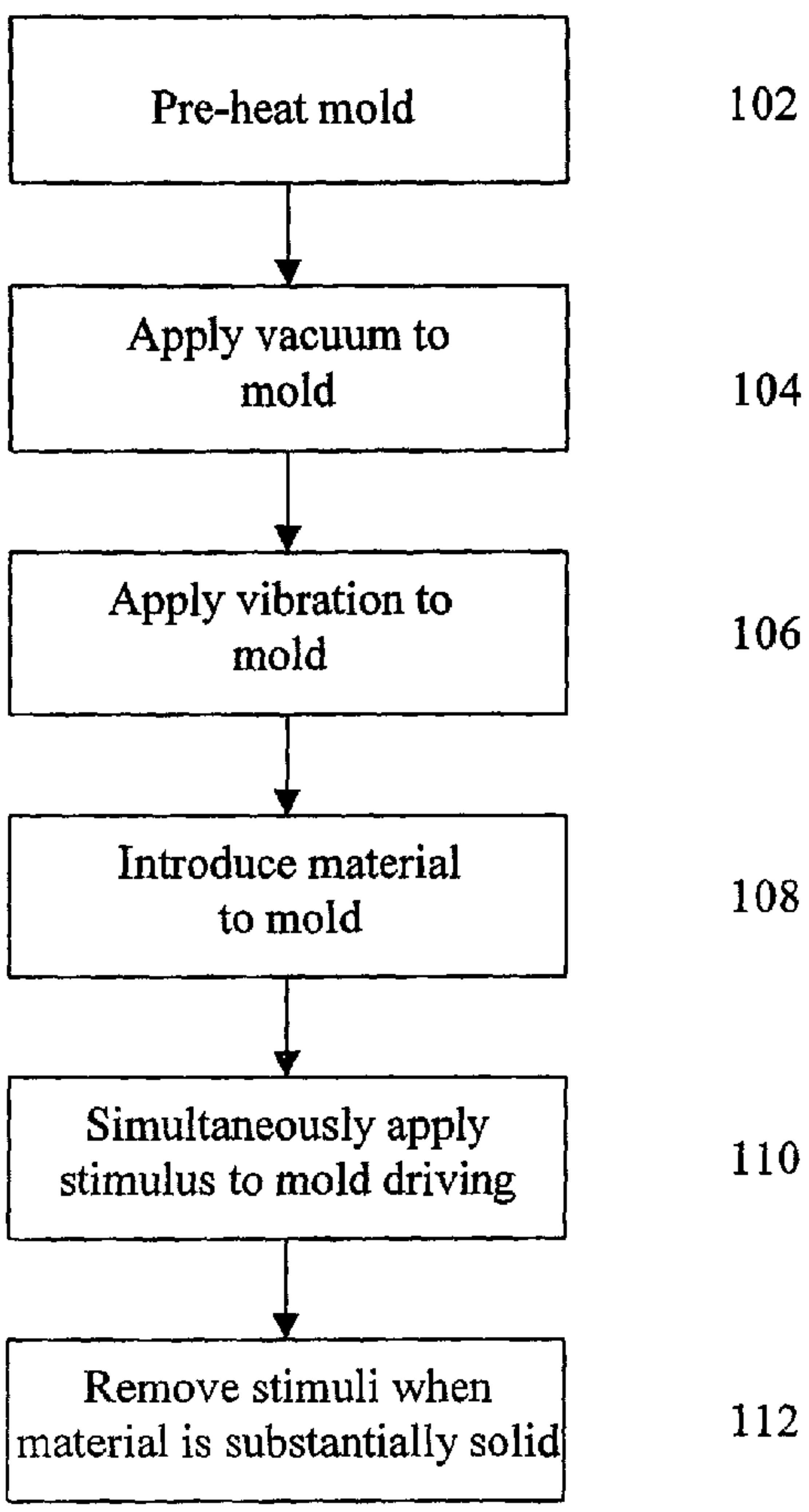

(57) **Abstract:** There is a method of manufacturing a cast collimator that includes pre-heating a mold (102), filling the mold with material in a liquid phase (110), and simultaneously applying vacuum (104), heat and vibration (106) to the mold until the material reaches a substantially solid phase.

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For two-letter codes and other abbreviations, refer to the "Guidance Notes on Codes and Abbreviations" appearing at the beginning of each regular issue of the PCT Gazette.

CAST COLLIMATOR AND METHOD FOR MAKING SAME

BACKGROUND OF THE INVENTION

[0001] Collimators are devices designed to absorb scattered rays (e.g., from x-ray and gamma ray sources). Methods and materials for producing collimators are continuously evolving to improve strength, fineness of grid details, and absorptive characteristics while reducing manufacturing costs. Cast collimators can be made by filling a mold with dry materials (e.g., metal powder) and applying a binding agent that encapsulates the dry materials when the binding agent hardens. Cast collimators can also be made by filing a mold with one or more dry materials and heating the mold to melt that materials in-situ.

[0002] Where strength and durability of the collimator are of particular concern, it is desirable to produce the cast collimator by filing a mold with molten materials. Manufacturers of cast collimators made from pouring molten metals into a mold are challenged to ensure that the molten materials flow into and cast very small mold details on a consistent basis. This is particularly challenging due to the high surface tension of molten materials. However, high surface tension molten materials happen to have other desirable characteristics that make them preferable materials for casting collimators, as described further below. There is thus a need for dense, durable, finely detailed cast collimators and methods of making same.

SUMMARY OF THE PREFERRED EMBODIMENTS

[0003] In one embodiment, a method of manufacturing a cast collimator, such as a high resolution collimator, includes pre-heating a mold, filling the mold with flowable material (e.g., in a liquid, molten, solid, semi-solid, and granulate, or powder), simultaneously

[0004] applying vibration, vacuum and heat to the mold until the material reaches a substantially solid phase.

[0005] In a further embodiment of the inventive method, the step of pre-heating the mold includes heating the mold until it reaches a temperature that is within approximately about 30°C to about 80°C of the material to be poured into the mold. In one embodiment, where ambient temperature is within about 30°C to about 80°C of the molten material, no pre-heating may be necessary.

[0006] In other embodiments, the mold is then heated to melt the material in the mold.

[0007] In another embodiment of the inventive method, the material includes gold and tin.

[0008] In an exemplary method, the material used is selected from a group including antimony, arsenic, barium, beryllium, bismuth, cadmium, gold, indium, lead, mercury, osmium, palladium, platinum, thallium, tin, tungsten, zinc and mixtures thereof.

[0009] In another exemplary method, the material includes bismuth, tin, antimony and zinc and mixtures thereof.

BRIEF DESCRIPTION OF THE DRAWINGS

[0010] Reference is made to the accompanying drawings in which are shown illustrative embodiments of the invention, from which its novel features and advantages will be apparent.

[0011] In the drawings:

[0012] FIG. 1 is a flow chart depicting an exemplary method of the present invention.

[0013] Fig. 2 is a perspective view of an exemplary mold for use in the method of the present invention.

[0014] FIG. 3 is a side view of the exemplary mold shown in Fig. 2 for use in a method according to the present invention.

[0015] Fig. 4a is a perspective view of an exemplary spherical collimator of the present invention.

[0016] Fig. 4b is a plan view of the exemplary spherical collimator shown in Fig. 4a.

[0017] Fig. 5 is a side view of an exemplary vacuum chamber according to the present invention.

[0018] Fig. 6a is a perspective view of a cast collimator produced according to the present invention.

[0019] Fig. 6b is a partial side view of the cast collimator in Fig. 6a.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

[0020] Reference will now be made in detail to preferred embodiments of the present invention, examples of which are illustrated in the accompanying drawings. Wherever possible, the same reference numbers will be used throughout the drawings to refer to the same or like parts. To provide a thorough understanding of the present invention, numerous specific details of preferred embodiments are set forth including material types, dimensions, and procedures. Practitioners having ordinary skill in the art will understand that the embodiments of the invention may be practiced without many of these details. In other instances, well-known devices, methods, and processes have not been described in detail to avoid obscuring the invention.

[0021] Fig. 1 illustrates an exemplary method of the present invention. In step 102 a mold is pre-heated using any method selected by those skilled in the art, such as hot plates or ovens. By "pre-heating" is meant heating a mold prior to placement of material in the mold. In one embodiment, the mold is pre-heated approximately to the temperature of the material to be placed in the mold. In one embodiment, the temperature of the pre-heated mold is the temperature of the material to be placed in the mold +/- approximately 0°C to approximately 100°C, preferably +/- approximately 30°C to approximately 80°C. In one embodiment, the temperature of the mold is any temperature below the temperature of the material to be placed in the mold. For example, where material is placed in the mold at about 180°C, the mold is pre-heated to a temperature less than 180°C, preferably between approximately 100°C and approximately 150°C.

[0022] In one embodiment, the mold may be constructed of silicone (e.g., RTV silicone), fluorosilicone, Teflon, ceramic, metal or any other material those skilled in art may select for this application. The mold in one embodiment is a flexible mold. The mold in another embodiment is a rigid or a semi-rigid mold. Molds may be formed by any method, including but not limited to the methods described in PCT Application PCT/US02/17936, U.S. Provisional Applications 60/295,564 and 60/339,773 and U.S. Patent Applications 10/282,441 and 10/282,402, each of which are hereby incorporated by reference as if set forth in their entirety herein.

[0023] Figs. 2 and 3 show a side view of an exemplary mold 210 for use in the present invention. Mold 210 includes a casting chamber 220. Casting chamber 220 may further include product chamber 230 and reservoir 240 above product chamber 230. In Fig. 2, product chamber 230 houses precision components such as openings or chambers (e.g., micro-chambers) 250 and posts 260. In one embodiment, microchamber 250 and post 260 are arranged to form a series of openings 420 as shown in Figs. 4a and 4b. Microchambers 250 are openings of a predetermined shape and width, for example, as small as approximately 0.004 inches between posts 220. In Figs. 2 and 3, reservoir 240 is an upper portion of casting chamber 220 and above product chamber 230.

[0024] Using the methods described herein, any type or geometry of collimator including, for example, spherical, rectangular, focused, unfocused collimators and combinations thereof may be constructed. For example, spherical collimators can be constructed in a spherical mold such that x-rays coming from an x-ray tube that is radiating out in a spherical front can be collimated to parallel. Figs. 4a and 4b show perspective and plan views, respectively, of a spherical collimator produced by the method of the present invention. In Fig. 4a, collimator 410 includes openings 420 formed from microchambers 250 and posts 260, as shown in Figs. 2 and 3. In one embodiment, the collimator is a high resolution collimator.

[0025] In step 104, a vacuum is applied to a mold cavity. In one embodiment, a vacuum of 28 inches of mercury or higher is applied (e.g., by a simple rotational vacuum pump). As shown in Fig. 5, the vacuum pump 560 is preferably connected to mold 510 or product chamber 230. In one embodiment, the vacuum is applied in vacuum chamber 520, e.g., a bell-jar type vacuum chamber. Vent valve 530 is connected to vacuum chamber 520 so as to return vacuum chamber 520 to atmospheric pressure according to the present invention. In one embodiment, the vacuum removes air from product chamber 230 and from casting material 540.

[0026] In alternative embodiments, vacuum can be applied to remove air selectively from vacuum chamber 520 or product chamber 230. In the latter embodiment, mold 510 can be selectively isolated and placed under vacuum. In one embodiment, the degree of vacuum applied to mold 510 or product chamber 230 is selectively varied. In one embodiment, when vent valve 530 is opened, atmospheric pressure (e.g., 14.7 pounds per square inch) aids in forcing the casting material into the recesses and details of product chamber 230.

[0027] In one embodiment, mold 510 is pre-heated (e.g., as described herein) while it is under vacuum. In another embodiment, mold 510 may be pre-heated prior to exposing it to vacuum. In yet another embodiment, mold 510 is pre-heated after it is exposed to vacuum.

[0028] In step 106, the mold is exposed to gravitational forces. In one embodiment, the mold is vibrated, such as by vibration source or vibration table 550, as shown in Fig. 5. An exemplary vibration source 550 is a Syntron Model V-2-B. Preferably, the mold is vibrated in a vertical direction between 30 and 60 cycles per second.

[0029] In one embodiment, the vibration frequency is between about 20 cycles per second and about 80 cycles per second, preferably between approximately 30 cycles per second to approximately 60 cycles per second. Vibration at this rate can impart large momentary forces to the material when placed in the mold. Vibration at this rate imparts large momentary forces to the material when placed in the mold (e.g., approximately up to 30 or more gravitational forces) thus achieving a high degree of compaction and/or consolidation into the intimate details of the mold by, for example, overcoming the surface tension of the material.

[0030] In another embodiment, centrifugal casting imparts the gravitational force. The fixtures for centrifugal casting may be any fixture known to those skilled in the art. Using centrifugal casting, many multiples of gravity can be applied to a casting material in a mold, causing the material to flow more readily into the mold and mold details, than it would under normal gravity. In some embodiments, vibration is a more convenient method of accelerating material into mold details. For example, in one embodiment, the mold may be placed on a table 550, to impart the necessary gravitational force as opposed to mechanically slinging the mold through an arc. In another embodiment, vibration is preferred for its ability to cause powders or pastes of solid particles in a liquid to fluidize. In some embodiments, these particles are fluidized suddenly during application of a vibrational force. In embodiments where pastes are applied to a mold, the pastes may undergo a collapse in viscosity that can be often dramatic under vibration. In one embodiment, a mound of such a paste, upon application of vibration, can instantly collapses to a free-flowing liquid, thus allowing highly-filled compositions, or metal alloys in a paste-like phase to be cast. For example, a mixture of gold powder in an epoxy resin, with a very high amount of gold by weight, such as greater than 90%, is so stiff in viscosity that it cannot be poured at all under normal circumstances. Upon application of vibration, such stiff mixtures collapses into a free flowing liquid that readily fills the mold cavities. Such compositions would normally not be pourable or castable, or would be very difficult to pour or cast.

[0031] In another embodiment, the vibration can be applied to a metal filled resin, wherein the filler can include a very dense metal such as tungsten, gold, or other heavy metal, or a mixture of two or more heavy metals. In such an embodiment, the metal particles preferably are driven downward into the mold details, and as vibration is continued, excess resin is expelled or expressed from the mixture. In one embodiment, the resulting casting is nearly all metal filler. In some embodiments, the casting is equal to or greater than 90%, preferably 92% metal filler. The surplus expressed resin it trimmed off the top of the mold reservoir area after curing and discarded. Accordingly, vibrational compacting allows dense, accurate castings to be made from materials that heretofore were not castable or were difficult to cast.

[0032] Exposure of the mold to gravitational force (e.g., vibration, centrifugation) in one embodiment is commenced prior to placement of material in the mold. In alternative embodiments, the mold is exposed to gravitational forces during material placement or after material placement in the mold. In some embodiments, application of gravity forces may take place either before or after pre-heating and/or vacuum application. In the preferred embodiment, at some point in the process according to one embodiment of the present invention, the mold simultaneously is heated, exposed to vacuum and exposed to gravitational forces. This simultaneous application of such external stimuli may take place prior to, during, or after placement of material in the mold.

[0033] In step 108, material is placed in the mold. Methods of placing the material include, without limitation, pouring, injecting and any other methods known to those skilled in the art for filling a mold. The material placed into the mold can be a solid, a semi-solid, a solid powder, a granular material, liquid, molten or any other suitable form. In a preferred embodiment, the material is liquid and/or fluid material, preferably a liquid and/or fluid high density material. In one embodiment, the high density material is heated prior to placing it in the mold to improve pourability of the material. In one embodiment, sufficient material is poured into the mold to create a head (e.g., a hydraulic head) of material above the mold.

[0034] In step 110, external stimuli (e.g., one or more of heated mold, vacuum, vibration) are applied to the mold during the curing (e.g., cooling) process. In one embodiment, one or more of the external stimuli are applied continuously until the material in the mold becomes substantially solid (e.g., cools to substantially form a solid). In another embodiment, one or more of the external stimuli are applied intermittently as the material in the mold cures.

[0035] In one embodiment, the material being cured has a relatively sharp transition from liquid to solid phase (e.g., a gold/tin eutectic). In another embodiment, the material being cured in the mold does not have a sharp liquid to solid transition. For example, multiple component mixtures such as commercially available bismuth/lead/tin alloys (e.g., Cerroshield (52.5% bismuth, 32% lead and 15.5%Tin), autobody or plumbing solders may be mixed so as to provide wide plastic ranges for extended working times (e.g., for modeling, trowlling or wiping the cooling metal). In one embodiment, a tin/lead eutectic material of 63% tin and 37% lead posses such sharp liquid solid transitions. Other alloys (e.g., 50-50 solder) have a wide range of solidification temperatures where they are past-like in a range of temperatures as the melt approaches solidification.

[0036] In an embodiment, where the poured material is molten metal, the one or more external stimulus can be applied as the molten metal transitions from liquid phase, to the solid phase. Where the transition is more gradual from liquid to solid, the material may exhibit slush characteristics wherein crystals form (e.g., grow) and are suspended within the liquid phase. In one embodiment, this phase is analogous to resin/metal casting composites as described herein.

[0037] In one embodiment, the material is de-gassed while it is in its liquid phase (e.g., by vibrating the mold). Vibrating the material during curing further ensures that the material stays in the liquid phase longer and therefore facilitates the migration of molten material into mold details.

[0038] The external stimuli (e.g., one or more of heated mold, vacuum, vibration) are removed in step 112. In one embodiment, external stimuli are removed in stages. For example, in one embodiment, the vibration force is removed after the heat is removed from the mold. In another embodiment the mold is vibrated until all other stimuli are removed. In one embodiment, vacuum is removed prior to the removal of the vibration force and/or heat. In another embodiment, vacuum is removed after the removal of the vibration force and/or heat.

[0039] One example of a collimator produced from this method is a heavy metal cast collimator, as shown in Figs. 6a and 6b. Preferably, the casting materials are of low melting point and high strength. In one embodiment, heavy metal is used to cast collimators. Preferably the materials are flowable. Suitable materials achieve a high stiffness and hardness to prevent (or at least reduce) deformation, and that are radiographically opaque. Examples of such heavy metal materials include, but are not limited to, antimony, barium, beryllium, bismuth, cadmium, gold, indium, lead, mercury, osmium, palladium, platinum, thallium, tin, tungsten, zinc, hafnium, ruthenium, tantalum, or any other metal or alloy having good mechanical strength, dimensional stability, resistance to atmospheric corrosion, and density and alloys and mixtures thereof. Preferably, densities of over 10 g/cc are achieved according to the present invention. Of course, lower and higher densities may result depending on the starting materials.

[0040] In one example, beryllium may be selected because it has favorable hardness, stiffness and elasticity characteristics. Beryllium, however, has a radiographic opacity that may not be desirable for some applications.

[0041] In one embodiment, the collimator is a eutectic mixture (e.g., gold and tin eutectic). A gold/tin eutectic has favorable melting point, hardness, stiffness and opacity qualities. In one embodiment, the ratio of gold to tin is 80:20. In one embodiment, gold is selected because it is a dense material and has a resistance to tarnishing. In one embodiment, non-eutectic mixtures are used to form a collimator.

[0042] In another embodiment, the collimator is an alloy containing bismuth. Bismuth has the desirable characteristic of a low melting point making it suited for use with molds that cannot withstand high temperatures (e.g., RTV silicon molds). This is desirable in one embodiment where pre-heating a mold poses concerns of dimensional instability of the mold details.

[0043] In another embodiment the collimator is derived from metallic powder exposed to the inventive process described herein. In one embodiment, such metallic powders are used in the present invention in combination with the process disclosed in European Patent Application No. 98119778.3, which is hereby incorporated by reference as if disclosed in its entirety herein.

[0044] However, some products containing alloys with high concentrations of bismuth or other heavy metals can pose dimensional stability problems in the finished products (e.g., the product may have a tendency to crumble). It has been found that bismuth concentrations in a useable finished product preferably range from approximately 50% to approximately 90% or more, preferably 60% to 75%, more preferably 65% to 75%. In some instances, alloys with bismuth concentrations above 90% become impractical to use where mechanical strength is a concern in the finished product. In one embodiment, a bismuth alloy containing about 68%

bismuth is preferred. The substantial balance of the alloy may contain tin, antimony and zinc. In one embodiment, tin concentrations range from approximately 5 to approximately 50%, preferably approximately 10% to 30%, more preferably approximately 20%. In one embodiment, the alloy preferably contains antimony in ranges from approximately 0.5 to approximately 5%. In preferred embodiments, antimony comprises approximately 1% to approximately 3%, preferably about 1.5% of the alloy. In another embodiment, zinc comprises preferably between approximately 1% and approximately 20% zinc. In preferred embodiments, zinc comprises approximately 5% to approximately 15%, preferably about 0.5% of the alloy.

[0045] Experimentation has shown that a preferred alloy comprises 68% bismuth, 20% tin, 1.5% antimony and 10.5% zinc. At these ratios, there has been achieved a satisfactory combination of low melting point and strength. This alloy is particularly useful because it possess characteristics of semi-liquid combined with semi-solid (e.g., "slush") over a relatively large range of temperatures. Thus, in one embodiment, over a large range of temperatures the alloy simultaneously possess crystals of an antimony/tin intermetalic compound, a zinc/bismuth intermetalic compound, a zinc/antimony intermetalic compound and a liquid quaternary eutectic of antimony, tin, zinc, and bismuth which are simultaneously exposed to outside stimuli (e.g., vibration, vacuum, heated mold) as the crystalline portion grows and the liquid quaternary eutectic solidifies. In one embodiment, arsenic or tellurium can be substituted for antimony, cadmium can be substituted for zinc, and/or indium can be substituted for tin.

[0046] Although the foregoing description is directed to the preferred embodiments of the invention, it is noted that other variations and modifications in the details, materials, steps and arrangement of parts, which have been herein described and illustrated in order to explain the nature of the preferred embodiment of the invention, will be apparent to those skilled in the art, and may be made without departing from the spirit or scope of the invention.

All references referred to herein are hereby incorporated by reference in their entirety as if recited herein.

What is Claimed:

1. A method of manufacturing a high resolution casting comprising:

pre-heating a mold;

filing the mold with material in a liquid phase;

simultaneously applying vacuum, heat and vibration to the mold before the material reaches a substantially solid phase.

2. The method of claim 1 wherein the pre-heating reaches a temperature that is within approximately 30°C to approximately 80°C of the material in the liquid phase.

3. The method of claim 1 wherein the material is a mixture of gold and tin.

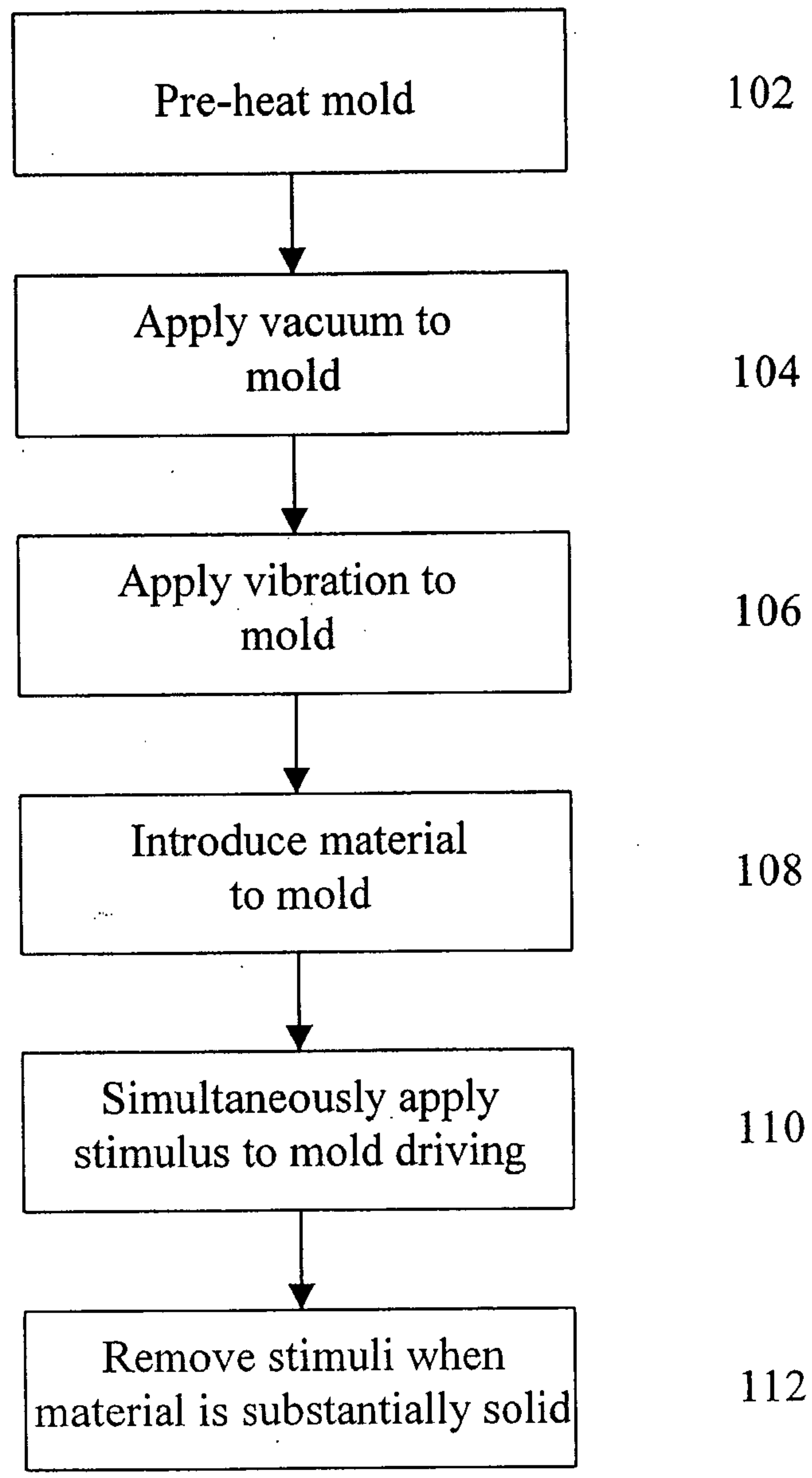
4. The method of claim 1 wherein the material is selected from a group consisting of antimony, arsenic, barium, beryllium, bismuth, cadmium, gold, indium, lead, mercury, osmium, palladium, platinum, thallium, tin, tungsten, zinc and combinations thereof.

5. The method of claim 1 wherein the material is a mixture of bismuth, tin, antimony and zinc.

6. The method of claim 1 wherein the material comprises approximately 68 percent bismuth, approximately 20 percent tin, approximately 1.5 percent antimony and approximately 10.5 percent zinc.

7. The method of claim 1 wherein the material comprises approximately 80 percent gold and approximately 10 percent tin.

FIG. 1


Pre-heat mold
102
Apply vacuum to mold
104
Apply vibration to mold
106
Introduce material to mold
108
Simultaneously apply stimulus to mold driving
110
Remove stimuli when material is substantially solid
112

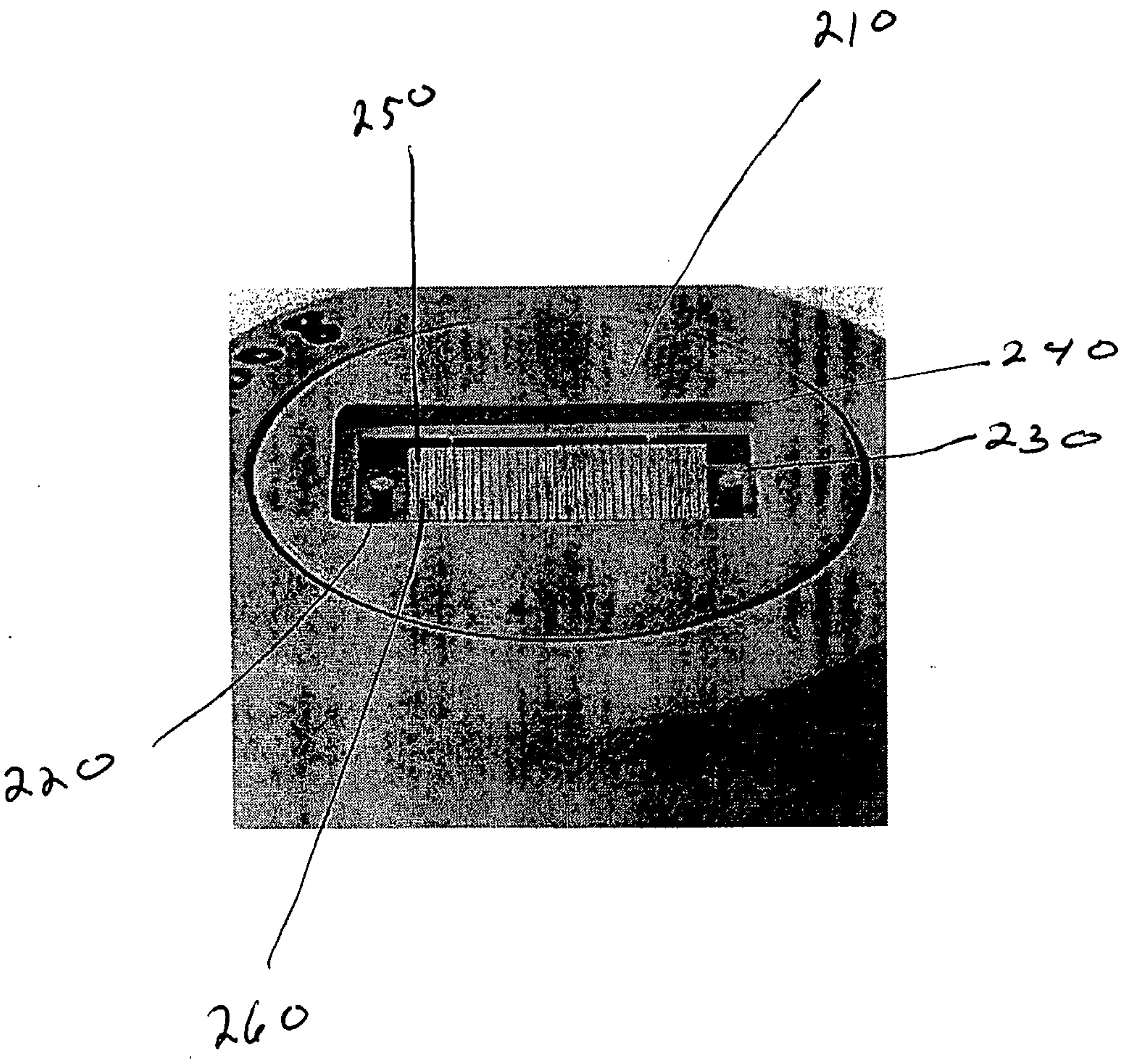


Fig. 2

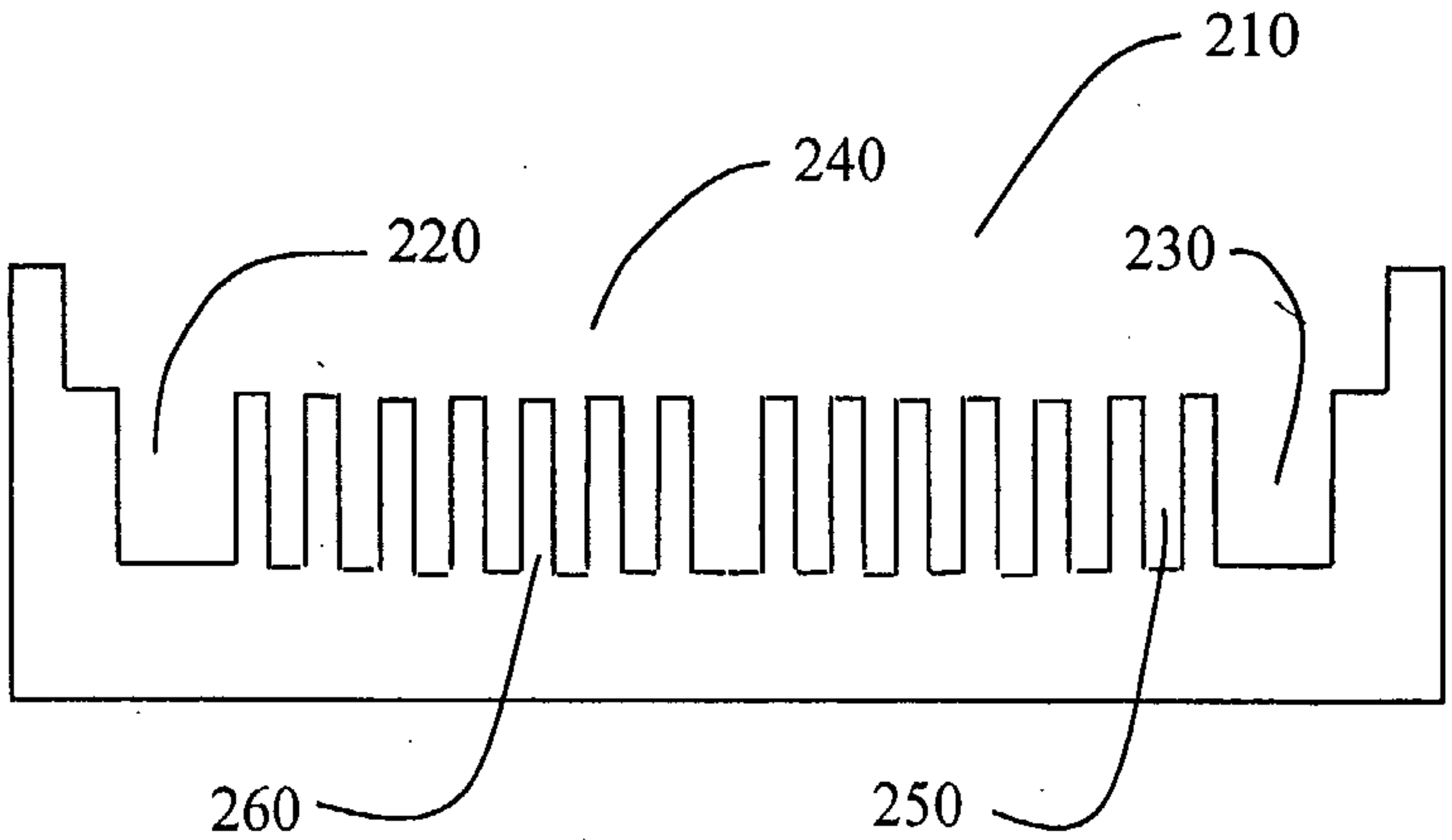


Fig. 3

FIG. 4a

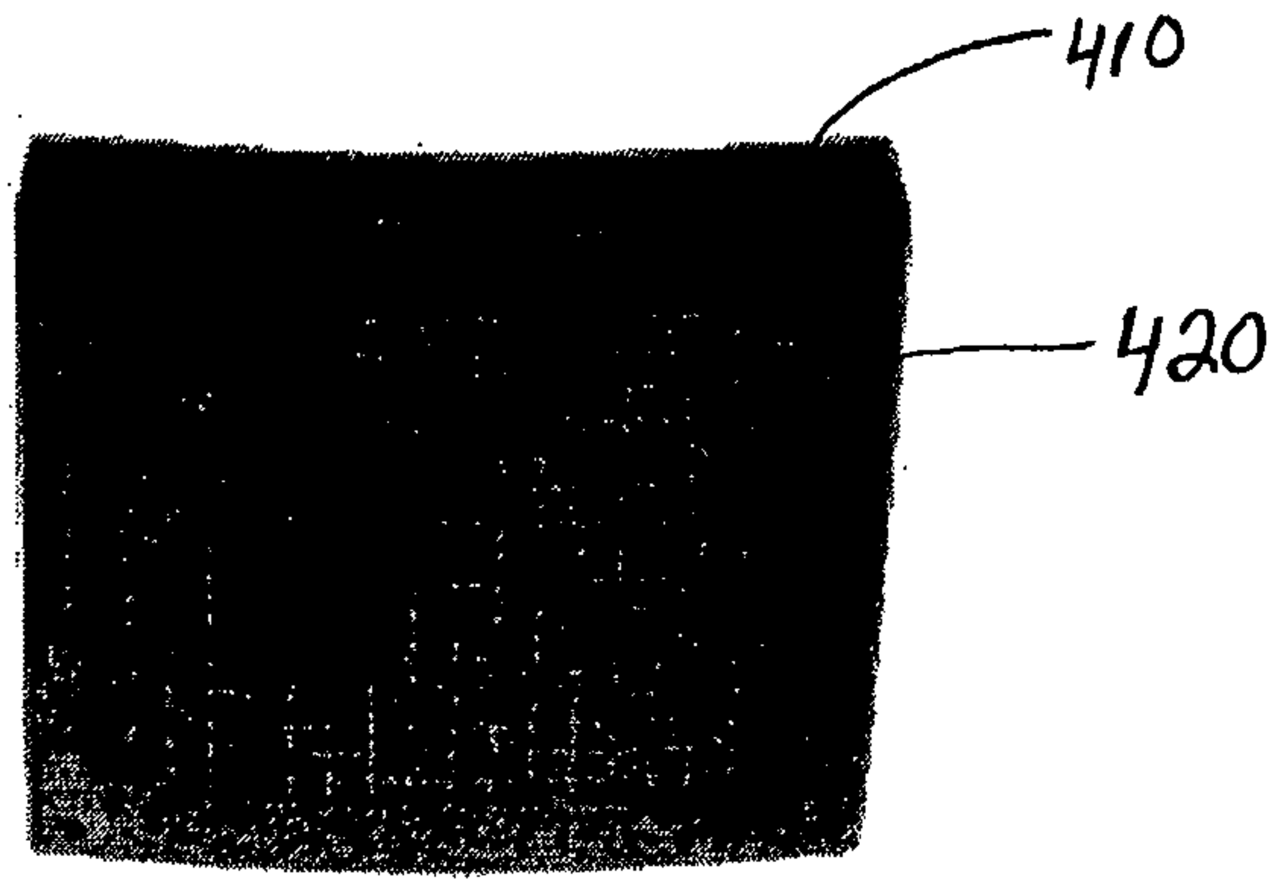
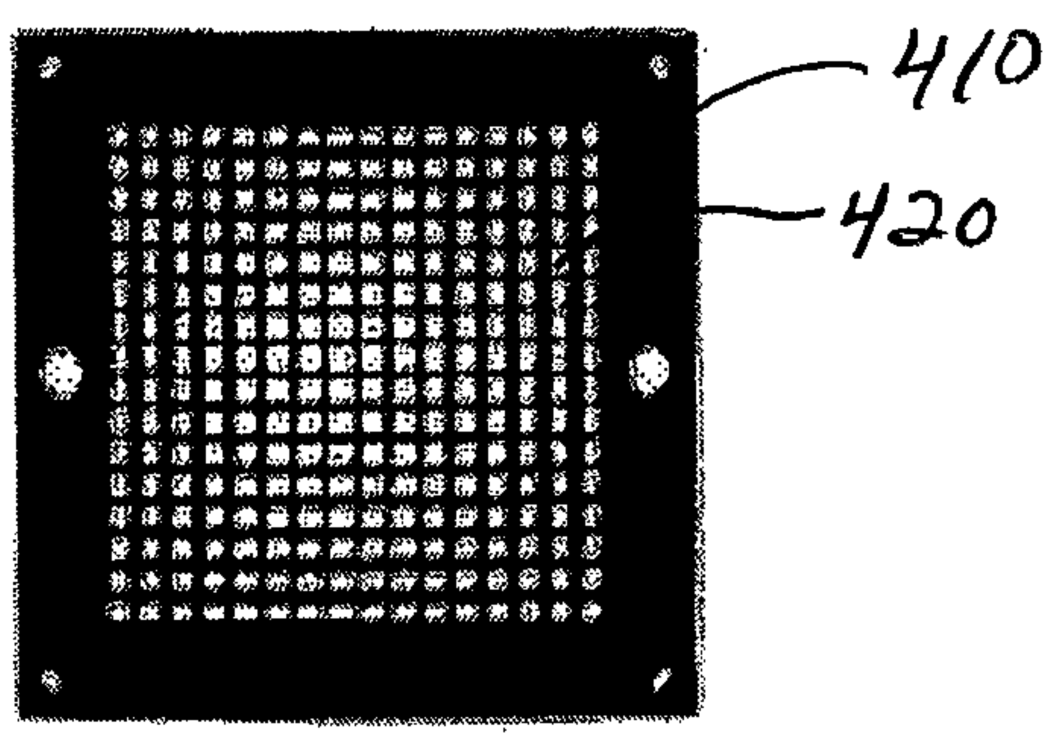


FIG. 4b



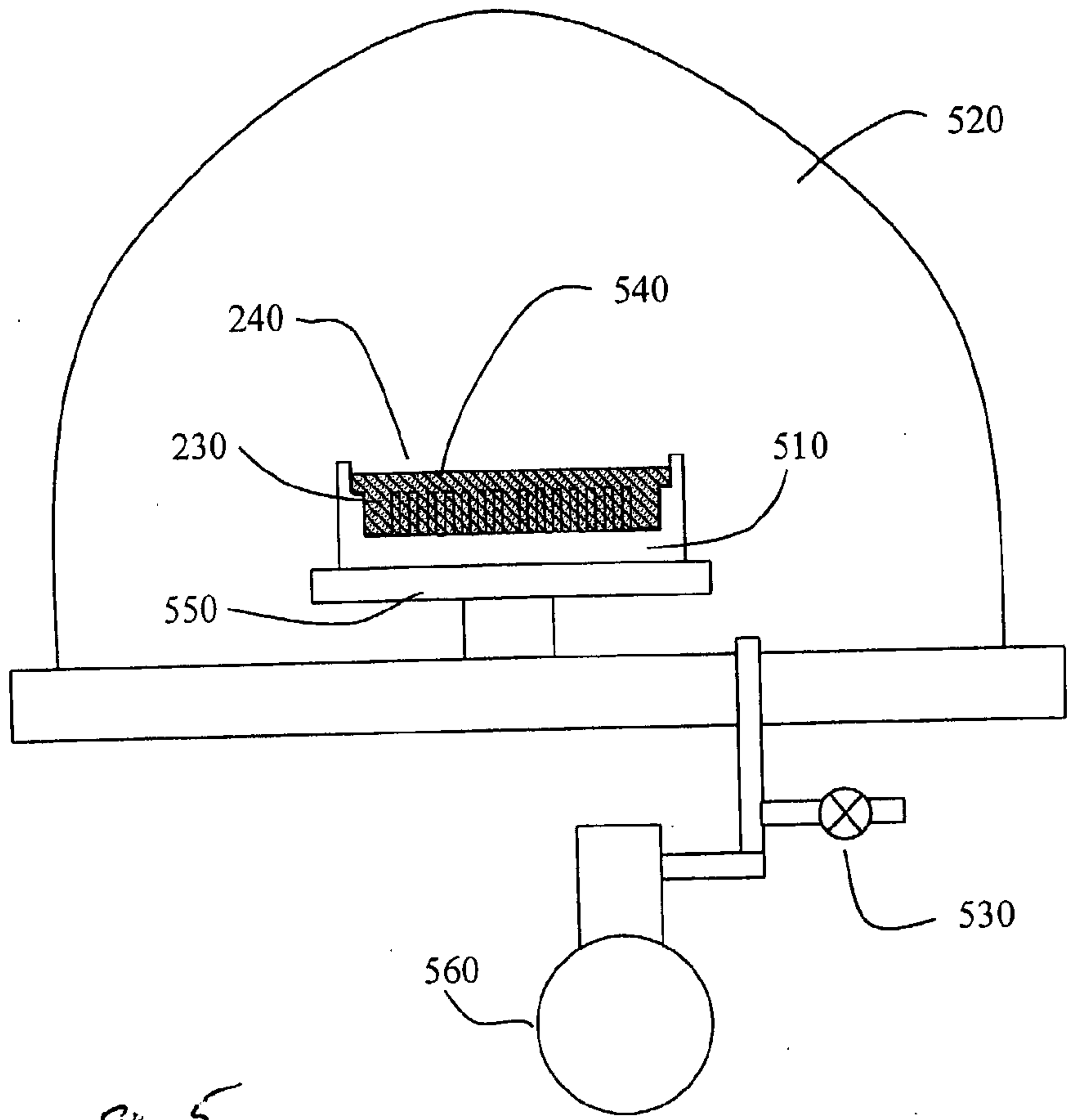


Fig. 5

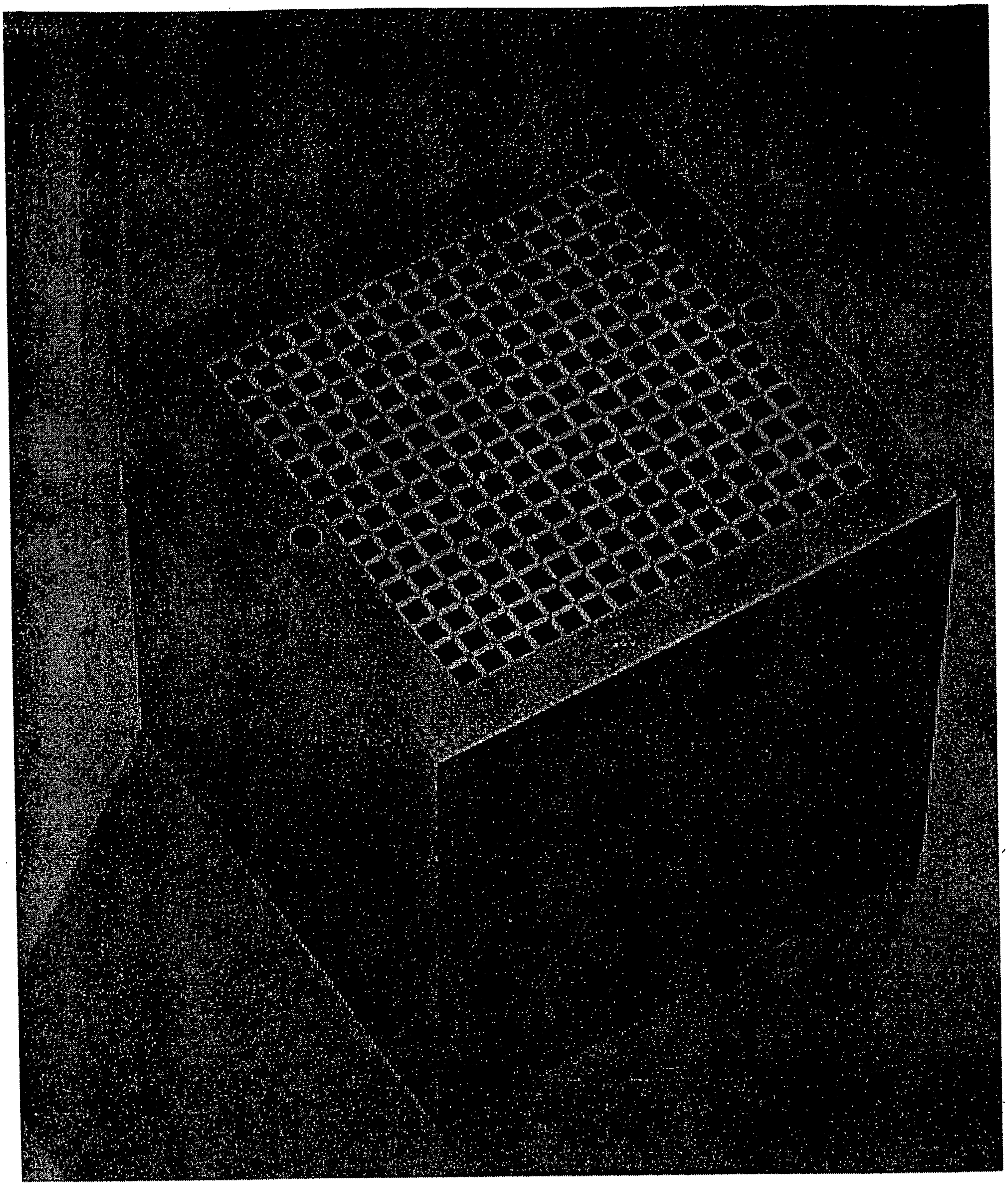


FIG. 6a

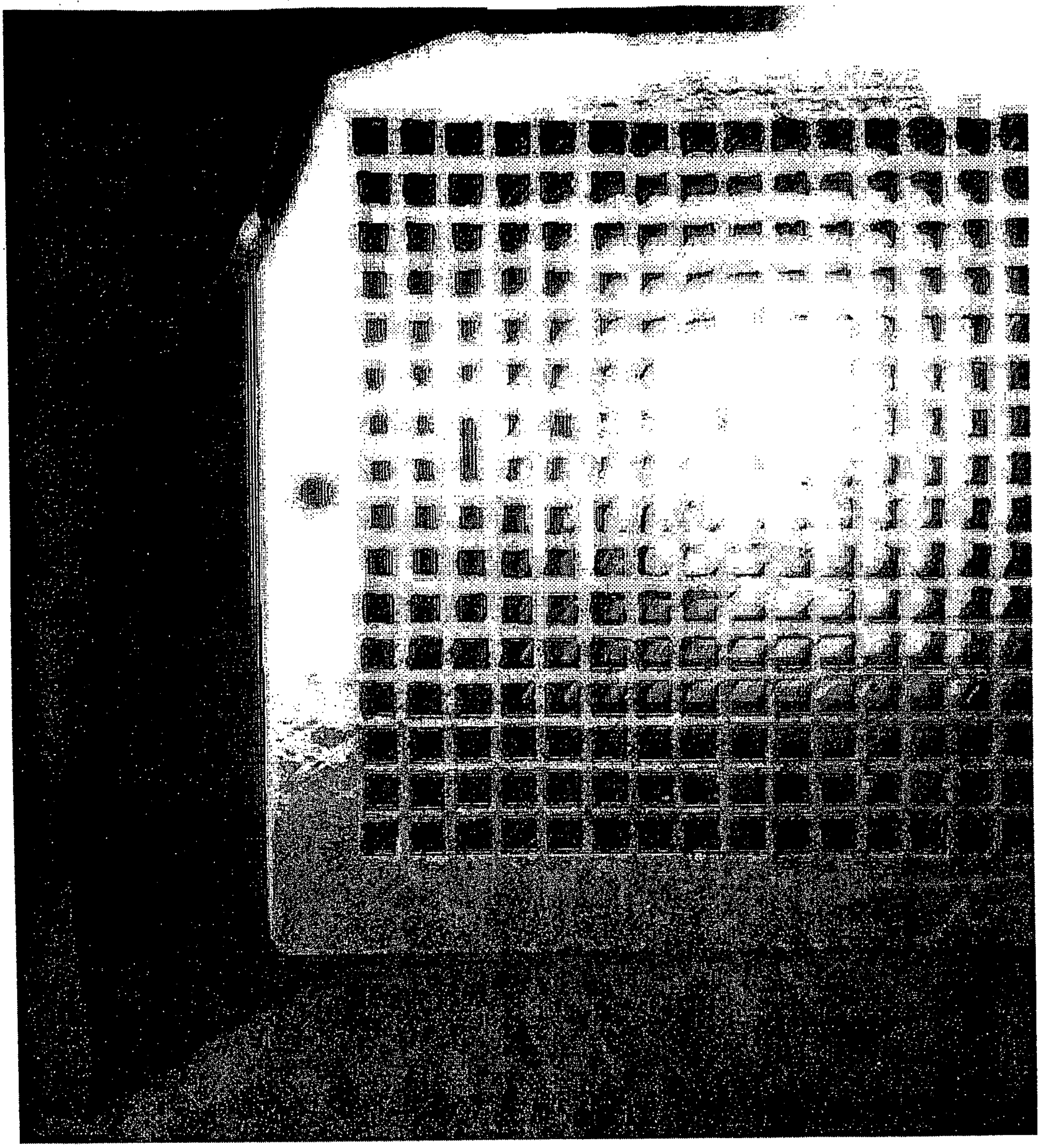
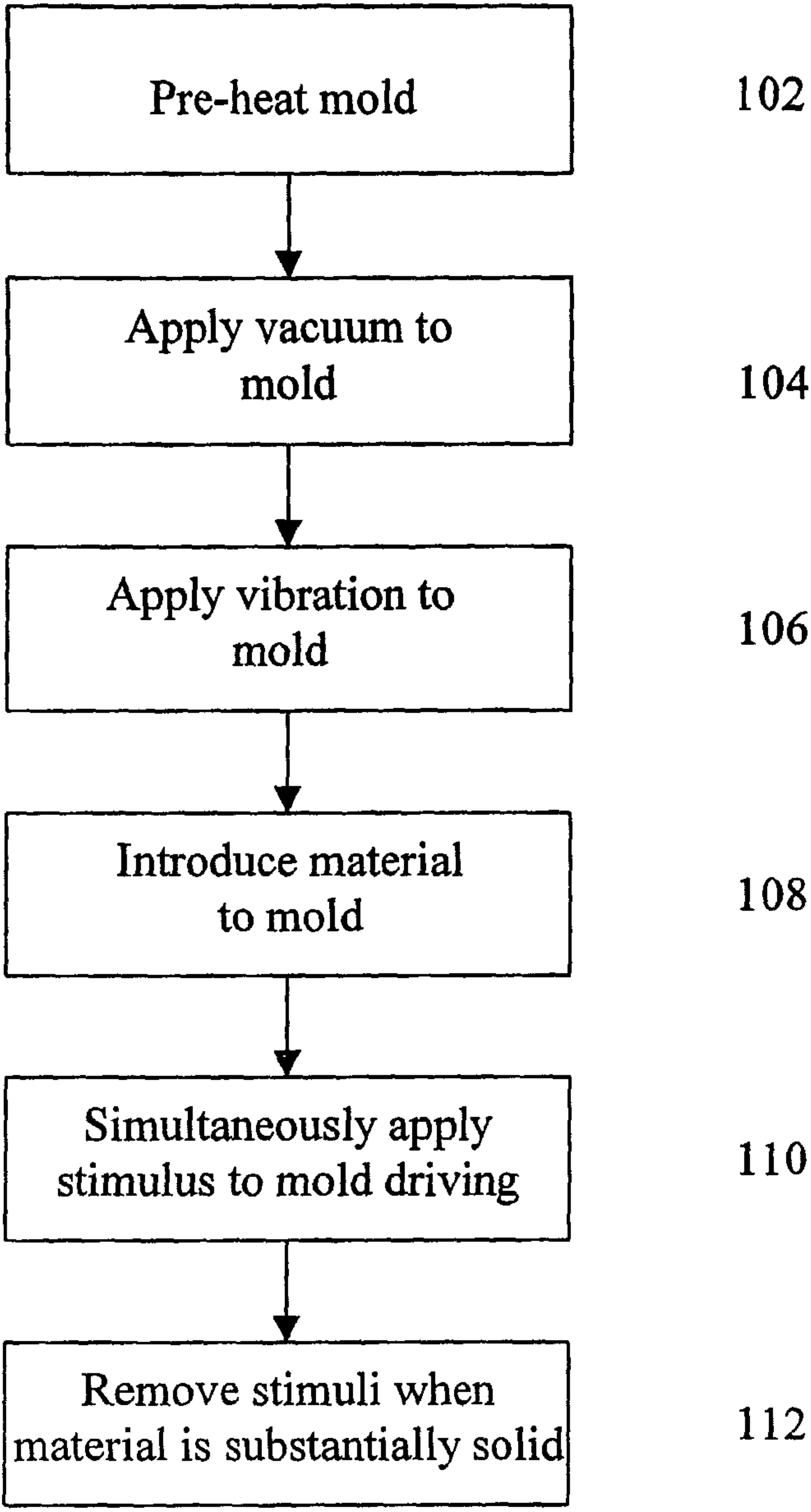


FIG. 6b


Pre-heat mold
102
Apply vacuum to mold
104
Apply vibration to mold
106
Introduce material to mold
108
Simultaneously apply stimulus to mold driving
110
Remove stimuli when material is substantially solid
112