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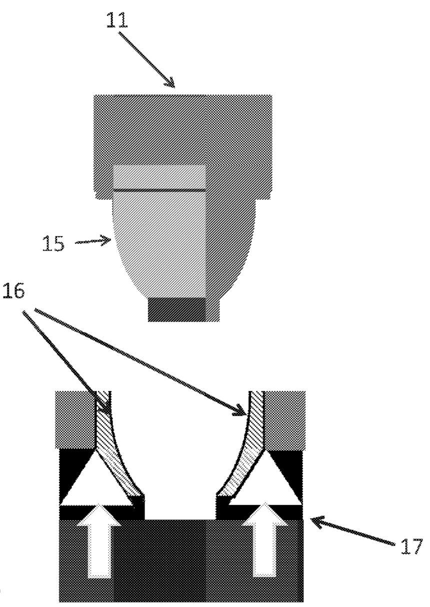

Figure 5

(57) Abstract: A method of manufacturing a hohlraum in large quantities is disclosed. The method includes steps of electroplating a mandrel having a surface configured to correspond to the interior surface of half the hohlraum and then pressing the mandrel into the half hohlraum and adhering it in place. The same steps are performed on the other half of the hohlraum, and then the two halves are joined together.

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HOHLRAUM AND METHOD OF FABRICATION

STATEMENT AS TO RIGHTS TO INVENTIONS MADE UNDER FEDERALLY SPONSORED RESEARCH AND DEVELOPMENT

[0001] The United States Government has rights in this invention pursuant to Contract No. DE-AC52-07NA27344 between the United States Department of Energy and Lawrence Livermore National Security, LLC, for the operation of Lawrence Livermore National Laboratory.

REFERENCE TO RELATED APPLICATION

[0002] This application claims priority from U.S. provisional patent application entitled: "Method of Fabricating Hohlraums," filed January 3, 2012, as serial number 61/582,676, the contents of which are incorporated by reference.

BACKGROUND OF THE INVENTION

[0003] This invention relates to fuel for inertial confinement fusion power plants, and in particular to the design and manufacture of a hohlraum which contains a fuel capsule, for use in such fusion power plants.

[0004] The National Ignition Facility (NIF) is a laser-based inertial confinement fusion research machine located at the Lawrence Livermore National Laboratory (LLNL) in Livermore, California. NIF uses lasers to heat and compress a capsule of deuterium and tritium (DT) fuel held in a hohlraum to the temperatures and pressures to cause a nuclear fusion reaction. In NIF a bank of 192 lasers fires upon the capsule held in a hohlraum at the center of the chamber by a fixed arm.

[0005] Inertial confinement fusion power plants using the technology now being developed at NIF have been proposed. The equipment, systems and support necessary for the deployment of such a fusion power plant are now being investigated and designed at LLNL. In the indirect drive approach to inertial confinement fusion (often "ICF" herein), a spherical capsule on the order of 4 mm in diameter containing the DT fuel is held inside a hohlraum; the two together being referred to herein as a "target." The targets are injected into a fusion chamber and, as they arrive at the center of the chamber, are fired upon by a bank of lasers. The hohlraum absorbs and re-radiates the energy of the laser beams striking the inside of the hohlraum as x-rays onto the fuel capsule. This causes the outer surface of the fuel capsule to ablate, compressing and heating the DT fuel to cause a fusion reaction.

[0006] As presently contemplated, a megawatt size inertial confinement fusion power plant will rely upon fusion reactions from on the order of 10 to 15 targets per second. Thus, inertial confinement fusion target designers must consider many engineering requirements in addition to the physics requirements for a successful target implosion. Among these considerations is a need to manufacture large numbers of targets, e.g. more than 300 million targets per year per plant. The hohlraum must survive injection into the hostile environment of the fusion chamber, while resisting high acceleration forces and extreme environmental conditions. Of particular importance to this invention, the hohlraum for each target must have a precise configuration so as to re-radiate energy evenly onto the fuel capsule, yet be able to be manufactured at low cost in high volumes.

[0007] The NIF hohlraum is a generally cylindrical cavity whose walls emit radiant energy towards the interior. A typical prior art NIF hohlraum and capsule is shown in Figure 1. In that illustration hohlraum 100 is shown held in place by the arms 101. Laser beam entrance openings 102 in each end of the cylinder allow laser beams 103 to strike the interior wall of the hohlraum 100 where the fuel capsule 104 is located. To date hohlraums used at NIF have been “custom” made in small batches suitable for a scientific research operation, as opposed to the lower cost, higher volume necessary for commercial applications. The NIF hohlraum is described in NIF Ignition, JSR-05-340, June 29, 2005, available from LLNL.

BRIEF SUMMARY OF THE INVENTION

[0008] In a preferred embodiment of the invention, a method of manufacturing a hohlraum includes a series of steps. A mandrel having a surface configured to correspond to an interior surface of a lower (or upper) half of a hohlraum is placed in an electroplating bath to form an electroplated layer on the surface on the mandrel. In a separate operation, typically performed in parallel with the electroplating step just described, a lower portion of the hohlraum body is formed, for example, by a swaging operation. The lower portion of the hohlraum body includes an interior surface, an exterior surface, a joining region, and an end region opposite the joining region. The mandrel upon which the electroformed layer has been deposited is then pressed into the lower portion of the hohlraum body to place the electroplated layer against the interior surface of the lower portion of the hohlraum body.

[0009] The electroplated layer is then caused to adhere to the interior surface of the lower portion of the hohlraum. In one embodiment this is achieved by having previously roughened the interior surface of the lower portion of the hohlraum, thereby causing the electroplated layer to adhere more strongly to the surface of the lower portion of the hohlraum than to the surface of the mandrel. In another embodiment, dust comprised of the same material as the hohlraum body is applied to the interior surface of the lower portion of the hohlraum, thereby causing the electroplated layer to adhere more strongly to the surface of the lower portion of the hohlraum. By mechanically bonding the two surfaces together, a stronger bond is made between the hohlraum body and the electroplated layer, than between the mandrel and the electroplated layer. Additional operations are then performed to add windows over the laser entrance holes, infrared shields, a capsule support membrane, etc. Typically at the same time all of the operations described above are being performed, the same operations are being performed on the other half (upper portion) of the hohlraum. Once both halves (or portions) of the hohlraum are ready, the fuel capsule can be inserted, and the lower portion of the hohlraum and the upper portion of the hohlraum are placed in juxtaposition with each other to cause the joining region of the lower portion to abut the joining region of the upper portion. A step is then performed to join the lower portion of the hohlraum to the upper portion of the hohlraum, thereby forming the completed hohlraum.

[0010] Typically the upper and lower portions of the first portion of the hohlraum and the second portion of the hohlraum are substantially identical in shape and size, however, provided the joining surfaces are compatible, the portions of the hohlraum need not be identical. In some embodiments, the electroplated layer covers the joining region, and the two halves of the hohlraum are joined using that surface. Of course, while the steps described above can be used to form a hohlraum, they can also be used to form other components.

BRIEF DESCRIPTION OF THE DRAWINGS

[0011] Figure 1 is a diagram illustrating a prior art hohlraum;

[0012] Figure 2 is a diagram illustrating a hohlraum as for use in an ICF power plant;

[0013] Figure 3 is a cross-sectional view of the electroforming mandrel;

[0014] Figure 4 is a cross-sectional view of the electroforming mandrel in an electroplating bath;

[0015] Figure 5 is a cross-sectional view of the electroforming mandrel with an electroplated layer positioned over the press formed mass of the hohlraum body;

[0016] Figure 6 is a cross-sectional view of the electroforming mandrel with the inner shell of the hohlraum being pressed onto the hohlraum body;

[0017] Figure 7 is a cross-sectional view of the formed component;

[0018] Figure 8 is a cross-sectional view of the half hohlraum with the laser entrance hole;

[0019] Figure 9 is a cross-sectional view showing the laser entrance hole window being pressed into place;

[0020] Figure 10 is a cross-sectional view of the half hohlraum with the IR shield being pressed into place;

[0021] Figure 11 is a cross-sectional view of the half hohlraum with the fuel capsule support being pressed into place;

[0022] Figure 12 illustrates the half hohlraum in the die;

[0023] Figure 13 illustrates the finished half hohlraum after ejection from the die; and

[0024] Figure 14 is a cross-sectional view of two half hohlraums ready for capsule insertion and final assembly.

DETAILED DESCRIPTION OF THE INVENTION

[0025] This invention relates to techniques for mass production of, and the structure of, hohlraums for an inertial confinement fusion engine used as the heart of a fusion power plant. Figure 2 illustrates a preferred embodiment of the architecture for such a target.

[0026] In Figure 2 the capsule 40 containing the fusion fuel is about a 4 mm diameter hollow spherical capsule 40. The hohlraum 100 is preferably made of lead, about 1 cm in diameter by about 2 cm long, with a wall 30. In one embodiment, an approximately 20μm thick layer of high-Z material 20, e.g., plated lead, on the inside hohlraum wall, provides for more efficient x-ray production. The hohlraum has a rugby ball-shaped interior 80 for better coupling of the expected approximately 2.2 megajoule (MJ) laser energy to the capsule 40. The shape of the interior surface is a circular arc with origin vertically offset to satisfy the prescribed dimensions of the hohlraum, e.g., maximum and minimum inner radii, and length.

[0027] Infrared reflectors 50, typically a low-Z membrane material such as carbon or polyimide coated with a thin reflective metal layer, for example, 30 nm thick aluminum, help protect the capsule from radiant heat in the fusion chamber. "P2" shields 60 and 70 provide symmetry and enhancement of the x-ray bath around the capsule 40. The shields are typically manufactured from the same material as the hohlraum, and deposited onto the polyimide membrane. An additional low-Z membrane (or membranes) is used to support the capsule 40 within the hohlraum 100. The hohlraum is filled with helium gas which tamps the degree of the hohlraum wall expansion to provide greater symmetry control. The gas is sealed in by the windows 50 over the laser entrance holes at opposite ends of the hohlraum. The exterior surface of the hohlraum 100 has cylindrical sides 10 to enable guidance by a target injector used to introduces the targets into the fusion chamber.

[0028] Targets, as just briefly described, are described in more detail in commonly assigned U.S. patent application entitled "Indirect Drive Targets for Fusion Power," serial number 13/290,282, filed November 7, 2011, the contents of which are incorporated herein by reference.

[0029] This invention provides techniques for the production of the hohlraum itself, as opposed to the fuel capsule, by stamping and electroforming separate components, and then combining those components to form a single metal component with an optical grade inner surface. The invention also pertains to a continuous process for the mass production of these assemblies. A method of fabrication combining electroforming and stamping is used to provide an optical inner surface and a precision assembly surface for a metal component in a mass production process. The invention can be used for the manufacture of fusion targets, as well as for other purposes, for example, the manufacture of precision optical components, and the mass manufacture of robust optical components. For the present invention the terms electroplating and electroforming refer to the same deposition of material on a mandrel, and are used herein jointly and interchangeably.

[0030] Figure 3 is a cross-sectional view of an electroforming mandrel 11 with optically smooth electroforming surfaces 13 mounted on mandrel 11. The electroforming surfaces 13 will be used to define half of the interior surface of the hohlraum. The mandrel 11 upon which these surfaces are formed can be any suitable material, but preferably is a conductive ceramic, metal, glass or plastic material. More generally, the mandrel 11 is manufactured from a material which is resistant to the conditions of the electroplating bath into which it will be inserted, as described below. Thus the mandrel will have an inherently passive surface such as those found in polished stainless steel, chromium and nickel metals, and to variable degrees in conductive ceramics, glass and plastics. A solid, non-plated mandrel is required to avoid potential replication of variations in the formed surface due to any thickness variations in the mandrel coating. A highly polished, continuous surface is preferred without capture folds or points. The surface roughness of the mandrel is selected to produce the required surface roughness of the hohlraum. If a coating is used to facilitate separation, it will be soluble and removable from the formed part without contamination. Note that no electroforming surface 12 is provided on the lower surface of the mandrel 11.

[0031] The next step of the manufacturing process is illustrated in Figure 4. As shown there, the mandrel 11 with the electroforming surfaces 13 is lowered into a bath 14 which electroplates the surfaces 13 with a layer 15. In a preferred embodiment electroplated layer 15 comprises lead and is plated to form a surface with roughness characteristics determined by the mandrel roughness and plating bath characteristics. It is a preferred embodiment, the hohlraum optical surface will be replicated between 1/20 and 50 λ with a surface finish between 5 and 20,000 Å. Variations in the surface finish allow for either exact beam power placement or the averaging of beam power across the target surface. This electroplated layer will ultimately form the inside optical surface of the hohlraum 100, for example, surface 20 as illustrated in Figure 2.

[0032] The electroplating step is carried out for a time period sufficiently long to deposit between about 1 micron and 500 microns of lead onto the exposed surfaces 13 of the mandrel 11. The time and temperature for carrying out such electroplating processes is well-known, and a wide variety of such processes can be used to form a satisfactory coating 15 on the surfaces 13. Once the desired thickness of lead is formed on the mandrel 11, the mandrel is removed from bath 14.

[0033] The next steps in the fabrication process are illustrated in Figure 5. One technique for performing this process is to use swaging. Swaging is a forging process in which the dimensions of an item are altered using a die into which the item is forced. Swaging is usually a cold working process; however, it can be performed as a hot working process. As illustrated in Figure 5, the typically lead body 16 of the hohlraum is formed by a press forming process in a die 17. In such a process, the hohlraum body 16 in rough form is placed in a die 17 and stamped or press formed to the confirmation illustrated in the figure. In this manner the shape of one half of the hohlraum in the die 7 is close to the desired shape of one half of the hohlraum.

[0034] The appearance of the half hohlraum shown in Figure 5 illustrates that half of the hohlraum after the press forming operation has been performed. Note that in Figure 5 the illustration is of either the lower half or the upper half of the completed hohlraum (illustrated in Figure 2). In other words, Figure 5 illustrates half of the hohlraum as if sliced horizontally through the hohlraum in Figure 2 along the cut line 110. Figure 5 also shows the electroplated layer 15 on mandrel 11.

[0035] In the next step of the process, as illustrated in Figure 6, the mandrel 11 with the now plated surfaces 15, and the die 17 holding the half of the hohlraum 16, are pressed together. By virtue of the materials and methods chosen to produce the electroplated layer 15 and the half hohlraum 16, the electroplated layer 15 will adhere to the hohlraum 16 more than to the surface of the mandrel upon which it was originally formed. In one embodiment, the plated surface 15 and the half of the hohlraum 16 may be pressed together with sufficient force to deform the contacting surfaces into each other resulting in a mechanical bond between the materials. This will form a single half hohlraum 16 that is strongly bound together, the bond strength being stronger than the adherence of the plated surface 15 to the mandrel 11. The half hohlraum 16 is further retained by the die 17. In an alternative embodiment, the mandrel is thermally shocked to loosen the plated layer from the mandrel. In a further alternate embodiment the exposed surface of the hohlraum portion 16 is roughened, e.g. by forming it using a swaging process with a roughened die used for the pressing operation. In this circumstance the electroplated layer 15 will adhere better to the roughened surface than to the mandrel 11. The formation of dendrites and other surface protuberances during the electroplating process are encouraged to aid in this process.

[0036] The result of the process described above is that the interior optical surface of the hohlraum is based upon the dimensional accuracy of the mandrel and the electroplating operation, two factors which may be carefully, and relatively precisely, controlled. The exterior surface of the hohlraum results from the configuration of the die 17, providing dimensional accuracy sufficient for the exterior surface of the hohlraum, but not as crucial as that necessary for the interior optical quality surface 15.

[0037] In some embodiments of the invention appropriate choices of materials and swaging operations makes it possible to swag the interior surface of the half hohlraum and achieve the required precision, thus eliminating the electroplating step. For example , by pressing the polished mandrel into the surface and deforming through pressure alone (cold forming), a virtual optical quality surface may be achieved, thus eliminating the electroplating and layer transfer steps. Of course the temperature for the process can be also selected and controlled.

[0038] Figure 7 illustrates the appearance of the half hohlraum 16 with electroplated layer 15, after withdrawal of the mandrel. The mandrel is now ready to be used again for the next half hohlraum.

[0039] Figure 8 illustrates the next step in the process. As shown there, a punch 18 is now inserted through the half hohlraum and the residual portions of the electroplated layer 15 formed in the preceding steps to define the laser entrance hole 19 in that half of the hohlraum. This punching step removes any remaining material from the end of the hohlraum through which the laser beams will enter, thus more accurately defining the opening. Of course, if the opening is sufficiently accurate from earlier processing, without being "punched," this step can be omitted.

[0040] Preferably, at the same time the operations illustrated in Figures 3-8 are being performed, the same process is also carried out on corresponding other apparatus to form the opposite half of the hohlraum. Of course, if the desired hohlraum configuration is not symmetrical about the horizontal axis 110 illustrated in Figure 2, the process carried out on the other half of hohlraum may use a different configuration mandrel 11, electroforming surfaces 13 and die 17 as necessary to achieve the desired configuration for the other half of the hohlraum.

[0041] Figure 9 is a cross-sectional view of the laser entrance hole window 24 being press fitted by die press 28 near the outer laser entrance hole opening of the hohlraum. Lead ping 29 is pressed into place by displacement from a gouge. For clarity of illustration these features are shown enlarged in the figure. In practice these features will be much smaller than shown.

[0042] Figure 10 illustrates additional steps in forming the hohlraum. Using a press 28, the IR shield 25 is press fitted into the half hohlraum.

[0043] Figure 11 is a cross-sectional view of the hohlraum body half in forming mold 17 with the laser entrance hole window 24 in place, the IR shield 25 in place and the capsule support 27 being pressed into place by die press 28.

[0044] Figure 12 is a cross-sectional view of the completed half hohlraum in die 17. At this stage, the laser entrance hole window 24, the IR Shield 25, and the capsule support 7 are each in place.

[0045] Figure 13 is a cross-sectional view the ejected hohlraum assembly half 9.

[0046] Once both halves of the hohlraum are formed, Figure 14 illustrates the next step in the process. Figure 14 is a cross-sectional view of two half hohlraums ready for the capsule insertion and final assembly. In this step one half 9 of the hohlraum and electroplated layer are joined with the other half of the hohlraum and electroplated layer to form the completed hohlraum. The two halves may be bonded together, for example, by locally heating them to a temperature high enough to soften the electroplated layers or the hohlraum body in the region where they contact each other, or by using solder or other suitable material to affix the two halves to each other. In some embodiments the die in which the half hohlraum is manufactured can retain the hohlraum half and then release that component after it is joined to the other half.

[0047] In some embodiments the contact surfaces of the two halves have serrated surfaces to enable a larger bonding area between the two halves. In another embodiment, the lead metal (Pb), typically used for the body of the hohlraum, can be softened enough to allow the two halves to be joined at a relatively low temperature by pressing. In another embodiment a portion 20 of the electroplated layer 15 (see Figure 8) is used as the bonding surface, and bonded to a corresponding portion of the electroplated layer on the other half of the hohlraum by contact welding. Finally, in some embodiments of the invention the two halves of the hohlraum are bonded together. By pressing them together tightly and twisting one of them a reasonably strong junction can be made by the process of inertial contact welding. Alternately, the hohlraum halves may be configured with a lip such as illustrated in Figure 14 so that the contacting surfaces generate an interference fit, an outer ring of protruding material overlapping a corresponding inner ring of protruding material.

[0048] Of course the figures and the description above depict the manufacture of only one half of one hohlraum. It will be appreciated that by duplicating the mandrels 11, the electroplating bath 14, and the die 17 hundreds of times over, large numbers of hohlraums may be manufactured in a mass production environment to create the necessary number for a fusion engine used in an ICF-based power plant.

[0049] The present invention enables the fabrication of an optical grade inner surface and precision mating surface for a metal component in a combined manufacturing methodology facilitating mass manufacture of the item. The method of fabrication combines electroforming/electroplating and stamping to provide an optical inner surface and a precision assembly surface to a metal component in a mass production process.

[0050] Embodiments of the invention provide for the formation of an optical surface by electroforming techniques and the fabrication of the mass of the hohlraum by stamping and/or swaging. In particular embodiments the invention includes a means to form the mass in a die and press the electroformed component into the die formed component before the die formed component is removed from the die or the electroformed component is removed from the mold, therefore preventing damage or distortion of the overall precision component.

[0051] The invention as described above is particularly suitable for the production of soft metal, and in particular lead metal components, useful in forming the hohlraum for an

ICF engine. Advantageously, the invention is particularly suitable to forming a precision optical surface, yet in doing so allowing forming the majority of the structure separately by stamping or swaging. The components and combining these components by pressing for the high speed, high volume production of the hohlraum.

[0052] The need for the electroplated surface is generally driven by the desire to have an optical surface for the laser beams. If the swaging or pressing operations carried out as described with regard to Figure 6 above, provide a sufficiently smooth surface, then the electroplated mandrel step may be eliminated. In this embodiment, the pressing operation configures the inside surface of the hohlraum with sufficient smoothness.

[0053] The preceding description of the preferred embodiment of our hohlraum and methods of manufacturing it has been described with many specific details, for example, materials and particular process technology. It will be appreciated that these details are provided to illustrate the invention, but that the scope of the invention is defined by the appended claims.

What is claimed is:

1. A method of manufacturing a hohlraum comprising:

placing a mandrel having a surface configured to correspond to an interior surface of a first portion of a hohlraum in an electroplating bath to thereby form an electroplated layer on the surface;

forming a first portion of a hohlraum body having the interior surface, an exterior surface, a joining region, and an end region opposite the joining region;

pressing the mandrel into the first portion of the hohlraum body to place the electroplated layer against the interior surface;

causing the electroplated layer to adhere to the interior surface of the hohlraum;

performing the steps of placing, forming; pressing, and causing set forth above on a second portion of the hohlraum; and

placing the first portion of the hohlraum and the second portion of the hohlraum in juxtaposition with each other to cause the joining region of the first portion to abut the joining region of the second portion; and

joining the first portion to the second portion to form the hohlraum.

2. A method as in claim 1 wherein each of the first portion of the hohlraum and the second portion of the hohlraum are substantially identical in shape and size.

3. A method as in claim 1 further comprising, after the step of causing, a step comprising punching an opening through the end region.

4. A method as in claim 1 wherein the step of forming the first portion of the hohlraum body comprises swaging a blank into a die.

5. A method as in claim 4 wherein the step of pressing the mandrel into the first portion of the hohlraum body comprises pressing the mandrel into the first portion of the hohlraum body while the first portion of the hohlraum body is held in the die.

6. A method as in claim 1 wherein the surface of the mandrel configured to correspond to an interior surface of the first portion of the hohlraum includes a portion of the

surface which is configured to correspond to the joining surface, and the electroplated layer is formed on the joining surface.

7. A method as in claim 1 wherein the electroplated layer includes lead, and the first portion of the hohlraum body includes lead.

8. A method as in claim 7 wherein the step of causing the electroplated layer to adhere to the interior surface of the hohlraum comprises pressing the mandrel against the interior surface and then thermally shocking the mandrel to loosen the electroplated layer.

9. A method as in claim 8 wherein the step of joining the first portion to the second portion comprises pressing the first portion against the second portion and twisting one of the portions with respect to the other.

10. A method as in claim 1 wherein the interior surface of the first portion of the hohlraum body is roughened, and the step of causing the electroplated layer to adhere to the interior surface of the hohlraum comprises pressing the pressing the mandrel into the first portion of the hohlraum body to cause the electroplated layer to adhere to the roughened surface.

11. A hohlraum manufactured using the method of claim 1.

12. A method as in claim 1 wherein prior to the step of placing the first portion of the hohlraum and the second portion of the hohlraum in juxtaposition with each other, a step is performed of inserting a fuel capsule.

13. A method of manufacturing a component having an optical quality surface comprising:

placing a mandrel having a surface configured to correspond to an interior surface of a first portion of the component in an electroplating bath to thereby form an electroplated layer on the surface;

forming a first portion of a component having the interior surface, an exterior surface, a joining region, and an end region opposite the joining region;

pressing the mandrel into the first portion of the component to place the electroplated layer against the interior surface;

causing the electroplated layer to adhere to the interior surface of the component;

performing the steps of placing, forming; pressing, and causing set forth above on a second portion of the component; and

placing the first portion of the component and the second portion of the component in juxtaposition with each other to cause the joining region of the first portion to abut the joining region of the second portion; and

joining the first portion to the second portion to form the component.

14. A method as in claim 13 wherein each of the first portion of the component and the second portion of the component are substantially identical in shape and size.

15. A method as in claim 13 wherein the step of forming the first portion of the component comprises swaging a blank into a die.

16. A method as in claim 13 wherein the step of pressing the mandrel into the first portion of the component body comprises pressing the mandrel into the first portion of the component body while the first portion of the component body is held in the die.

17. A method as in claim 13 wherein the electroplated layer includes a first material, and the first portion of the component also includes the first material.

18. A method as in claim 13 wherein the step of joining the first portion to the second portion comprises pressing the first portion against the second portion and twisting one portion with respect to the other.

19. A method as in claim 13 wherein the interior surface of the first portion of the component is roughened, and the step of causing the electroplated layer to adhere to the

interior surface of the component comprises pressing the pressing the mandrel into the first portion of the component to cause the electroplated layer to adhere to the roughened surface.

20. A component manufactured using the method of claim 13.

21. A method of manufacturing a hohlraum comprising:

providing a mandrel having a surface configured to correspond to an interior surface of a first portion of a hohlraum;

forming a first portion of a hohlraum body having the interior surface, an exterior surface, a joining region, and an end region opposite the joining region;

pressing the mandrel into the first portion of the hohlraum body to configure the interior surface;

performing the steps of providing, forming; and pressing set forth above on a second portion of the hohlraum; and

placing the first portion of the hohlraum and the second portion of the hohlraum in juxtaposition with each other to cause the joining region of the first portion to abut the joining region of the second portion; and

while pressing the first portion of the hohlraum and the second portion of the hohlraum together, twisting one portion with respect to the other to join the first portion to the second portion and thereby form the hohlraum.

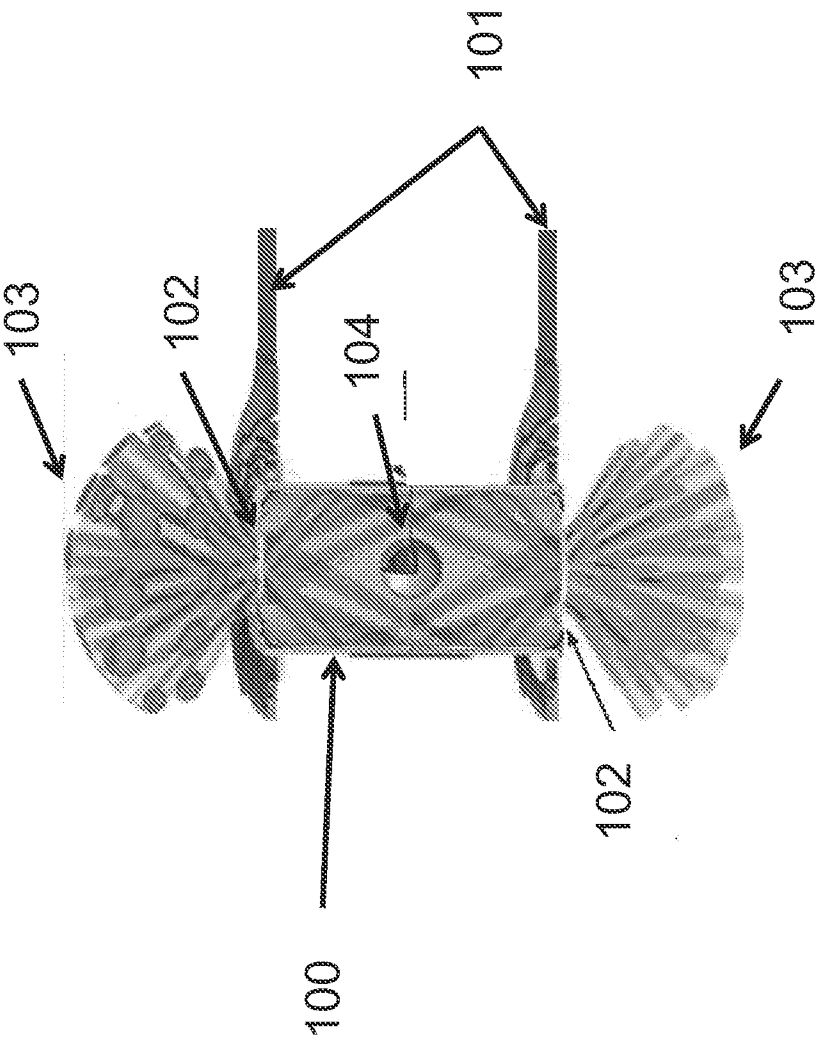


Figure 1 (Prior Art)

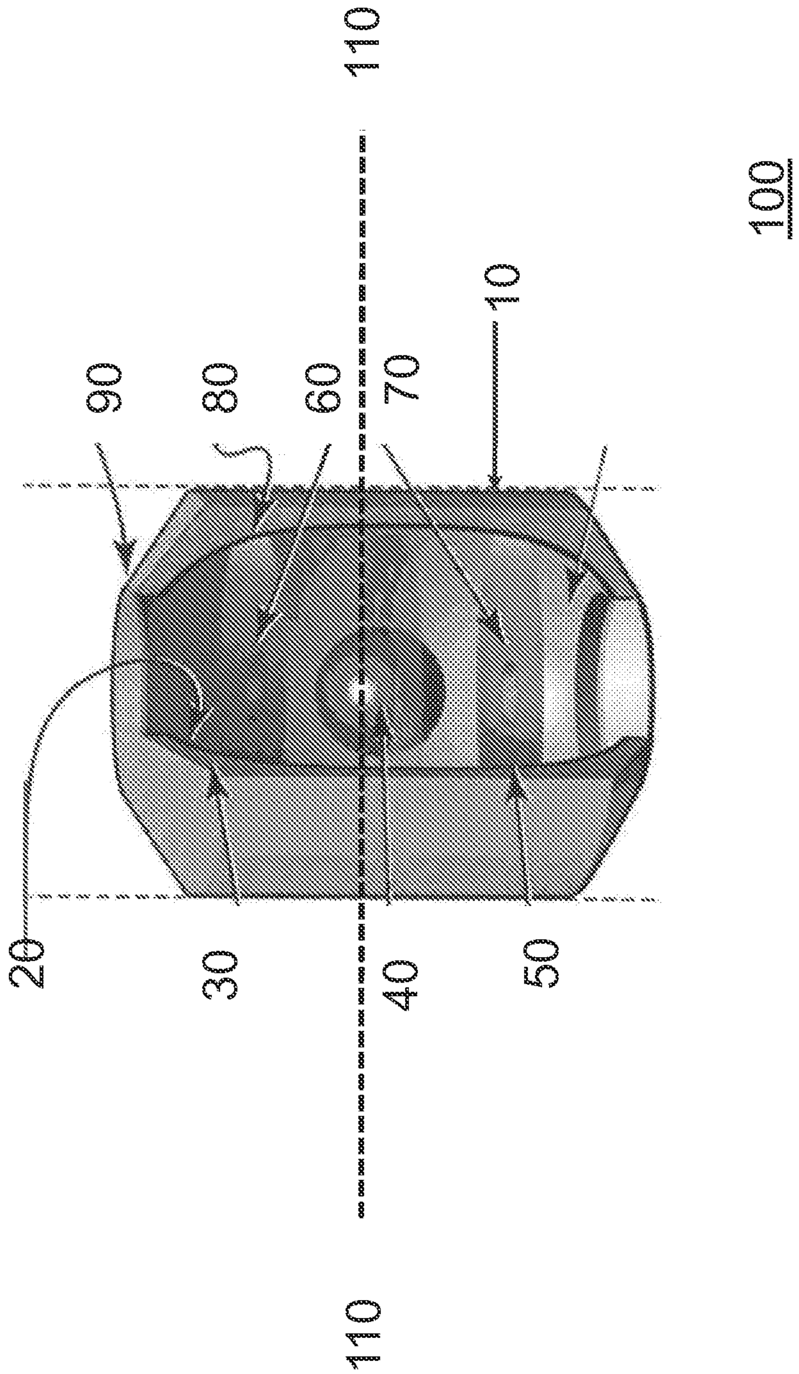


Figure 2

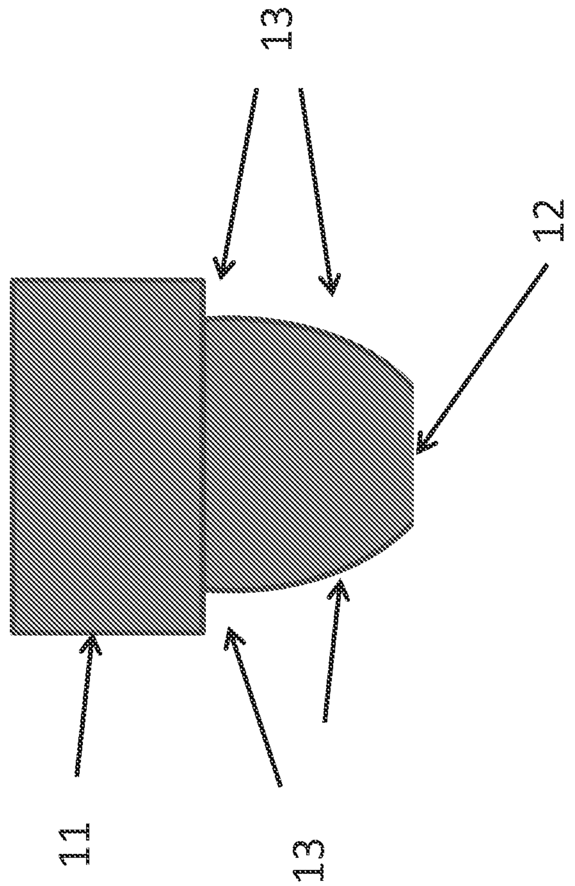


Figure 3

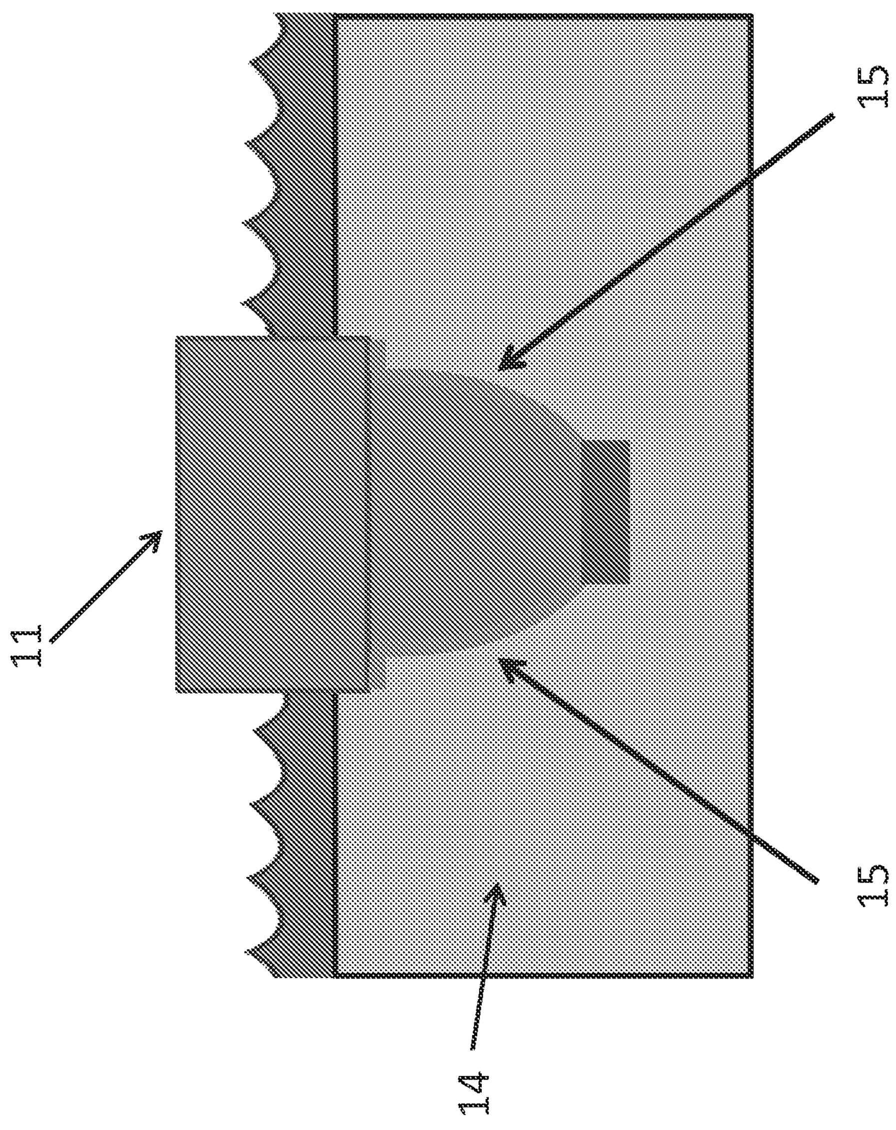


Figure 4

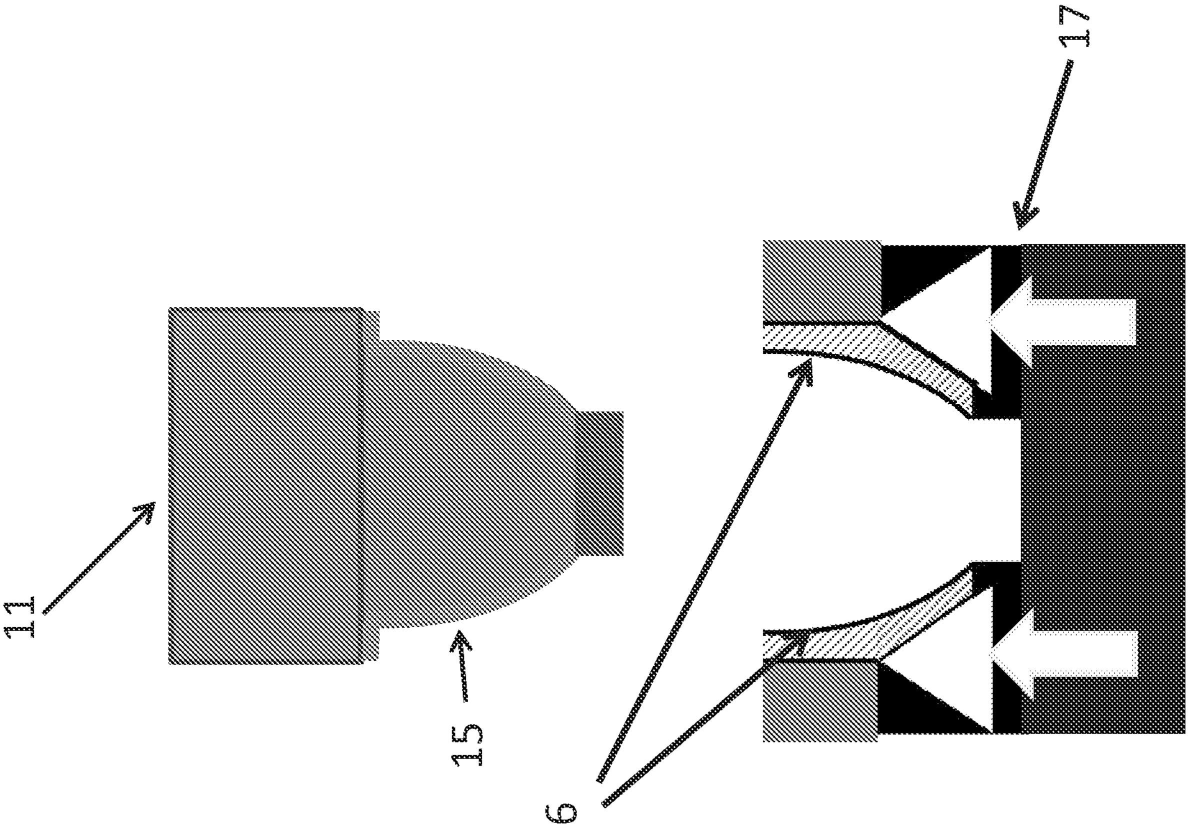


Figure 5

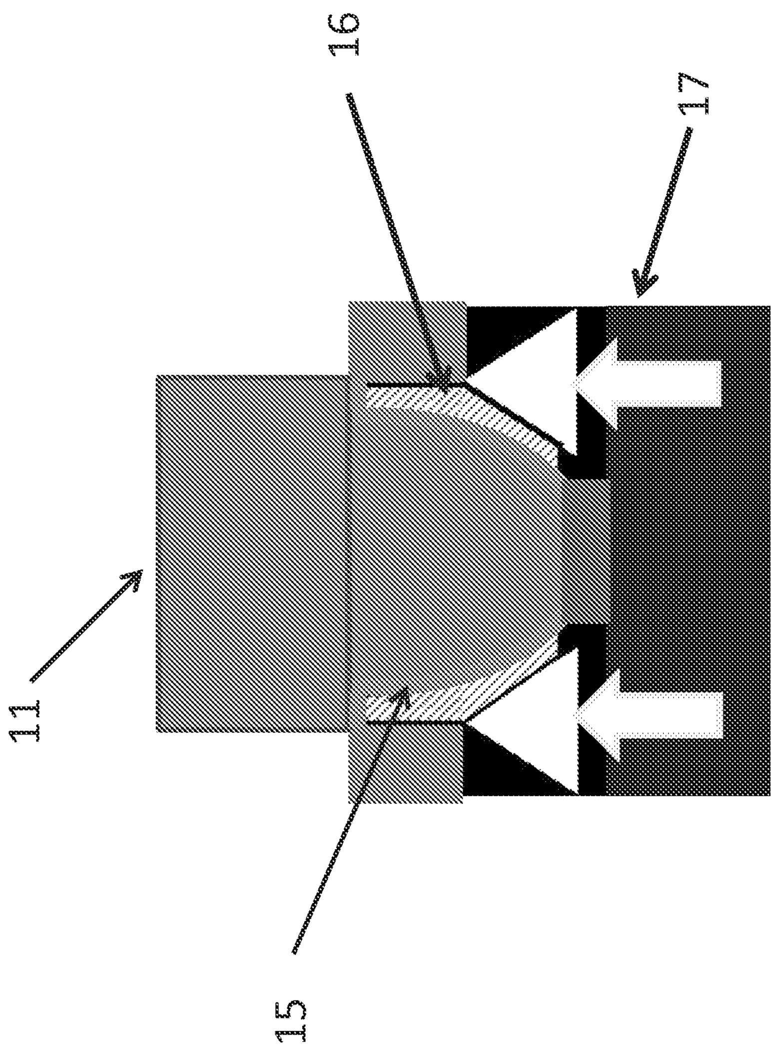
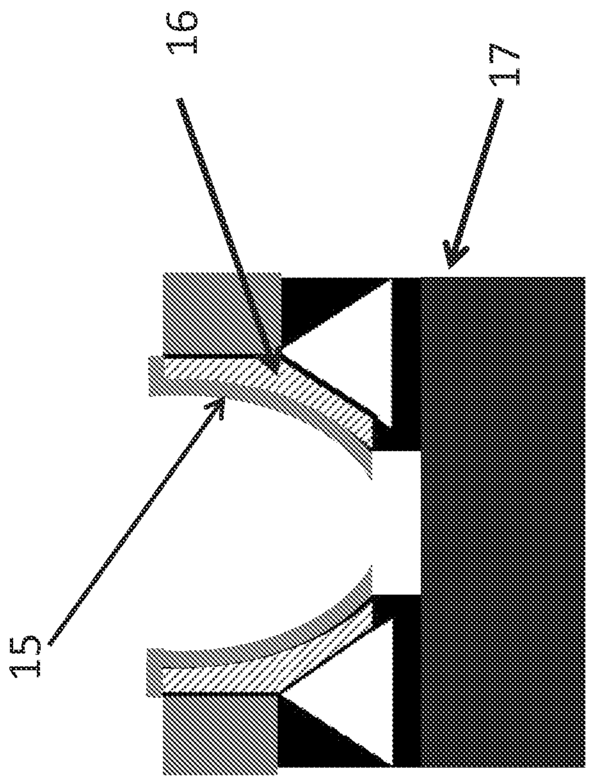


Figure 6



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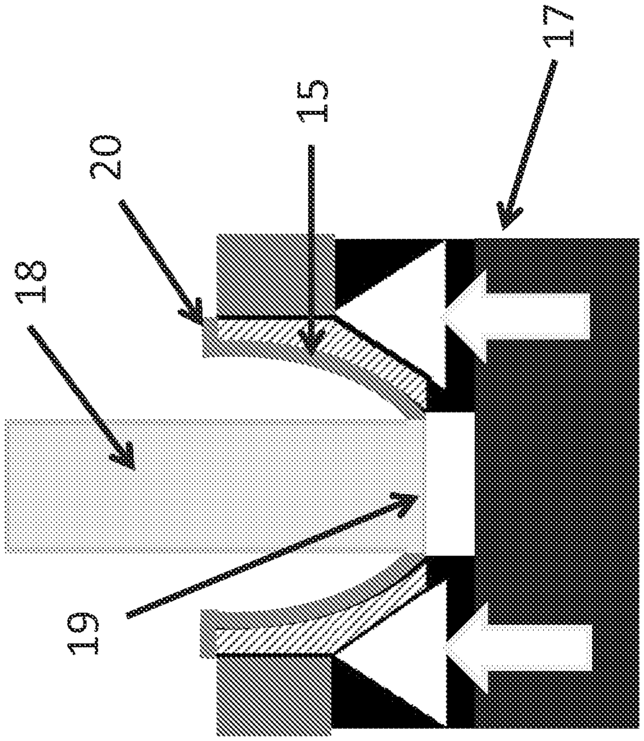


Figure 8

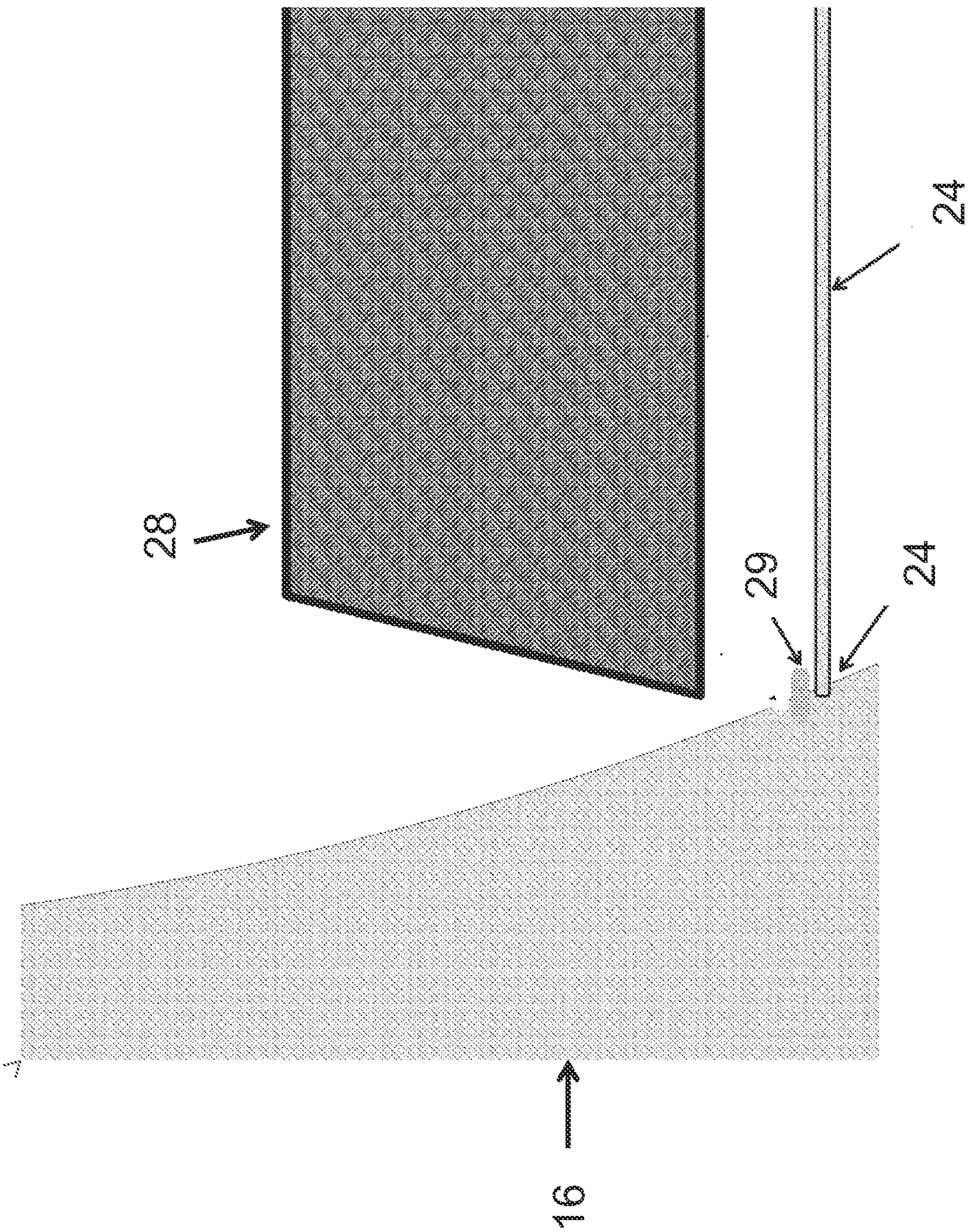


Figure 9

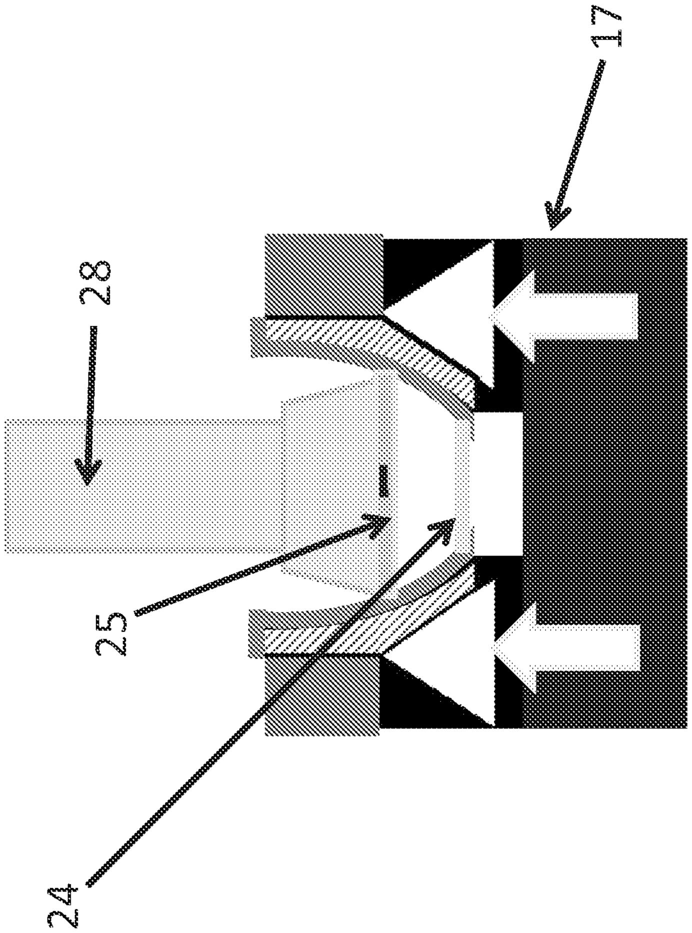


Figure 10

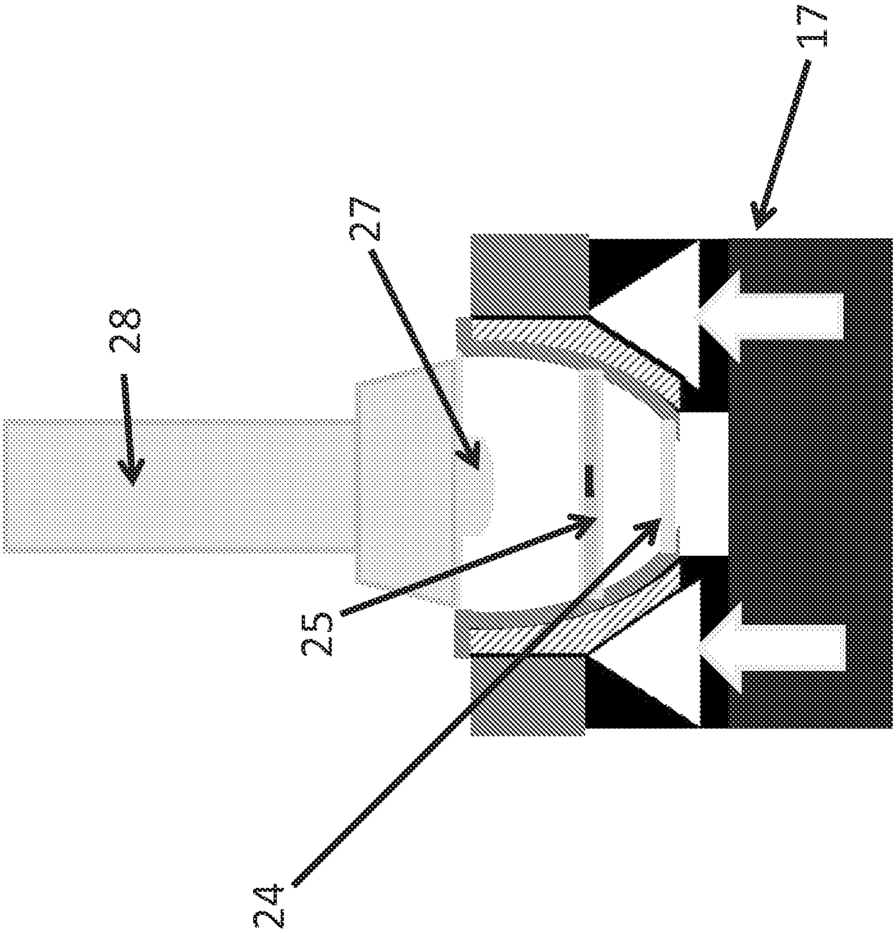


Figure 11

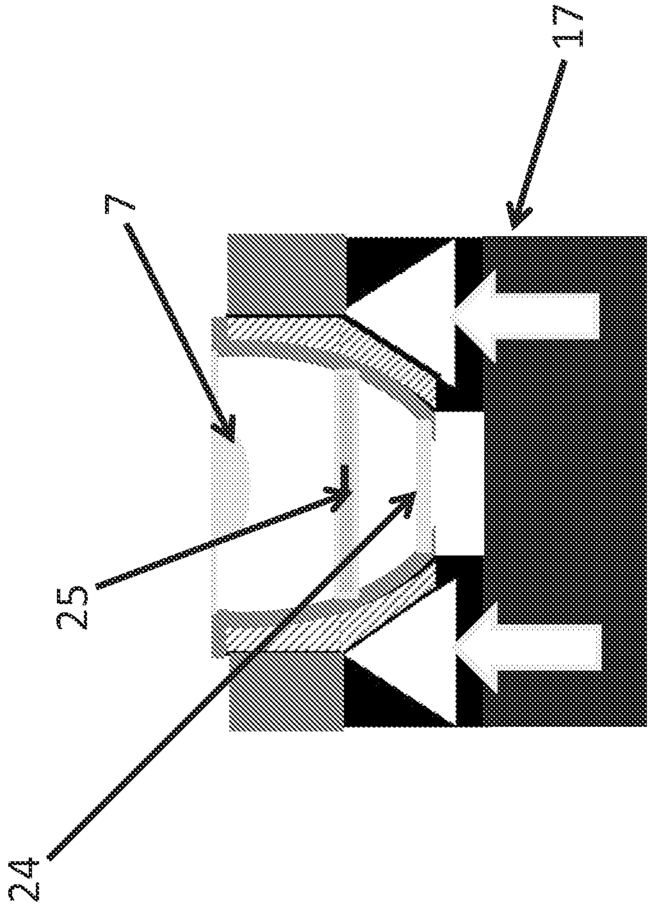


Figure 12

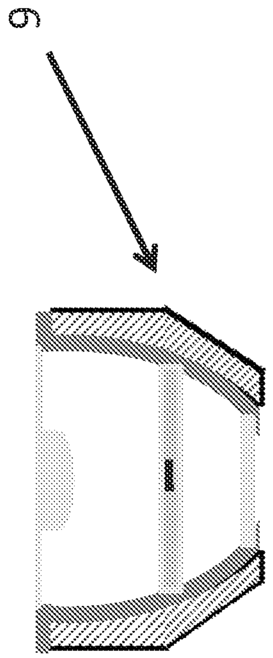


FIG. 13

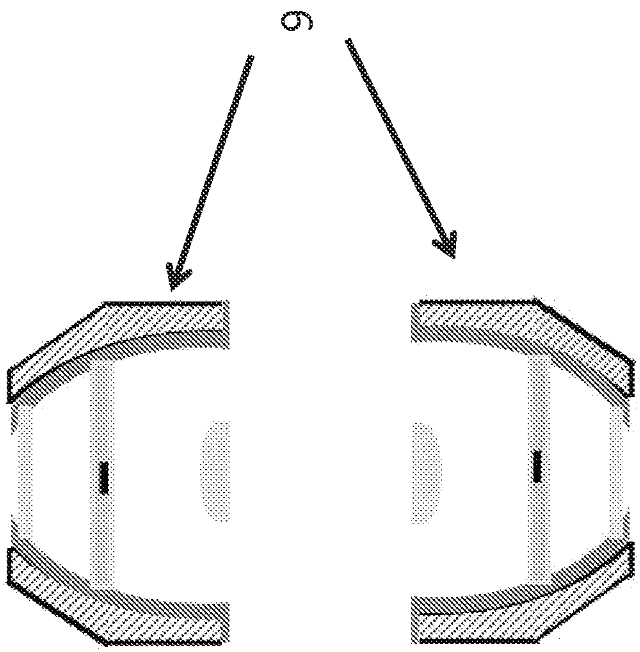
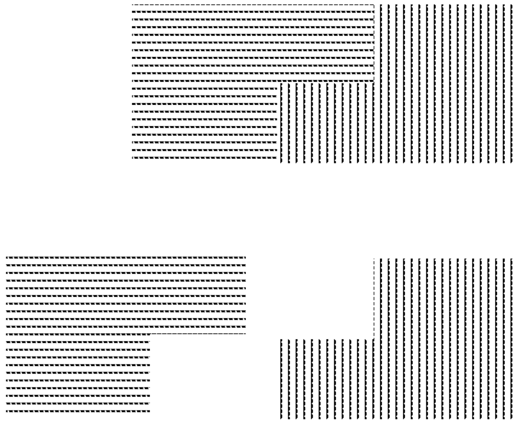


Figure 14



Contacting surfaces
in cross-section

INTERNATIONAL SEARCH REPORT

International application No.
PCT/US12/70519

A. CLASSIFICATION OF SUBJECT MATTER
IPC(8) - G21B 1/03; G21B 1/00; C25D 7/04 (2013.01)
USPC - 376/151, 202; 29/282
According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
IPC (8) - G21B 1/03; G21B 1/00; C25D 7/04 (2013.01)
USPC - 376/151, 152, 102, 202; 29/282

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)
MicroPatent (US-Granted, US-Applications, EP-A, EP-B, WO, JP, DE-G, DE-A, DE-T, DE-U, GB-A, FR-A); DialogPRO (Derwent, INSPEC, NTIS, PASCAL, Current Contents Search, Dissertation Abstracts Online, Inside Conferences); Google Scholar; Search terms used: hohlraum, cavity, manufacture, mandrel, electroplate, bath, inertial, confinement, fusion, press

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	US 5,908,285 A (GRAFF, J) June 1, 1999; column 4, lines 60-65; column 5, lines 10-15	1, 13 and 21
A	US 5,881,972 A (SMITH, B et al.) March 16, 1999; whole document	1-21
A	WO 2009/058185 A2 (MOSES, E et al.) May 7, 2009; paragraph [0127]	1-21

☐ Further documents are listed in the continuation of Box C. ☐

* Special categories of cited documents:
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"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art
"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
12 August 2013 (12.08.2013)	20 AUG 2013

Name and mailing address of the ISA/US	Authorized officer:
Mail Stop PCT, Attn: ISA/US, Commissioner for Patents P.O. Box 1450, Alexandria, Virginia 22313-1450 Facsimile No. 571-273-3201	Shane Thomas PCT Helpdesk: 571-272-4300 PCT OSP: 571-272-7774