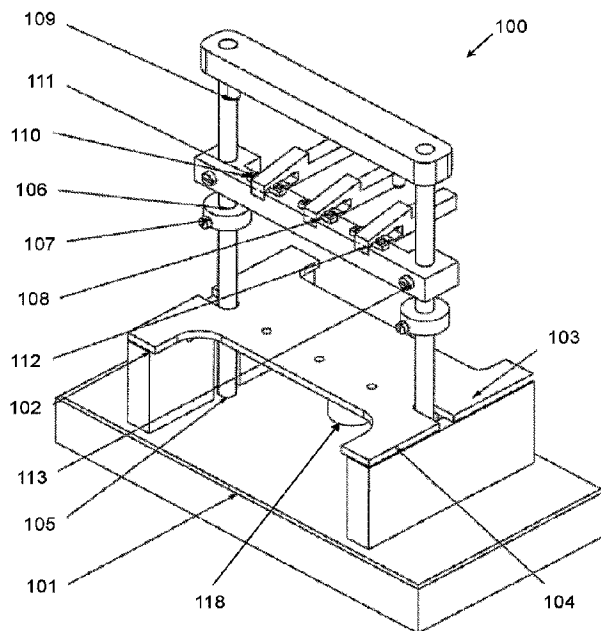




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(57) **Abrégé/Abstract:**

Disclosed herein are a system and method for electroplating an alpha emitting radionuclide, such as an actinide, for use in alpha spectroscopy. The electrodeposition system for electroplating an alpha emitting radionuclide can include an electroplating cell containing a solution of an electrolyte and the alpha emitting radionuclide, a metal target within the electroplating cell, and a metal anode at a distance from the metal target. The system also includes a platform for supporting the electroplating cell, coupling mechanism connected to the platform, an electric motor on the elastic cushion, and a flywheel with an uneven weight distribution operatively connected to the electric motor. Rotation of the unevenly distributed flywheel generates a vibration in the electroplating cell which dislodges gas bubbles that have formed between the metal target and the metal anode.



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SYSTEMS AND METHODS FOR ELECTROPLATING SOURCES FOR ALPHA SPECTROSCOPY

FIELD

[0001] The present disclosure relates to systems and methods for electroplating actinides onto a source in preparation for alpha spectroscopy to minimize gas bubbles between electrodes during electroplating.

BACKGROUND

[0002] Preparing alpha spectrometry sources requires plating a thin, uniform sheet of the material, such as an actinide, to minimize energy losses. If the coating is too thick, there will be attenuation of the alpha spectrum due to self-absorption. In addition, additional material cannot be covering the actinide, as this can also cause attenuation of the alpha spectrum.

[0003] Electrodeposition plays an important role in both purification and preparation of alpha spectrometry sources by providing a uniform and adherent source for high resolution alpha spectrometric measurement. However, during the electroplating procedure, various gas bubbles can form between the anode and the cathode. During an aqueous deposition process, gas is being formed at both electrodes. Hydrogen gas is being formed at the cathode, and oxygen gas at the anode. If left alone, these bubbles can act as insulators and slow or even stop the electroplating process.

BRIEF DESCRIPTION OF DRAWINGS

[0004] The description will be more fully understood with reference to the following figures and data graphs, which are presented as various examples of the disclosure and should not be construed as a complete recitation of the scope of the disclosure, wherein:

[0005] **FIG. 1** is an isometric view of the electrodeposition system in one example.

[0006] **FIG. 2A** is an isometric view of the base plate in one example.

[0007] **FIG. 2B** is an isometric view of the left platform support in one example.

[0008] **FIG. 2C** is an isometric view of the right platform support in one example.

[0009] **FIG. 2D** is an isometric view of the platform in one example.

[0010] **FIG. 2E** is another view showing the bottom of the platform in one example.

[0011] **FIG. 2F** is an view of the shaft in one example.

[0012] **FIG. 2G** is an isometric view of the sliding ring in one example.

[0013] **FIG. 2H** is an isometric view of the clip bar in one example.

[0014] **FIG. 2I** is an isometric view of the top shaft connection in one example.

[0015] **FIG. 2J** is another view showing the bottom of the top shaft connection in one example.

[0016] **FIG. 2K** is an isometric view of the clip holder in one example.

[0017] **FIG. 2L** is an isometric view of the motor housing in one example.

[0018] **FIG. 3A** is top view of the platform in one example.

[0019] **FIG. 3B** is a side view of the platform, coupling mechanism and platform supports in one example.

[0020] **FIG. 4** is a photograph of metal targets that can be used in the electrodeposition system in various example.

[0021] **FIG. 5** is a photograph of electroplating cells that can be used in the electrodeposition system in various examples.

[0022] **FIG. 6** is a photograph of a metal anode that can be used in the electrodeposition system in various examples.

[0023] **FIG. 7** is a photograph of a current source that can be used in the electrodeposition system in various examples.

[0024] **FIG. 8** is a photograph of an alpha fume hood that can be used with the electrodeposition system in various examples.

DETAILED DESCRIPTION

[0025] The disclosure can be understood by reference to the following detailed description, taken in conjunction with the drawings as described below. It is noted that, for purposes of illustrative clarity, certain elements in various drawings cannot be drawn to scale. In addition, numerous specific details are set forth in order to provide a thorough understanding of the implementations described herein. However, those of ordinary skill in the art will understand that the implementations described herein can be practiced without these specific details. In other instances, methods, procedures and components have not been described in detail so as not to obscure the related relevant feature being described. Also, the description is not to be considered as limiting the scope of the implementations described herein.

[0026] Several definitions that apply throughout this disclosure will now be presented. The term “coupled” as used herein can refer to the linking or connection of two objects. The coupling can be direct or indirect. An indirect coupling includes connecting two objects through one or more intermediary objects. Coupling can also refer to electrical or mechanical connections. Coupling can also include magnetic linking without physical contact.

[0027] Another term used herein is “electroplating cell.” An electroplating cell is any container that can be used to conduct an electrodeposition process. For example, an electroplating cell can be a container which includes a cathode, an anode, and an electrolyte solution.

[0028] Another term used herein is “coupling mechanism” is a mechanism that allows for vibrational motion of the platform in a planar direction. For example, a coupling mechanism can be a ball bearing or an elastic cushion.

[0029] The present disclosure provides a system and method for the electrodeposition of alpha emitting radionuclides on a target for use in an alpha spectrometer by dislodging gas bubbles that form between the electrodes in an electroplating cell. The systems and methods herein provide for electroplating alpha emitting radionuclides in a thin, uniform sheet without the presence of gas bubbles. The

reduction or absence of gas bubbles can reduce or prevent bubbles from acting as insulators or slow or even stop the electroplating process.

[0030] The electrodeposition system and method described herein provide for the electrodeposition of alpha emitting radionuclides onto a target that can then be counted under the vacuum of an alpha spectrometer. In various examples, the alpha emitting radionuclides can be actinides. Non-limiting examples of alpha emitting radionuclides include actinium, thorium, protactinium, uranium, neptunium, plutonium, americium, curium, berkelium, californium, einsteinium, fermium, mendelevium, nobelium, lawrencium, and any isotope thereof.

[0031] As seen in **FIG. 1**, the electrodeposition system **100** can include a base plate **101**, a platform **104** that is supported by a left platform support **102** and a right platform support **103**, a clip bar **108**, and a motor housing **118** with a motor **129** and flywheel **130**. The clip bar **108** is suspended above the platform **104** with at least two shafts **105** that extend from the base plate **101** to a top shaft connection **109**. The clip bar **108** can further include at least one clip holder **110** and at least one clip **112** in the clip holder **110**. The electrodeposition system **100** can further include a coupling mechanism **128** that allows vibrational motion of the platform **104** in its plane. In an example, there can be sliding ring stops **106** on each of the shafts **105** below the clip bar **108**. The sliding ring stops **106** can attach to the shafts **105** by screws **107**, the clip bar **108** can attach to the shafts **105** by screws **113**, and the clip holders **110** can attach to the clip bar **108** by screws **111**.

[0032] The electrodeposition system **100** can further include at least one electroplating cell **117** supported by the platform **104**. An electroplating cell **117** is any container that can be used to conduct an electrodeposition process. For example, the electroplating cell **117** may be configured to include a metal target **119** that acts as the cathode, a metal anode **116**, and an electrolyte solution with the alpha emitting radionuclide.

[0033] **FIG. 5** is an example of an electroplating cell **117** that can be used with the electrodeposition system **100**. In an example, the metal target **119** can be placed within the electroplating cell **117** or rest at the bottom of the electroplating cell **117** and

the metal anode **116** can be hanging from a clip **112** in a clip holder **110** on a clip bar **108** or other support above the electroplating cell **117** by a wire **115**. In this example, the metal anode **116** may be hanging such that the metal anode **116** sits in the electrolyte solution at the top of the electroplating cell **117**. The electrodeposition system **100** can include any number of electroplating cells **117** needed for the desired output of electroplated disks. In an example, the electrodeposition system **100** can include at least about 1 electroplating cell, at least about 2 electroplating cells, at least about 3 electroplating cells, at least about 5 electroplating cells, or at least about 10 electroplating cells, each of which include their own cathode target and anode. In one example, the electrodeposition system **100** can have up to about 3 electroplating cells **117** with 3 adjustable plating positions with isolated contacts for the hanging metal anodes **116**.

[0034] The electrodeposition system **100** includes a metal target **119**, as seen in **FIG. 4**. In various examples, the metal target **119** can be a metal disk, such as a stainless steel disk or another metal disk with a clean surface. The metal target can also take on other shapes as needed to fit within an alpha spectrometer. The electrodeposition system **100** further includes a metal anode **116**, as seen in **FIG. 6**. The metal anode **116** can include, but is not limited to platinum, a platinum-iridium alloy, or other noble/inert metals, including for example ruthenium, rhodium, palladium, silver, osmium, iridium, platinum, and gold. The metal anode **116** can be suspended from a wire **115** that is held in place by a clip **112** on the clip bar/holder **108/110** of the electrodeposition system **100**. In at least one example, all materials used in the electroplating cell **117** are chemical and corrosion resistant. The cathode and the anode can together be referred to as the electrodes of the electroplating cell **117**.

[0035] Further included in the electrodeposition system **100** is an elongated clip bar **108** that is suspended above the platform **104** by at least two shafts **105** and spans the length of the platform **104**. As seen in **FIG. 1**, **FIG. 2H**, and **FIG. 2K**, the clip bar **108** can have multiple grooves for receiving a clip holder **110** and/or a clip **112**. In one example, a clip holder **110** can sit in the groove of the clip bar **108** and a clip **112** can

attach to the clip holder **110**. In various examples, the clip bar **108** can include at least three grooves such that the clip bar **108** can hold at least three clips **112**. Each of the at least three clips **112** can be used to suspend a metal anode **116** by a wire **115** into at least three separate electroplating cells **117**. The clip bar **108** can further include at least two openings, each for receiving a shaft **105**. The openings can be on opposite ends of the clip bar **108** as to not interfere with the clips **112** on the clip bar **108** or the electroplating cells **117** below the clip bar **108**. Screws **113** can be used to adjust the height of the clip bar **108** above the platform **104**.

[0036] As seen in **FIG. 1** and **FIG. 2A**, the base plate **101** supports the electrodeposition system **100**. In an example, the base plate **101** may be about 30 cm to about 35 cm in length, about 15 cm to about 20 cm in width, and about 3 cm to about 5 cm in height. The platform **104** is supported by a left platform support **102** and a right platform support **103**. The left platform support **102** and the right platform support **103** may be about 10 cm to about 20 cm in length, about 2 cm to about 5 cm in width, and about 5 cm to about 10 cm in height. In an example, the platform **104** is about 20 cm to about 25 cm in length, about 10 cm to about 20 cm in width, and about 0.5 cm to about 1 cm in thickness.

[0037] The platform **104**, as seen in **FIG. 2D**, **FIG. 2E**, and **FIG. 3A**, has a general rectangular or “I” shape with grooves **121** for guiding the shafts **105** in a vertical orientation. In an example, the width and length of the grooves **121** are larger than the diameter of the shafts **105** such that the shafts **105** within the grooves **121** do not make contact with the platform **104** and allow for the vibrational movement of the platform **104**. The platform **104** can include openings **122** that extend the full thickness of the platform **104** for accepting or connecting the cathode or metal target **119** in the electroplating cell **117**. The number of openings **122** corresponds to the number of electroplating cells **117** being supported by the platform **104**. The platform **104** can also include a motor recess **127** for receiving the motor housing **118** containing the motor **129** and the flywheel **130**. In various examples, the motor housing **118** may or may not contact the platform **104**. The platform **104** can be made of PCV to provide for easy

transfer of the vibrational motion from the motor **129** and flywheel **130** to the platform **104**.

[0038] As illustrated in **FIG. 2E**, the platform **104** can also include receiving recesses **123** on the lower surface **124** of the platform **104**. In an example, the platform **104** can include at least 2 receiving recesses **123** or at least 4 receiving recesses **123**. The receiving recesses **123** can be on each corner of the platform **104** and may not extend the full thickness of the platform **104**. As seen in **FIG. 3B**, the system **100** can include at least 2 or at least 4 coupling mechanisms **128** which can be situated within or be incorporated into the receiving recesses **123**. The coupling mechanisms **128** can extend beyond the lower surface **124** of the platform **104** such that the platform **104** rests on the coupling mechanism **128** when the platform **104** rests on the left and right platform supports **102/103**. In an example, the coupling mechanism **128** can be situated within corresponding support receiving recesses **125** on the left and right platform supports **102/103**. The left platform support **102** can include at least one or at least two support receiving recesses **125** and the right platform support **103** can include at least one or at least two support receiving recesses **125**. In an example, the left platform support **102** can couple to at least one coupling mechanism **128** on the lower surface **124** of a first end of the platform **104** and the right platform support **103** can couple to at least one coupling mechanism **128** on the lower surface **124** of a second end of the platform **104**. In various examples, the coupling mechanisms **128** can be ball bearings, an elastic cushion, or any material which allows for the vibrational motion of the platform **104** by transferring the motion of the motor **129** and flywheel **130** to the platform **104**. The ball bearings can be stainless steel balls having a diameter of about 1 cm in one example. If ball bearings are used as the coupling mechanism **128**, the receiving recesses **123** and the support receiving recesses **125** can have a length, width, or both that is wider than the point of contact for the ball bearing to allow for free motion of the platform in a plane along its width and/or length.

[0039] The elastic cushion can be made of any elastomeric material that allows for the transfer of energy from the flywheel to the electroplating cells. In one example, the elastic cushion is rubber. The elastic cushion can be any shape or size necessary to

suspend and cushion the platform **104**. In various aspects, the elastic cushion can be circular, oval, or rectangular. In another example, the platform **104** includes at least two tabs (not shown) made of the elastic cushion material that can be inserted into corresponding support grooves **126** on the left and right platform supports **102/103** to allow vibrational movement of the platform **104**. In an example, the platform **104** can include at least 2 tabs or at least 4 tabs which can be seated within at least at least one support groove **126** or at least two support grooves **126** on each of the left and right platform support **102/103**, respectively. In yet another example, the platform **104** does not couple or touch the left or right platform supports **102/103**.

[0040] As seen in **FIGS. 2B** and **2C**, the left and right platform supports **102/103** can also include longitudinal grooves **120** for guiding the shafts **105** in a vertical orientation. The shafts **105**, as seen in **FIG. 2F**, can connect to the base plate **101** at a first end and connect to a top shaft connection **109** at a second end. **FIG. 2I** shows that the top shaft connection **109** can include at least two openings for receiving the shafts **105** at opposing ends of the top shaft connection **109**. As seen in **FIG. 2J**, the top shaft connection **109** can further include at least two parallel pins **114** for spacing the distance between the clip bar **108** and the top shaft connection **109**. In various examples, the clip bar **108**, the platform **104**, the left platform support **102**, and the right platform support **103** can attach to or rest on the shafts **105** at points between the base plate **101** and the top shaft connection **109**. In other examples, as seen in **FIG. 1** and **FIG. 2G**, the electrodeposition system **100** can include sliding ring stops **106** coupled to the rods with screws **107** between the clip bar **108** and the platform **104**. The sliding ring stops **106** can be set at a height on the shafts **105** such that it limits the distance that the clip bar **108** can be lowered. The sliding ring stops **106** therefore prevent the metal anode **116** from being lowered a distance in which it would touch the metal target **119** and short the electroplating cell.

[0041] The electrodeposition system **100** can further include a current source and/or a voltage source, as seen in **FIG. 7**, to provide current between the anode and cathode and drive the deposition of the alpha emitting radionuclide on the cathode

metal target **119**. The current source and/or the voltage source can provide stable and constant current or potential and both values can be adjustable.

[0042] The electrodeposition system **100** can further include a motor **129** and a flywheel **130**. In an example, the motor and the flywheel can be contained within the motor housing **118**, as seen in **FIG. 1**, **FIG. 2L**, and **FIG. 3A**. In various examples, the motor **129** in the motor housing **118** can rest on top of, sit below, or be mounted on the base plate **101** or the platform **104**. The motor **129** is coupled to the flywheel **130**, and the flywheel **130** can be in any orientation such that it acts as a mechanical oscillator. The motor **129** can be configured to rotate the flywheel **130**. In addition, the platform **104** supporting the electroplating cell **117** of the electrodeposition system **100** can be vibrated by the motion of the motor **129** and flywheel **130** through the coupling mechanism **128**. The coupling mechanism **128** provides for transferring the kinetic energy from the flywheel **130** of the motor **129** to the electroplating cell **117** sitting on the platform **104**. In an example, the motor can be mounted on the elastic cushion or the motor can be below the elastic cushion. The motor can be an electric motor that is capable of rotating the flywheel. In various examples, the motor frequency can range from about 1 Hz to about 5 Hz, from about 5 Hz to about 10 Hz, from about 10 Hz to about 15 Hz, from about 15 Hz to about 20 Hz, from about 20 Hz to about 25 Hz, and from about 25 about 30 Hz. In an example, the motor can rotate the flywheel at a speed ranging from about 1 Hz to about 10 Hz. The flywheel can be rotated at about 2 Hz to about 3 Hz, in one example. The speed of rotation of the motor can be adjustable such that the rotation is sufficient to create a vibration in the flywheel to dislodge gas bubbles while not strong enough to cause the electrolyte solution to spill out of the electroplating cell.

[0043] To create the vibration, the flywheel can have an uneven weight distribution. In an example, the flywheel can be heavier on one side than the other side to create the uneven weight distribution. The uneven weight distribution in combination with the rotation of the flywheel can cause the flywheel to vibrate and therefore cause the platform holding the electroplating cell(s) to vibrate. The vibration can then cause any bubbles that have formed between the electrodes of the electroplating cell to be

dislodged or rocked up to the surface of the electrolyte solution and therefore the bubbles are no longer between the electrodes to interfere with the electroplating process.

[0044] Gas bubbles can form between the metal anode and the metal target receiving the alpha emitting radionuclide. If left alone, the bubbles can act as insulators and slow or even stop the electroplating process. Because of the sensitivities of alpha spectroscopy, any impurities can affect the output of the spectrometer. For example, impurities or disruption of the electroplating process can result in a false lower energy reading or broader peaks in the spectra. Therefore, the electrodeposition system can be used when electroplating an alpha emitting radionuclide on a metal target to remove the bubbles from between the electrodes and reduce the likelihood of impurities or an incomplete deposition.

[0045] The method for electroplating an alpha emitting radionuclide on a metal target for alpha spectroscopy can include vibrating an electroplating cell using an unevenly distributed flywheel to dislodge gas bubbles that have formed in the electrolyte solution between the electrodes of the electroplating cell. The vibration can dislodge the gas bubbles to the surface of the solution such that the gas bubbles do not interfere with, slow, or stop the electroplating process. The method can further include chemically purifying an alpha emitting radionuclide, transferring the purified alpha emitting radionuclide to a suitable electrolyte, placing the electrolyte-radionuclide solution into an electroplating cell containing a metal target, and inserting a metal anode into the solution prior to vibrating the electroplating cell. The electroplating cell, including the metal anode, is then placed onto a platform of the electrodeposition system for dislodging and removing gas bubbles from between the electrodes of the electroplating cell.

[0046] The method can further include using a current source and/or a voltage source to apply a current or voltage between the anode and cathode to drive the deposition of the alpha emitting radionuclide on the cathode metal target. In an example, the current between the electrodes can range from about 0.5 A to about 5 A. In various examples, the current may range from about 0.5 A to about 1.5 A, from about

1 A to about 2 A, from about 1.5 A to about 2.5 A, from about 2 A to about 3 A, from about 2.5 A to about 3.5 A, from about 3 A to about 4 A, from about 3.5 to about 4.5 A, and from about 4 A to about 5 A. In one example, the current can be about 1 A. In another example, the voltage provided by the current source and/or voltage source can range from about 5 V to about 10 V, from about 10 V to about 15 V, from about 15 V to about 20 V, and from about 20 V to about 25 V. Since gas bubbles have a higher electrical resistance than either the alpha emitting radionuclide or the electrolyte solution itself, the amount of gas has a significant effect on the current at a given applied voltage. For example, a high amount of bubbles between the electrodes can require a larger current to drive the electrodeposition, or could even stop the electrodeposition process altogether before it is complete. Therefore, the electrodeposition method provided herein, which either provides a low amount of bubbles or no bubbles between the electrodes, can require a lower current and/or voltage than conventional electrodeposition without the removal or reduction of the gas bubbles. The electrodeposition method thus provides a more reliable and consistent method for electrodeposition.

[0047] The electroplating process should be run long enough for the alpha emitting radionuclide to be deposited on the metal target. If the amount of alpha emitting radionuclide is too thick on the metal target, then the resulting alpha spectroscopy signal can be attenuated. In at least one example, only a few trillion atoms can be deposited on the metal target, which results in no measureable thickness and no visible quantities. The electrodeposition process can run for about 30 minutes to about 2 hours. In at least one example, the electrodeposition process can run for about 1 hour.

[0048] Having described several examples, it will be recognized by those skilled in the art that various modifications, alternative constructions, and equivalents can be used without departing from the spirit of the invention. Additionally, a number of well-known processes and elements have not been described in order to avoid unnecessarily obscuring the present invention. Accordingly, the above description should not be taken as limiting the scope of the invention.

[0049] Those skilled in the art will appreciate that the presently disclosed examples teach by way of example and not by limitation. Therefore, the matter contained in the above description or shown in the accompanying drawings should be interpreted as illustrative and not in a limiting sense. The following claims are intended to cover all generic and specific features described herein, as well as all statements of the scope of the present method and system, which, as a matter of language, might be said to fall therebetween.

The embodiments of the present invention for which an exclusive property or privilege is claimed are defined as follows:

1. An electrodeposition system for electroplating an alpha emitting radionuclide comprising:
 - at least one electroplating cell comprising:
 - a solution comprising an electrolyte and the alpha emitting radionuclide;
 - a metal target, wherein the metal target is a cathode; and
 - a metal anode at a distance from the metal target;
 - a current source to generate a current between the metal target and the metal anode;
 - a platform operable to support the electroplating cell;
 - a coupling mechanism coupled to the platform;
 - an electric motor proximate to the platform;
 - a flywheel with an uneven weight distribution coupled to the electric motor; and
 - a clip bar supported above the platform using at least two shafts, wherein the clip bar comprises at least one clip such that the metal anode is suspended by a wire from the clip on the clip bar above the electroplating cell and placed in the solution within the electroplating cell, and
 - wherein the electrochemical cell is configured to electroplate the alpha emitting radionuclide on the metal target.
2. The electrodeposition system of claim 1, wherein the alpha emitting radionuclide is an actinide.
3. The electrodeposition system of claim 1, wherein the flywheel is configured to rotate to generate a vibration of the platform and the at least one electroplating cell through the coupling mechanism.

4. The electrodeposition system of claim 3, wherein the vibration of the at least one electroplating cell is configured to dislodge gas bubbles that have formed between the metal target and the metal anode.

5. The electrodeposition system of claim 1, wherein the metal target comprises a stainless steel disk.

6. The electrodeposition system of claim 1, wherein the metal anode comprises platinum.

7. A method for electroplating an alpha emitting radionuclide, the method comprising:

placing at least one electroplating cell on a platform connected to a coupling mechanism;

placing a clip bar supported above the platform using at least two shafts, wherein the clip bar comprises at least one clip such that a metal anode is suspended by a wire from the clip on the clip bar above the at least one electroplating cell;

placing the metal anode in a solution comprising an electrolyte and the alpha emitting radionuclide within the at least one electroplating cell;

rotating a flywheel with an uneven weight distribution operatively connected to a motor to create a vibration of the flywheel;

generating a vibration in the at least one electroplating cell on the platform from the vibration of the flywheel; and

generating a current between a metal target and the metal anode in the solution within the electroplating cell.

8. The method of claim 7, wherein the alpha emitting radionuclide is an actinide.

9. The method of claim 7, wherein the vibration of the at least one electroplating cell dislodges gas bubbles that have formed between the metal target and the metal anode.

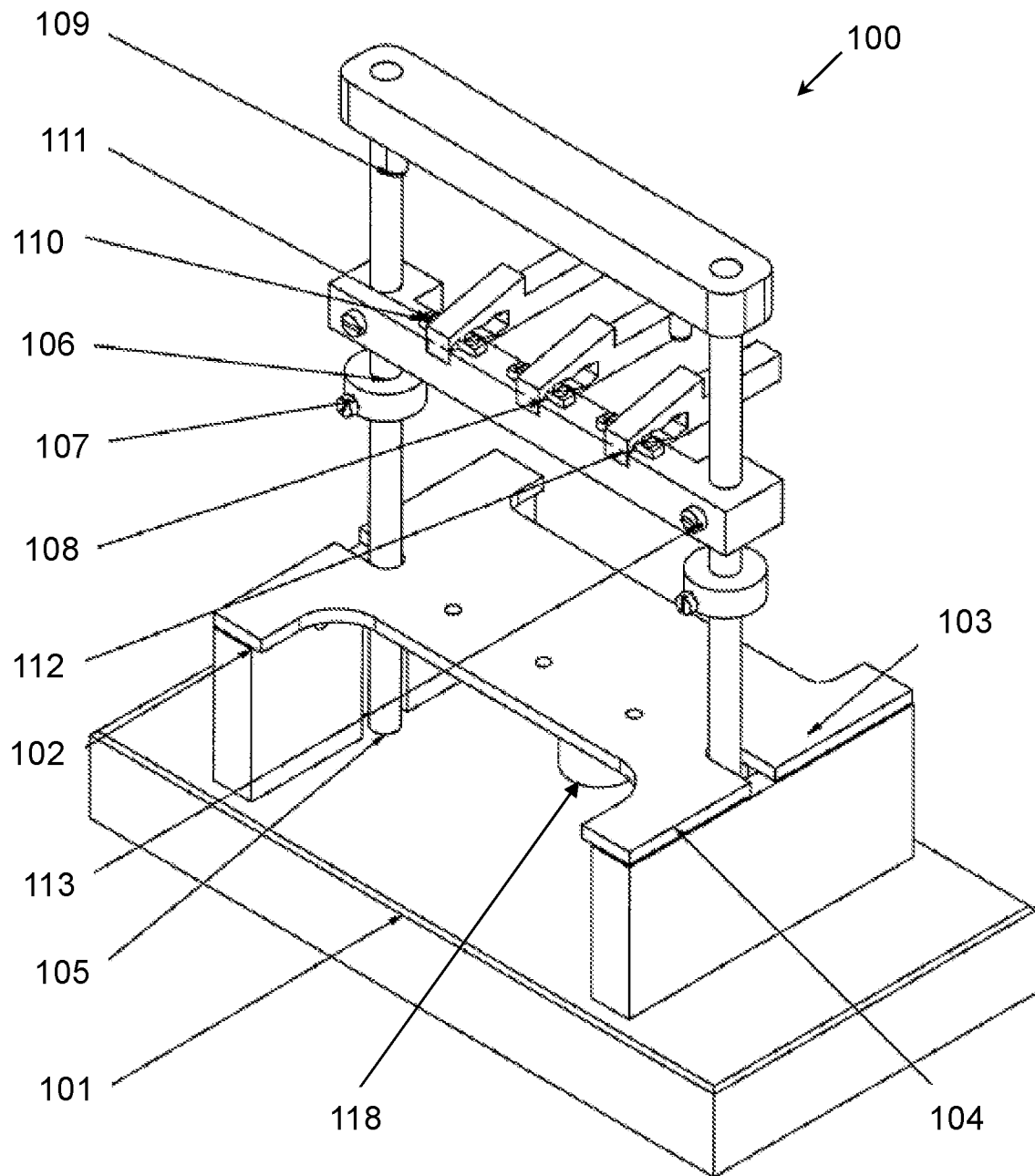
10. The method of claim 7, wherein the metal target comprises a stainless steel disk.

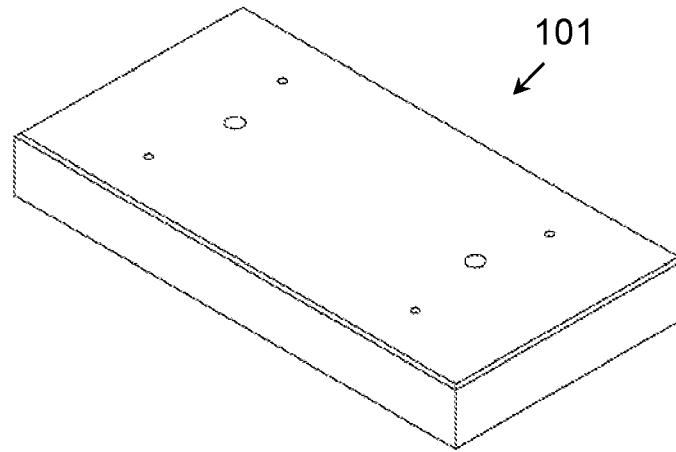
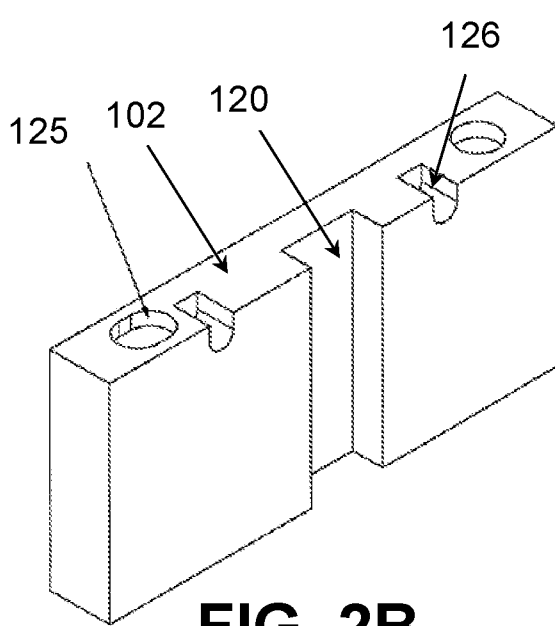
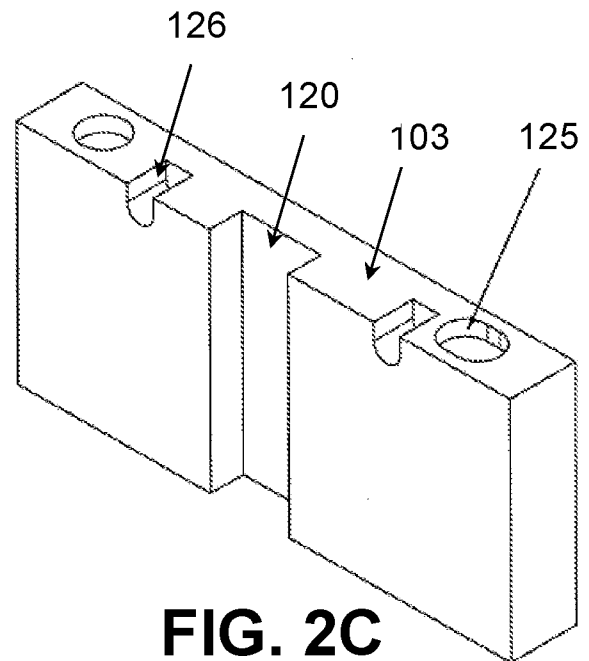
11. The method of claim 7, wherein the metal anode comprises platinum.

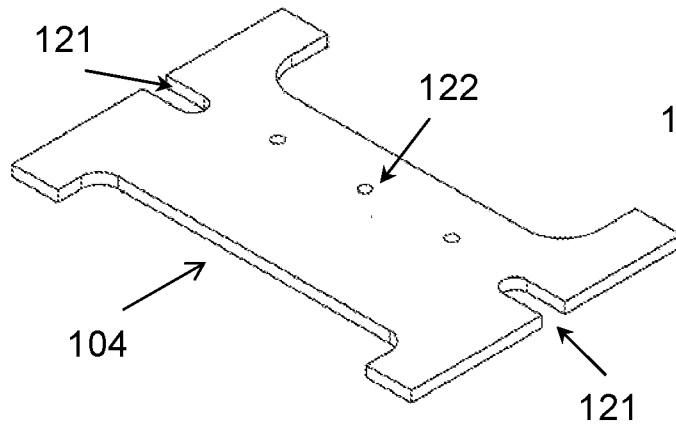
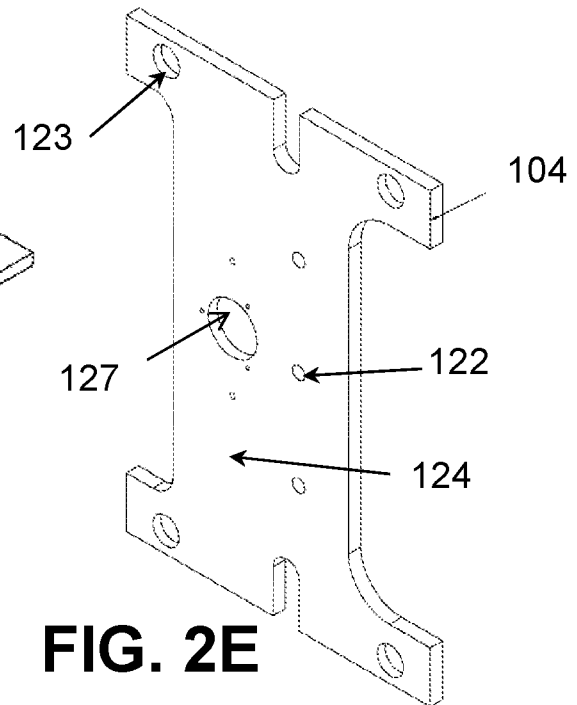
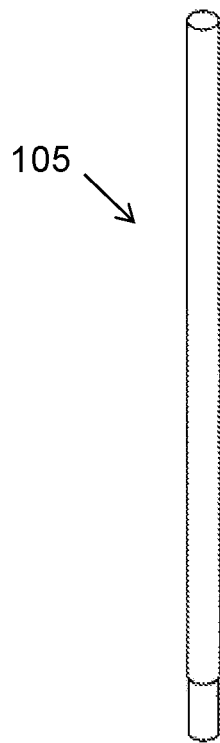
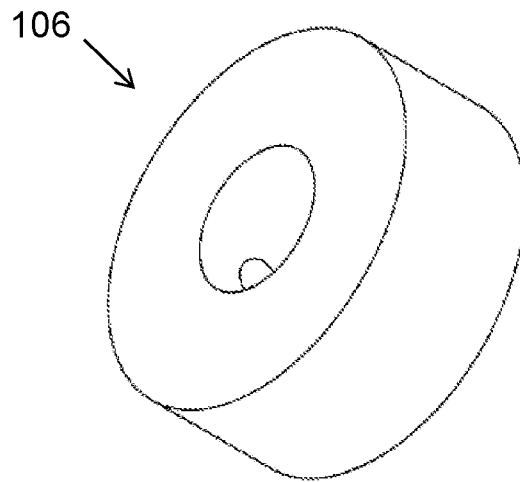
12. The method of claim 7, wherein the current between the metal target and the metal anode is between about 0.5 A and about 5 A.

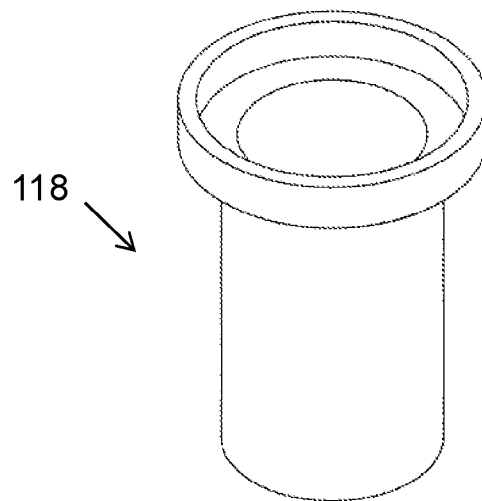
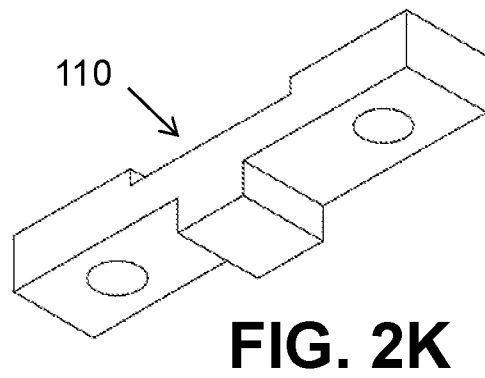
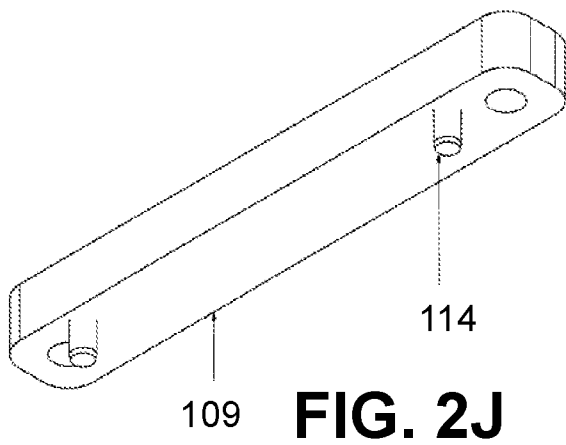
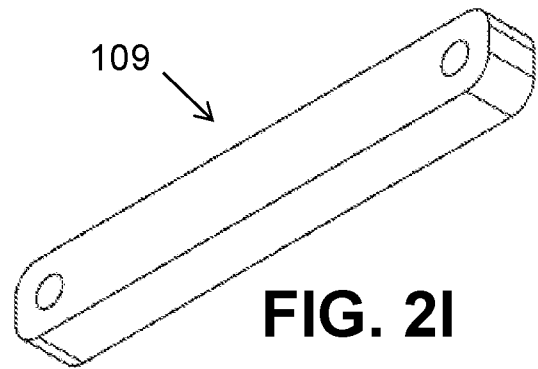
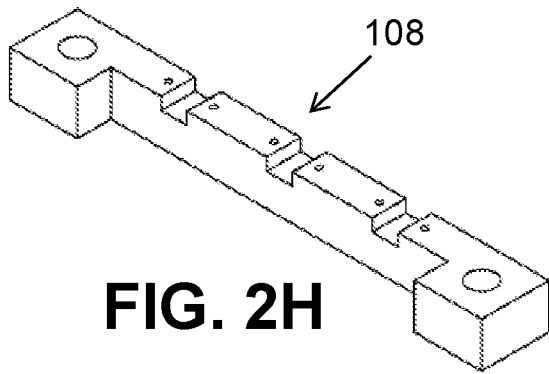
13. The method of claim 12, wherein the current between the metal target and the metal anode is about 1 A.

14. The method of claim 7, wherein the current is generated and the at least one electroplating cell is vibrated between about 30 minutes and about 2 hours.

**FIG. 1**

**FIG. 2A****FIG. 2B****FIG. 2C**

**FIG. 2D****FIG. 2E****FIG. 2F****FIG. 2G**



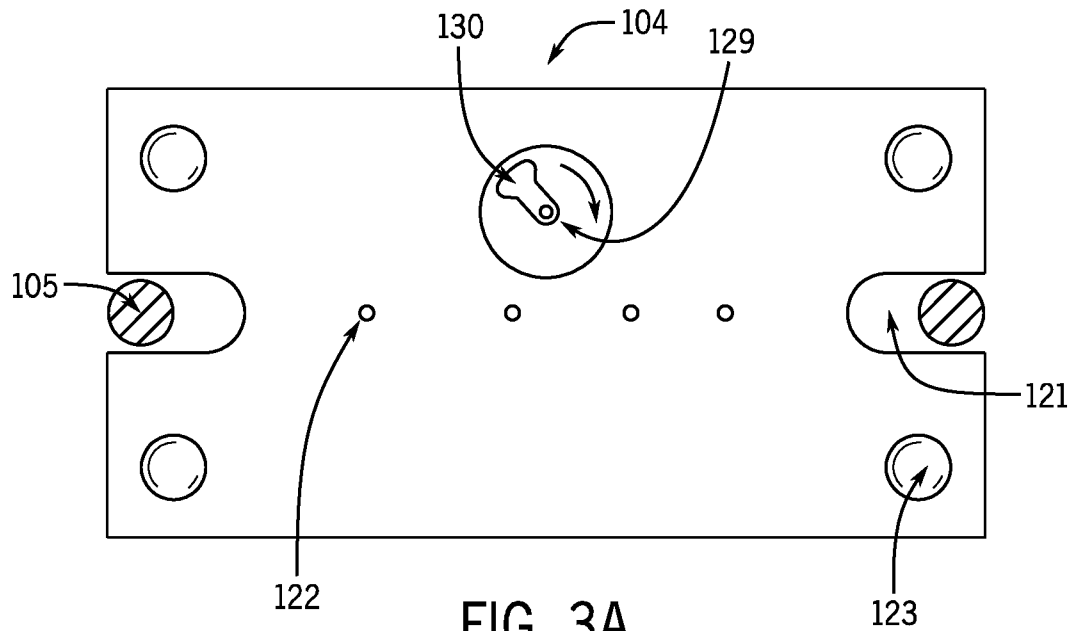


FIG. 3A

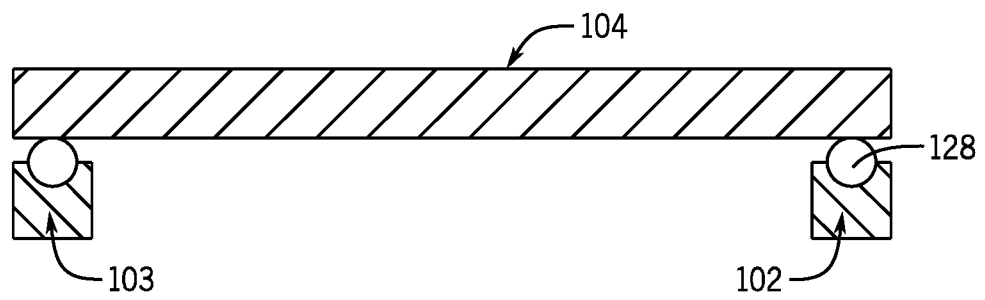
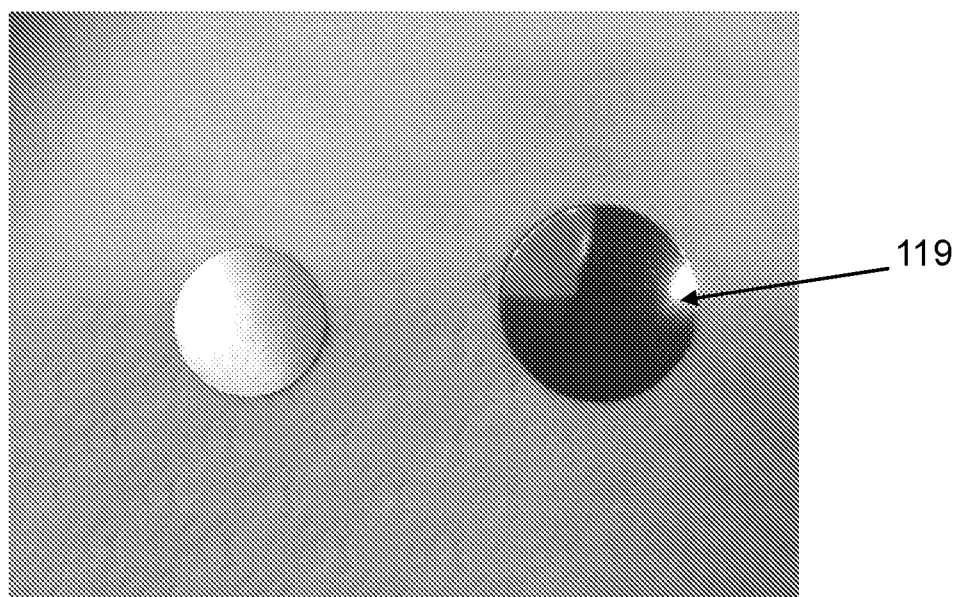
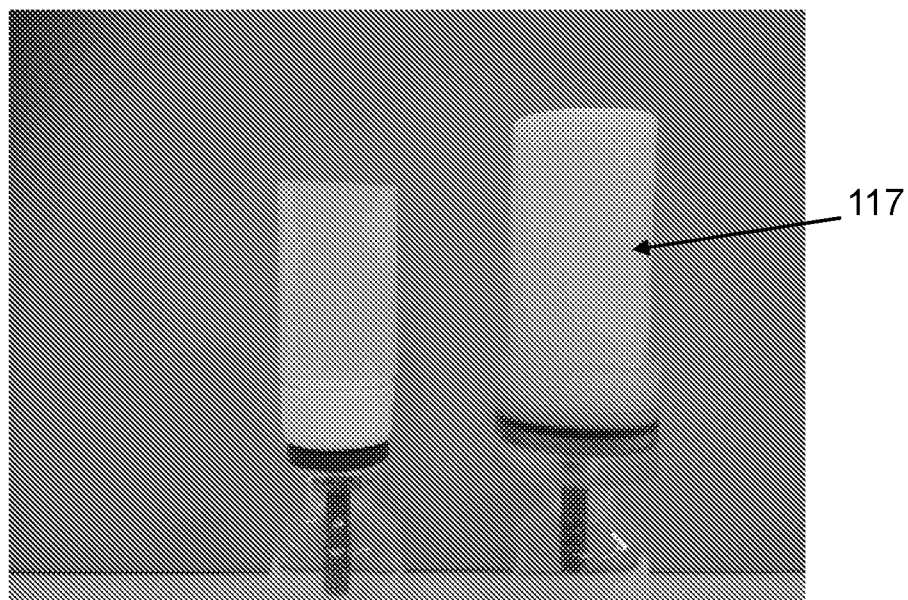
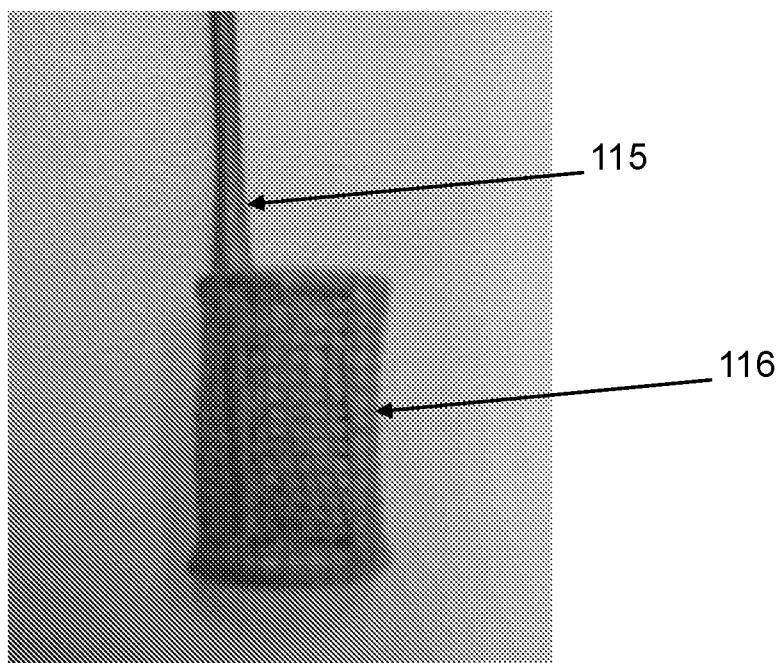
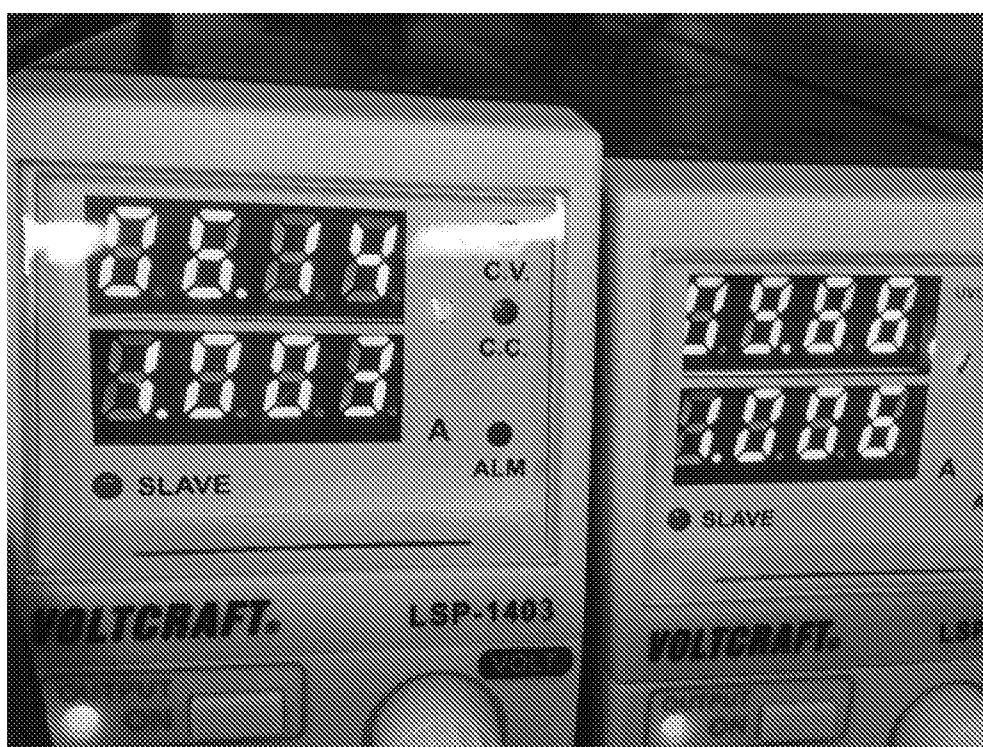


FIG. 3B

**FIG. 4****FIG. 5**

**FIG. 6****FIG. 7**

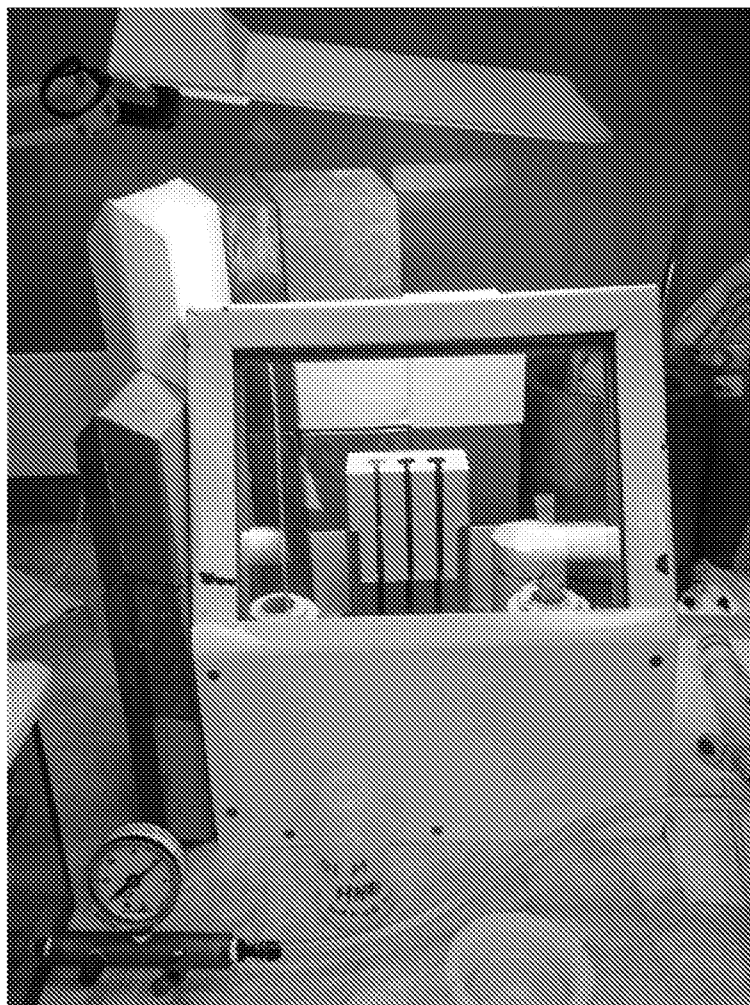


FIG. 8

