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(54) Title: AMPLIFICATION OF ENERGETIC REACTIONS

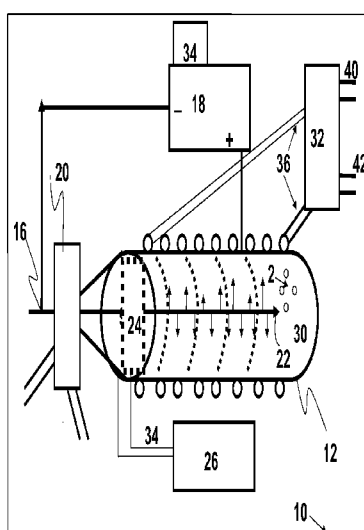


FIG. 1

(57) Abstract: Methods and apparatus for energy production through the amplification of energetic reactions. A method includes amplifying an energy release from a dispersion of nanoparticles containing a concentration of hydrogen/deuterium nuclei, the nanoparticles suspended in a dielectric medium in a presence of hydrogen/deuterium gas, wherein an energy input is provided by high voltage pulses between two electrodes embedded in the dispersion of nanoparticles.

## AMPLIFICATION OF ENERGETIC REACTIONS

## CROSS-REFERENCE TO RELATED APPLICATIONS

[001] This application claims the benefit of U.S. Provisional Application No. 61/341,198, filed March 29, 2010, and titled "Amplification of Nuclear Reactions in Metal Nanoparticles," which is incorporated by reference in its entirety.

## BACKGROUND OF THE INVENTION

[002] The present invention relates to energy production, and more particularly to amplification of energetic reactions.

[003] Conventional energy sources include fossil fuels, water power, nuclear energy, wind power, hydrogen, solar light, and so forth. However, when these energy sources are used, serious problems may arise, including exhaustion of resources, environmental destruction, inefficiency and so forth. Therefore, there are concerns over the use of these energy sources for the future. On the other hand, ultrahigh temperature nuclear fusion has been proposed as a new energy source, however, its practical use is still distant.

[004] Methods of utilizing electrolysis have been developed as an energy source. However, for most of them, there are doubts about the possibility of the practical use as an energy source.

## SUMMARY OF THE INVENTION

[005] The present invention provides methods and apparatus for amplification of energetic reactions.

[006] In general, in one aspect, the invention features a method including amplifying an energy release from a dispersion of nanoparticles containing a concentration of hydrogen/deuterium nuclei, the nanoparticles suspended in a dielectric medium in a presence of hydrogen/deuterium gas, wherein an energy input is provided by high voltage pulses between two electrodes embedded in the dispersion of nanoparticles.

[007] In another aspect, the invention features a method including amplifying an energy release from a dispersion of nanoparticles containing a concentration of hydrogen/deuterium nuclei, the nanoparticles suspended in water/heavy water dielectric medium, an energy input

provided by high voltage pulses between two electrodes embedded in the nanoparticle suspension.

[008] In another aspect, the invention features a method including amplifying an energy release from a dispersion of nanoparticles in a 3-20 nanometer (nm) size regime containing a concentration of hydrogen/deuterium nuclei, an energy input provided by a source of terahertz frequency electromagnetic energy.

[009] In another aspect, the invention features a method including amplifying an energy release from a dispersion of hydrated macroparticles containing a dispersion of nanoparticles in a 3-20 nanometer (nm) size regime by fluidizing the nanoparticles in a stream of gas or liquid or by simple mechanical agitation and then subjecting the fluidized particles to excitation by high voltage pulses, ultrasonic agitation and/or terahertz frequency range electromagnetic waves.

[0010] Other features and advantages of the invention are apparent from the following description, and from the claims.

#### BRIEF DESCRIPTION OF THE DRAWINGS

[0011] The invention will be more fully understood by reference to the detailed description, in conjunction with the following figures, wherein:

[0012] FIG. 1 is a block diagram of an exemplary apparatus.

[0013] FIG. 2 is a block diagram of an exemplary apparatus.

[0014] FIG. 3 is an exemplary diagram.

[0015] FIG. 4 is an exemplary circuit diagram.

[0016] FIG. 5 is an exemplary wave form.

[0017] FIG. 6 is an exemplary circuit diagram.

[0018] FIG. 7 is an exemplary diagram.

[0019] FIG. 8 is an exemplary diagram.

[0020] Like reference numbers and designations in the various drawings indicate like elements.

## DETAILED DESCRIPTION

[0021] Nanoscale metal particles that dissolve hydrogen isotopes can promote nuclear reactions under near equilibrium conditions. The reaction rates are greatly enhanced by the addition of localized energy input, which can include, for example, dielectric discharges, terahertz electromagnetic radiation or ultrasonic energy beyond a specific threshold.

[0022] Useful energy production can be obtained when deuterated/hydrated nanoparticles suspended in a dielectric medium are positioned interior to collapsing bubbles or dielectric discharges and their attendant shock waves. Highly self-focused shock waves have a sufficiently high energy density to induce a range of energetic reactions.

[0023] Certain nanopowders of metal or metal alloys are incipiently active sites for energy release. Adding nanoparticles to the water greatly increases energetic reaction rates as the nanoparticles focus ultrasonic shock wave energy onto particles that are incipiently prepared to react. The focusing of shock energy is maximized by having very small particles inside the collapsing shock wave at millions of locations in a liquefied reaction zone.

[0024] Ultrasonic amplification may have usefulness, but it is inferior to arc discharges through nanocomposite solids due to a process called the "inverse skin effect." In ordinary metals, a rapid pulse of current remains close to an outer surface in a process referred to as the "skin effect." Typically, the electric current pulses flow on the outer surface of a conductor. Discharges through a dielectric embedded with metallic particles behave very differently. The nanoparticles act as a series of short circuit elements that confine the breakdown currents to very, very small internal discharge pathways. This inverse skin effect can have great implications for energy densification in composite materials. Energetic reactions described fully herein are amplified by an inverse skin effect. These very small discharge pathways are so narrow that the magnetic fields close to them are amplified to magnitudes unachievable by other methods.

[0025] Distributing nanoparticles in a dielectric (ceramic) matrix between two high voltage electrodes is a method according to the principles of the present invention for amplifying an energy output from the hydrated/deuterated metal nanoparticles in the dielectric matrix. High voltage pulses cause arc formations. The arc formations focus energy and the arc formations are channeled from one macroscopic grain to another macroscopic

grain. Once a discharge is interior to a macroscopic grain the pulse is further focused into nanoparticles along the lowest impedance pathway. The arcs interior to the grains are where the energetic reactions are maximized.

[0026] The nanoparticles provide a constellation of short circuiting elements for each current pulse. Each succeeding pulse finds a different pathway that minimizes the impedance between two electrodes. An overpressure of hydrogen is needed to prevent discharges from sliding over a surface of the macroscopic grains rather than through the grains and thereby through the hydrated nanoparticles. Low pressure hydrogen gas favors surface discharging.

[0027] Liquid dielectrics produce similar energy focusing capabilities as the ceramic matrices. Liquid systems provide a direct method for producing nanoparticles in situ. The high voltage discharges through a fluid ablate electrode materials that are rapidly quenched and suspended in the polar fluid. Once formed, the nanoparticles can be hydrated/deuterated by the ionization of the water during the discharges. As such, the high voltage pulses fill the H<sub>2</sub>O/D<sub>2</sub>O volume with a constellation of suspended particles filled with interstitial hydrogen (H)/deuterium (D) atoms. The particles stay in suspension due to Coulomb Repulsion as each particle is surrounded by polar water molecules that attach the oxygen to the metal cluster surface and has the two deuterium atoms from the D<sub>2</sub>O molecules facing out. The deuterium atoms have a net positive charge associated with them, so each metal cluster looks like a large positive ion that repels all the other such clusters. The nanoparticles remain equally spaced in the dielectric liquid due to this repulsion process that is very effective at small mass/charge ratios. The suspension of the nanoparticles in the polar water medium is referred as a colloidal suspension.

[0028] Once a sequence of high voltage pulses has formed a sufficient concentration of deuterated nanoparticles, energy input can be used directly to focus discharge energy through the hydrogen/deuterium filled nanoparticles and thus initiate energetic reactions.

[0029] There are alternative methods for amplifying the energy output. The high voltage discharge pulses can be switched over to ultrasonic cavitation as an alternative method for energy production. The frequency and amplitude of the ultrasonic pulses should be modulated to establish a standing wave pattern that enables resonant amplification of the shock waves in a reaction zone.

[0030] Methods and apparatus of the present invention are not limited to deuterium with heavy water loading as hydrogen loading can produce as much excess energy. Hydrogen can be substituted with deuterium and water with heavy water in all aspects of the present disclosure.

[0031] Hydrated/deuterated nanoparticles are an important feature of the present invention. Hydrated/deuterated nanoparticles are prone to energetic reactions when processed into a narrow size regime. Hydrated/deuterated nanoparticles processed between 3 and 20 nanometers (nm), and preferably between 3 and 12 nm are optimal for amplifying energy output. Hydrated/deuterated nanoparticles larger than approximately 20 nm do not provide the anharmonic oscillations of the nanolattice metal atoms needed to drive the anharmonic oscillations of the dissolved deuterons to amplitudes sufficient to initiate interactions at a sub atomic level.

[0032] Having nano particles in size range of 3 to 20 nm exhibits a feedback mechanism that favors large amplitude, low frequency vibrational modes of the metal matrix nuclei; this nanoscale phenomenon is generally referred to as Energy Localization.

[0033] For the purposes of the present invention, energy localization means that the metal nanoparticle nuclei will acquire vibrational energy from the environment and 'up-pump it' to increase the amplitude of the anharmonic modes of the nanoparticle nuclei. This process in turn, further amplifies the oscillations of the dissolved hydrogen nuclei within each nanoparticle, which in turn enhances the rate of energetic reactions in and on the nanoparticles.

[0034] As shown in FIG. 1, an exemplary apparatus 10 includes a cylinder 12 containing a solution of water and nanoparticles 2. Exemplary nanoparticles 14 can include metals such as tantalum, silver, palladium, titanium, nickel, thorium, zirconium and cobalt. The hydrated/deuterated nanoparticles 14 can be of a dimension between 3-20 nanometers (nm) and suspended in macroscopic particles of a dielectric composition. The nanoparticles 14 can be alloys of tantalum, silver, palladium, titanium, nickel, thorium, zirconium or cobalt. The nanoparticles 14 can contain a spillover catalyst including of one or more of the elements thorium, cerium, palladium and zirconium. The nanoparticles 14 can be embedded in a zirconium oxide dielectric matrix, a titanium dioxide matrix or a thorium oxide matrix. The

nanoparticles 14 can include a promoter element as a spillover catalyst including one or more of cerium, thorium, selenium and zirconium.

[0035] The cylinder 12 includes an electrode system 16 for causing arc ablation of a wall of the cylinder 12. Ablated particles sequentially increase in number with every current pulse from a power supply 18. The pulses cause ionization of the water thus producing hydrogen ions that are incorporated into the metal nanoparticles created by the ablation.

[0036] High voltage pulses pass through an insulating fitting 20 and arc from electrode points 22 to the grounded wall of cylinder 12. After sufficient nanoparticle formation and filling has occurred, the pulses from the power supply 18 can be turned off and the energy input can be supplied by an ultrasonic transducer 24 mounted in the liquid water and powered by a power supply 26.

[0037] A cooling water coil 28 is wound helically around the outside of the cylinder 12. A circulating flow system 32 that extracts the heat from an ultrasonic zone 30 sends the heated water through the circulating flow system 32 before sending nanoparticles immersed in the water back around for a second pass.

[0038] Flow rates and energy input can be controlled with a feedback circuit 34 in the power supply 26 to produce a specified amount of heat at a predetermined water flow rate in the secondary circuit.

[0039] A central high voltage electrode 22 is immersed in heavy water or a water solution. The points of the electrode 22 are energized by high voltage pulses in a 150-15,000 volt range. Each pulse contains between 50 – 500 millijoules of energy. The electrodes 22 are controllably spaced a distance apart in order to insure breakdown of the fluid gap between the electrodes.

[0040] High voltage pulses from supply 26 cause ablation of the interior wall of cylinder 12 and metal melted off the surface cools in the water to form a distribution of suspended metallic nanoparticles. A peak voltage, energy content and pulse width all contribute to the dimensions of the ablated particles. Those parameters are preferably adjusted to maximize the number of particles forming in the 3-20 nm size range and more preferably in the 3-12 nm range. After thousands of such pulses, the ultrasonic zone 30 becomes colored with a color depending upon the electrode material and nanoparticle dimensions.

[0041] The ultrasonic transducer 24 is shown mounted at the left end of the cylinder 12 and in the solution 14 for clarity purposes. The sound waves from the ultrasonic transducer 24 should be of sufficient intensity to induce cavitation (i.e., bubble formation) within the solution 2. The bubbles ultimately collapse and focus their pressure waves to very small volumes. If this small volume encompasses deuterated nanoparticles, then the particles will be densified and the already close deuterium nuclei will come into sufficient proximity to induce energetic reactions.

[0042] The apparatus 10 may be used for extracting thermal energy from the reaction zone and sending it to a secondary heat transfer system. Inlet and outlet tubes 36 send the heated dispersion through the heat exchanger 32 where the thermal energy is transferred to an isolated fluid 40, 42 where it can be distributed to other energy conversion equipment. That equipment can be, for example, a boiler/generator system for producing electricity. Alternatively, apparatus 10 may be used to distribute live steam for heating and cooling purposes.

[0043] Apparatus 10 is not limited to uses described above and is can be useful for many energy conversion systems. For example, since the energy arises in part from large amplitude vibrational modes in the nanoclusters of metal, then another process for amplifying the oscillations can be achieve with two laser beams. Electromagnetic energy at two separate frequencies, A and B, result in a third frequency that results from a mathematical subtraction of A from B. This can result in an electromagnetic wave whose frequency matches the frequency of the anharmonic oscillations in the low terahertz frequency range.

[0044] Input of terahertz frequency electromagnetic waves can lead to a resonant amplification of the anharmonic modes and directly increase the energetic reaction rates.

[0045] Apparatus 10 is not limited to nanoparticles suspended in water. Any medium that can maintain particles in this narrow size regime may be useful for energy production and amplifications thereof. For example, the zirconium oxide matrix containing metallic nanopowders can be placed into a fluidized bed that is agitated by flow of gases or liquids containing deuterium/hydrogen and subjected to high voltage pulses, ultrasonic waves and/or electromagnetic waves to amplify the energy output.



[0046] The suspension medium can be any material that preserves the particle integrity against agglomeration into particles whose dimensions exceed 20 nm. Ceramic materials with a high dielectric coefficient may be used as a matrix because hydrogen ions can achieve a very high density at the metal/ceramic interface.

[0047] Employing water/heavy water for energy production has inherent limitations. Water can only maintain a liquid state up to 363°C, above which it is a supercritical fluid with no liquid properties. Therefore, cavitation of bubbles is impossible above this temperature. This temperature limitation places an upper bound on a boiler system for efficient electricity production. Therefore, a gas based system is preferred over the liquid based system.

[0048] Arata-like particles have a dielectric coating surrounding a distribution of metal nanoparticles. Surrounding these macroscopic particles in hydrogen/deuterium gas at elevated pressure allows for dielectric discharges to be self-focused into the interior of each macroscopic particle containing millions of hydrated metal nanoparticles.

[0049] The pressure of hydrogen gas should be kept above a minimum pressure to prevent discharges through the gas phase rather than through the nanoparticles. Therefore hydrogen gas pressure above two atmospheres is recommended.

[0050] The separation between the electrodes should be adjusted to match the high voltage input. Higher voltages are required for larger electrode spacing. It is important to match the spacing with a power supply operating between 150 – 15,000 volts. Such a supply with peak voltage pulses of 14,000 volts operating at 7 – 15 watts is described herein.

[0051] As shown in FIG. 2, an exemplary apparatus 50 includes a cylinder 52. Here, the local electric field intensity is the most important aspect for conducting a dielectric discharge. Sharp electrodes points 54 with close spacing to a wall of the cylinder 52 magnify the local electric field intensity such that the discharge 56 can occur with as little as 150 volts applied. At room temperature and one centimeter spacing between electrodes 54 no breakdown occurs up to 300 volts DC. However, breakdown occurs at this spacing with 14,000 volt pulses.

[0052] Nickel nanopowders filling region 58 is composed of a distribution of nanoscale metal islands embedded in a dielectric matrix. The nanopowder is placed inside the cylinder 52 containing a central electrode with a distribution of electrodes points 54 facing radially. Hydrogen gas is introduced into the cylinder 52 through pipe 60 at elevated pressure (e.g., >

2 atm). This gas serves two purposes. First, the gas provides the fuel for the energetic reactions. Second, the gas provides a discharge pathway between particles to confine the discharge to narrow cross-section.

[0053] The discharges between electrodes 54 and the wall of the cylinder 52 must travel through the hydrated nanocomposite material. This causes energetic reactions and a build up of thermal energy. This energy can be transferred away from the cylinder by water flowing through tubing 62 wrapped around the cylinder 52 and in good thermal contact. The heated water can be diverted to a secondary heat exchanger 64.

[0054] A pulsed power supply 66 can be modulated in pulse voltage and frequency to match the dynamic response of the system. Resonant conditions are anticipated and an optimal operating point can be found by matching the input energy to the natural frequency of the system.

[0055] FIG. 3 is an exemplary diagram showing discharges traversing a gap from a first electrode 100 to a second electrode 102 to micro-grain 104. A typical micro grain, such as micro-grain 104, is approximately 15 microns in cross-section and contains about 1,000,000 nanoparticle islands. The discharges within each micro-grain is self-focused down to the dimensions of a nanoparticle island 106 embedded in a dielectric matrix 108. The embedded nanonickel islands provide short circuiting routes 110 that focus the energy of the discharge to extremely high electric and magnetic field intensities and accompanying energy densities and thereby providing conditions for energetic reactions to occur. The discharges from micro-grain to micro-grain 112 in the dielectric matrix 108 require high over pressures of hydrogen gas to prevent sliding arcs along an outer surface of the micro-grains. Energy amplification can only occur by confining the discharge currents interior to the macro-grains.

[0056] An inverse skin effect causes all the discharge energy along routes, such as route 110, to achieve current densities in excess of  $10^{12}$  Amps/cm<sup>2</sup>.

[0057] FIGs. 4, 5, 6, 7 and 8 detail a power supply and its wave forms that are suitable for dielectric discharges in a nanoparticle environment.

[0058] FIG. 4 shows an exemplary circuit diagram for converting 12 volts of DC input into a half wave rectified voltage output at 50 volts.

[0059] FIG. 5 depicts an exemplary wave form leaving the oscillator circuit.

[0060] A rectified wave is fed into the pulser circuit shown in FIG. 8. Rectified waves are thereby formed into abrupt pulses as shown in FIG. 7. A duty cycle of the pulse output can be varied by adjusting resistor, R10 from FIG. 8.

[0061] These abrupt pulses are fed into an exemplary Cockcroft-Walton voltage amplifier circuit shown in FIG. 6. The voltage is amplified sequentially through the network of diodes and capacitors to increase the pulse voltage from 50 volts up to 15,000 volts. Higher voltage can be achieved with added diodes and capacitors to the amplifier.

[0062] FIGs. 4, 6 and 8 show the three partial exemplary circuits that combine to produce a source of high voltage pulses of negative polarity. It is recognized that this particular device is not the only way to achieve a high voltage pulsed power source. It is simply one method that has been thoroughly tested to provide over 120 microamperes of negative ion current in air at one atmosphere.

[0063] This device has a needle electrode that is spaced far from the ground electrode, because it is designed to ionize gases such as hydrogen. However, the same power supply can serve to produce dielectric discharges in a nanopowder matrix.

[0064] The circuit employs three ten megOhm resistors between the C-W amplifier and the needle for safety reasons. This limits the 14kV pulses to 100 micro Amperes. Lethal discharges may result without these three resistors.

[0065] The opposite polarity ions can be achieved by reversing the sign of the voltage pulses. This is the result of reversing the direction of the diodes in the Cockcroft-Walton amplifier circuit. Positive ions are not recommended for this application, but they have use in other chemical reactions such as thin film growth in systems like Chemical Vapor Deposition (CVD).

[0066] A 1 k Ohm resistor (R5) is connected in series to the battery ground (negative terminal) and it is also connected to a metallic grounding harness in the device handle. This allows the operator to remain at the floating potential of the battery ground. Without this grounding strap the operator will sustain shocking discharges.

[0067] The foregoing description does not represent an exhaustive list of all possible implementations consistent with this disclosure or of all possible variations of the implementations described. A number of implementations have been described. Nevertheless,

it will be understood that various modifications may be made without departing from the spirit and scope of the systems, devices, methods and techniques described here.

Accordingly, other implementations are within the scope of the following claims.

[0068] What is claimed is:

1. A method comprising:

amplifying an energy release from a dispersion of nanoparticles containing a concentration of hydrogen/deuterium nuclei, the nanoparticles suspended in a dielectric medium in a presence of hydrogen/deuterium gas, wherein an energy input is provided by high voltage pulses between two electrodes embedded in the dispersion of nanoparticles.

2. The method of claim 1 wherein the hydrated/deuterated nanoparticles are of a dimension between 3-20 nanometers (nm) and suspended in macroscopic particles of a dielectric composition.

3. The method of claim 1 wherein the nanoparticles are selected from the group consisting of composed of tantalum, silver, palladium, titanium, nickel, thorium zirconium and cobalt.

4. The method of claim 1 wherein the nanoparticles are alloys of tantalum, silver, palladium, titanium, nickel, thorium zirconium or cobalt.

5. The method of claim 1 wherein the nanoparticles contain a spillover catalyst comprised of one or more of the elements thorium, cerium, palladium and zirconium.

6. The method of claim 1 wherein the nanoparticles are embedded in a zirconium oxide dielectric matrix.

7. The method of claim 1 wherein the nanoparticles are embedded in a titanium dioxide matrix.

8. The method of claim 1 wherein the nanoparticles are embedded in a thorium oxide matrix.

9. The method of Claim 1 where the dispersion containing hydrated nanoparticles within a reaction chamber contain hydrogen gas at a pressure exceeding 2 atmospheres.

10. The method of claim 5 wherein the nanoparticles include a promoter element for the spillover catalyst comprising one or more of cerium, thorium, selenium and zirconium.

11. The method of claim 1 wherein the high voltage pulses are between 150 - 15,000 volts.

12. A method comprising:

amplifying an energy release from a dispersion of nanoparticles containing a concentration of hydrogen/deuterium nuclei, the nanoparticles suspended in water/heavy water dielectric medium, an energy input provided by high voltage pulses between two electrodes embedded in the nanoparticle suspension.

13. A composition of matter comprising:

isolated metal particles in a 3-20 nanometer (nm) size regime containing dissolved hydrogen/deuterium nuclei and isolated by a dielectric medium.

14. A composition of matter comprising:

isolated metal alloys in a 3-20 nanometer (nm) size regime containing deuterium nuclei, the alloys including mixtures of palladium and nickel, titanium and palladium, nickel and cobalt, and nickel and iron and nickel and thorium.

15. A method comprising:

amplifying an energy release from a dispersion of nanoparticles in a 3-20 nanometer (nm) size regime containing a concentration of hydrogen/deuterium nuclei, an energy input provided by a source of terahertz frequency electromagnetic energy.

16. The method of claim 15 wherein a terahertz frequency range is between 1 – 40 terahertz.

17. A method comprising:

amplifying an energy release from a dispersion of hydrated macroparticles containing a dispersion of nanoparticles in a 3-20 nanometer (nm) size regime by fluidizing the nanoparticles in a stream of gas or liquid or by simple mechanical agitation and then subjecting the fluidized particles to excitation by high voltage pulses, ultrasonic agitation and/or terahertz frequency range electromagnetic waves.

18. The method of claim 17 where a fluidizing gas is hydrogen with a pressure greater than 2 atmospheres.

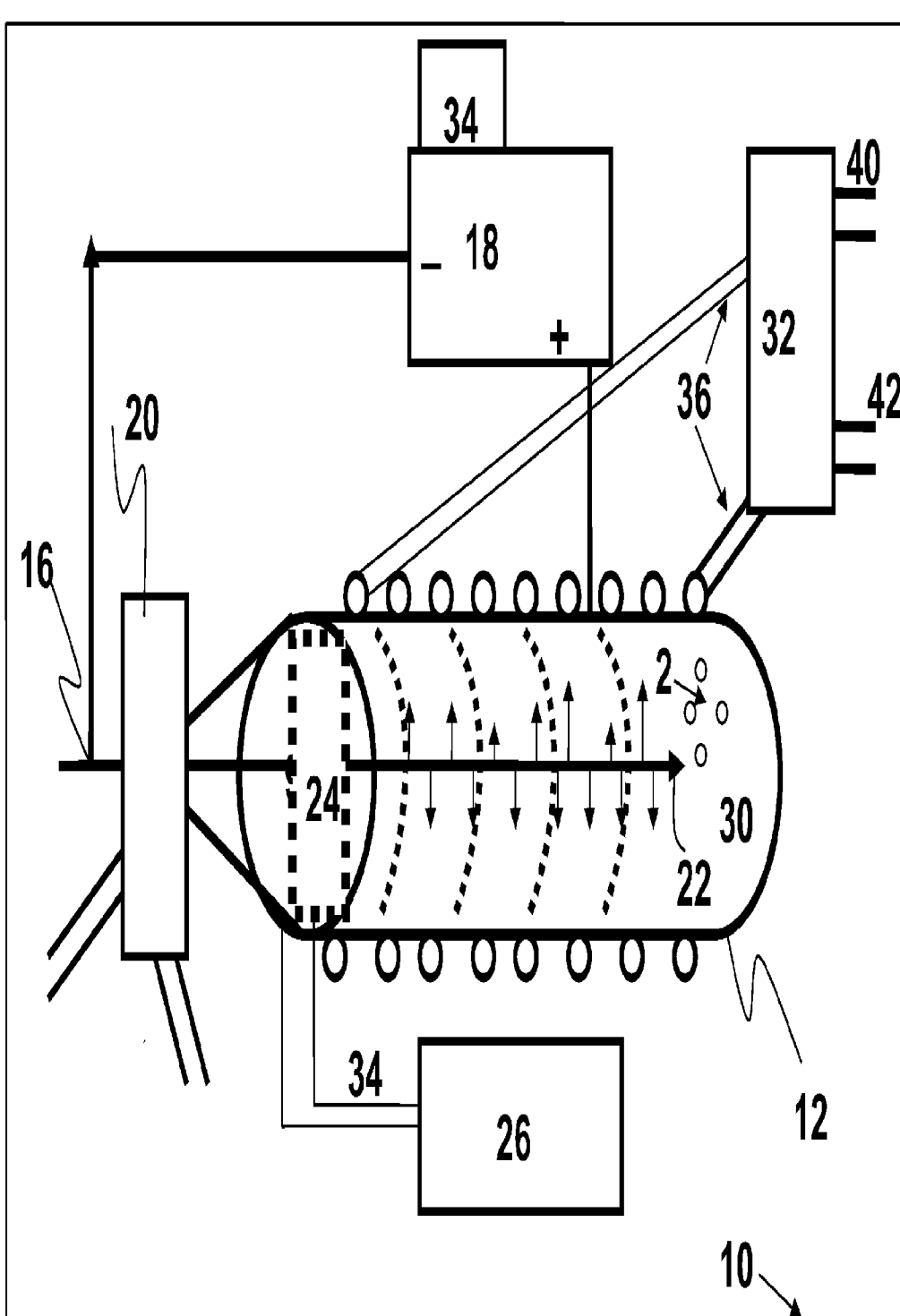


FIG. 1



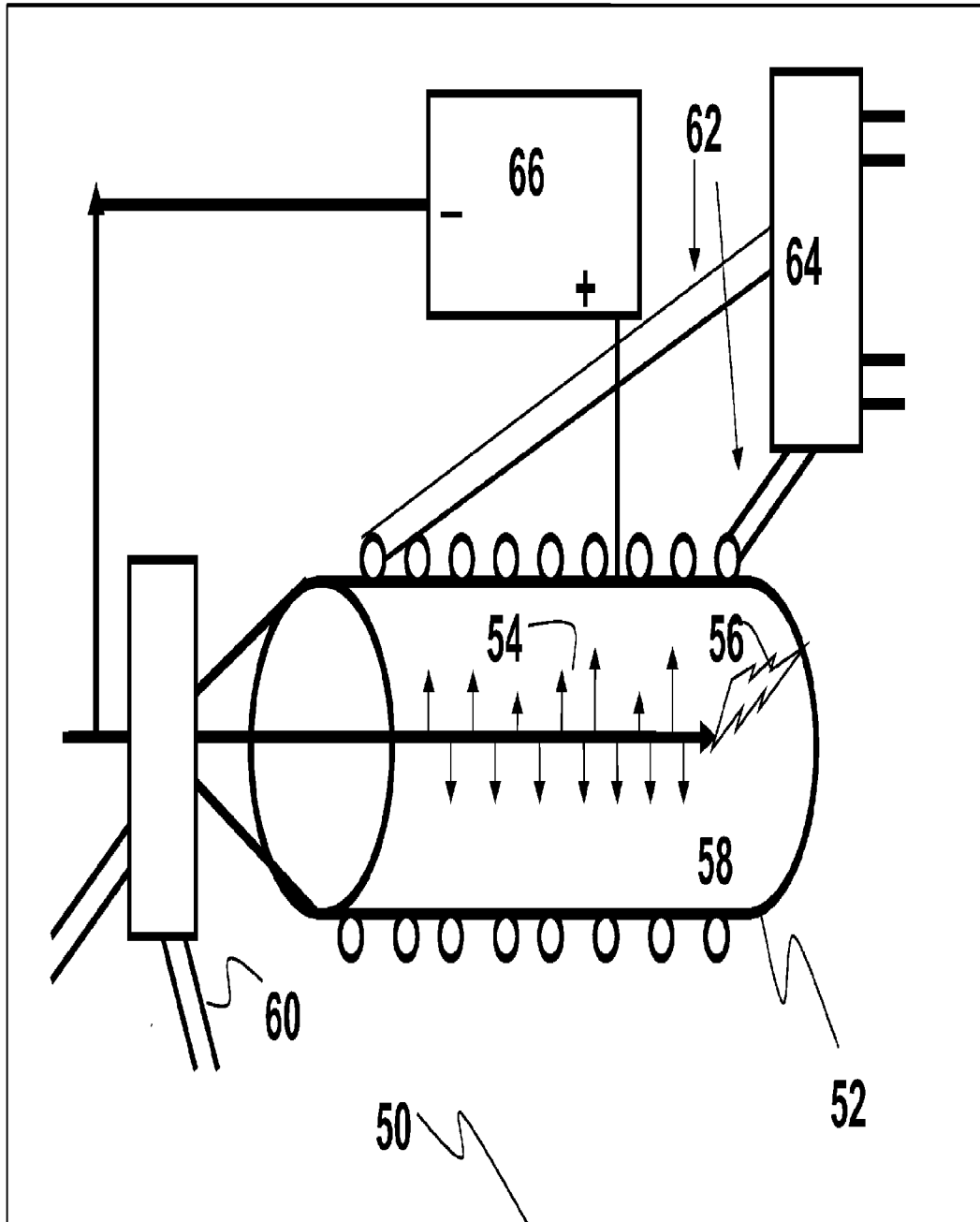


FIG. 2

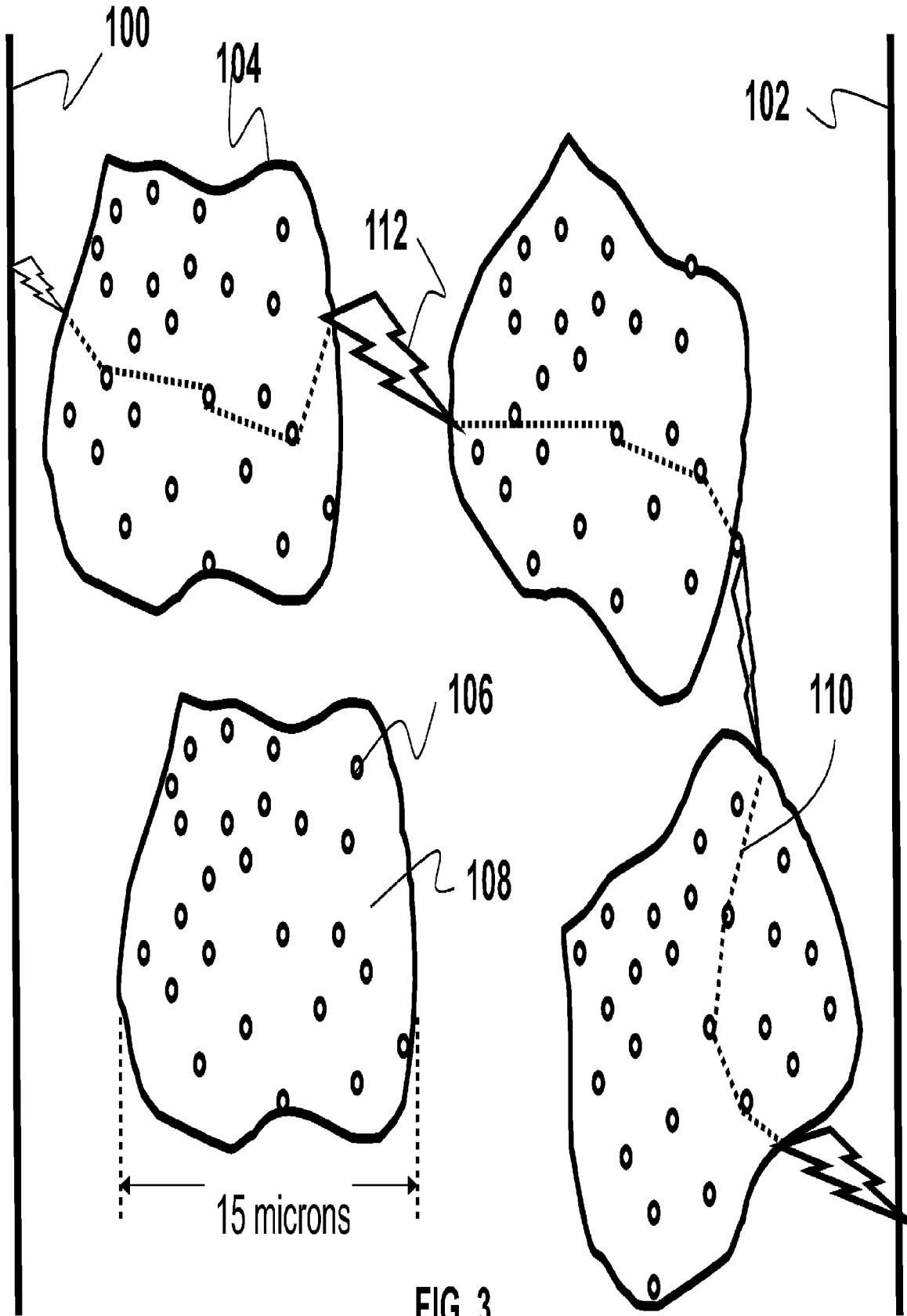


FIG. 3

# Oscillator circuit

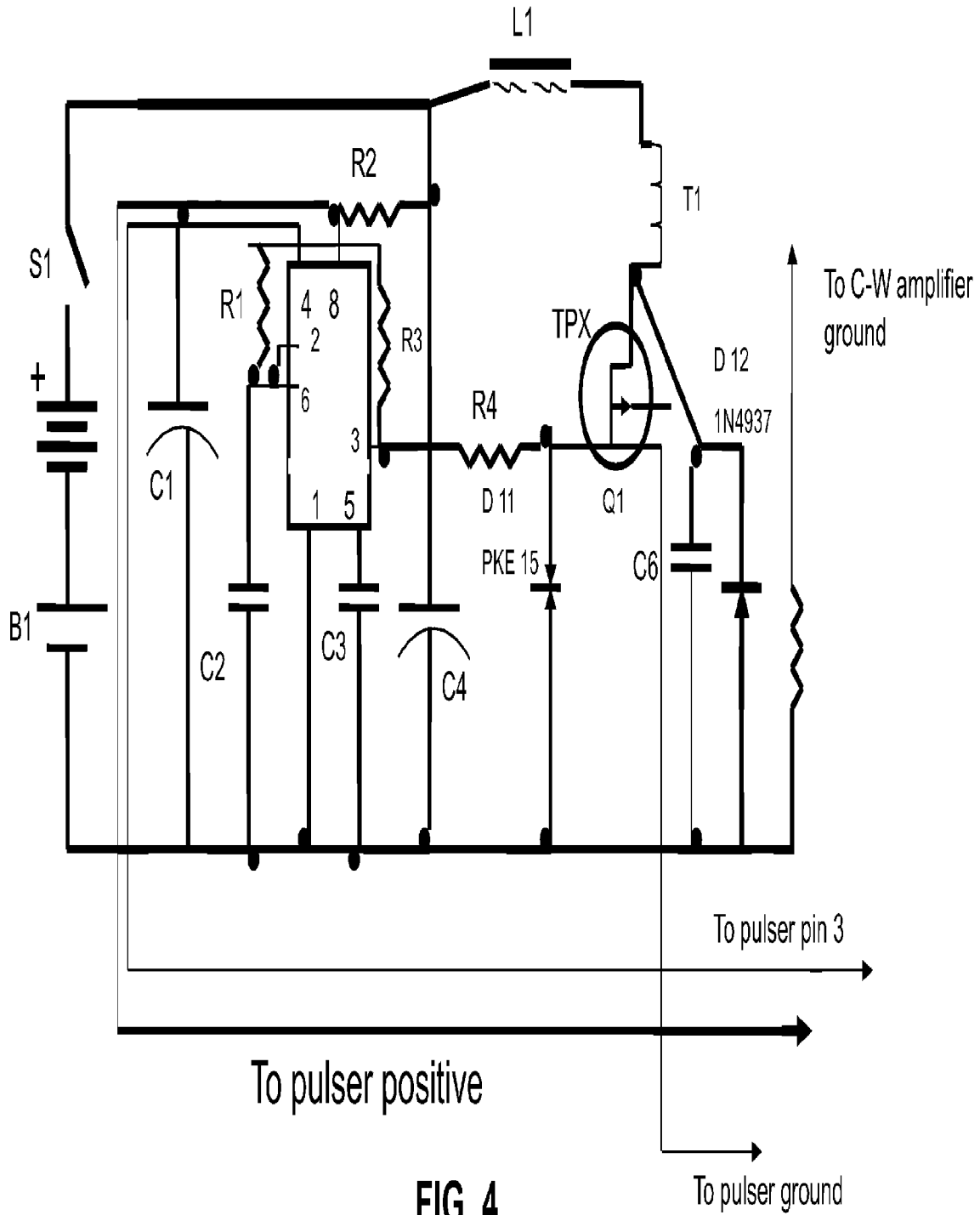


FIG. 4

# Oscillator output

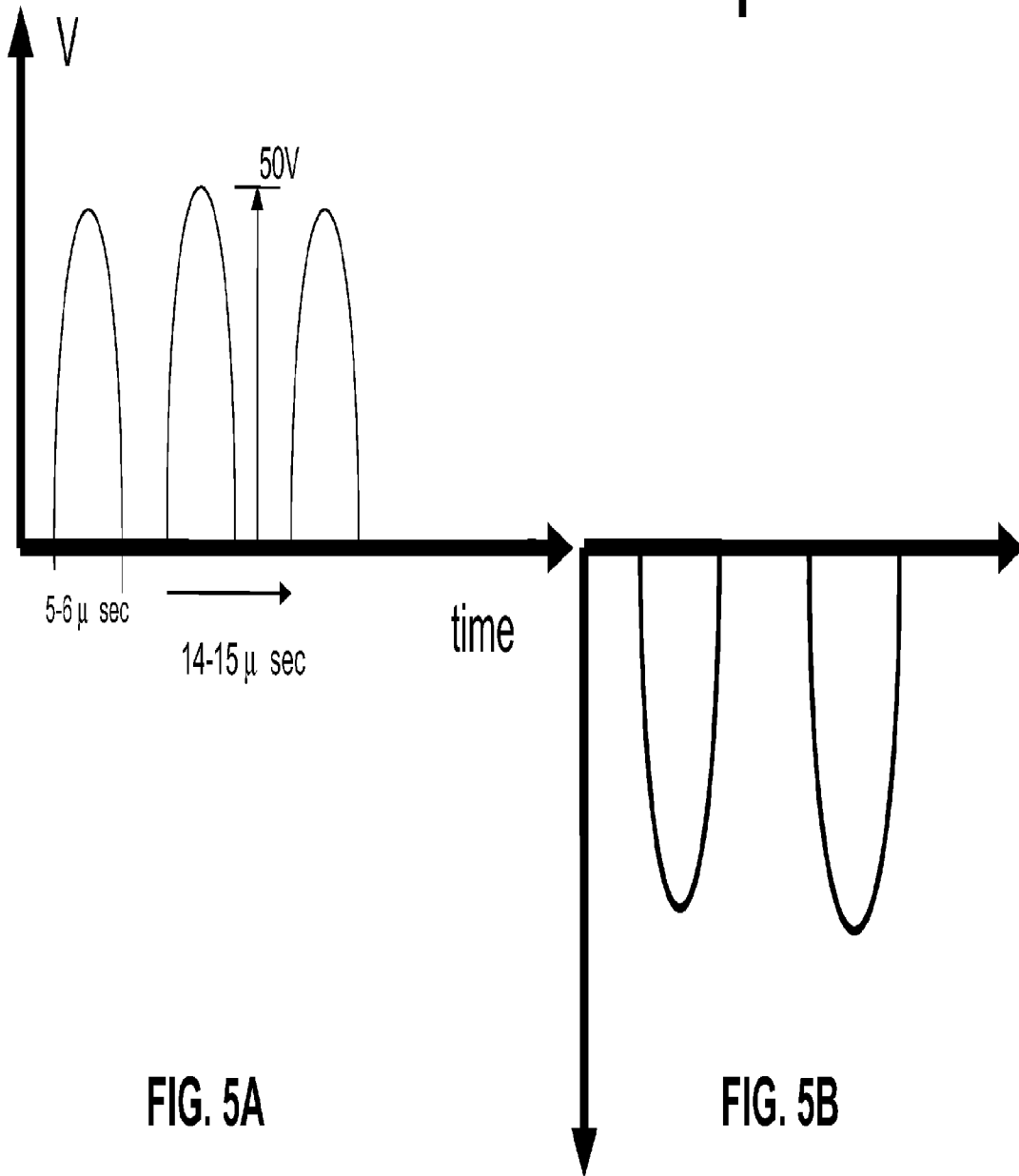
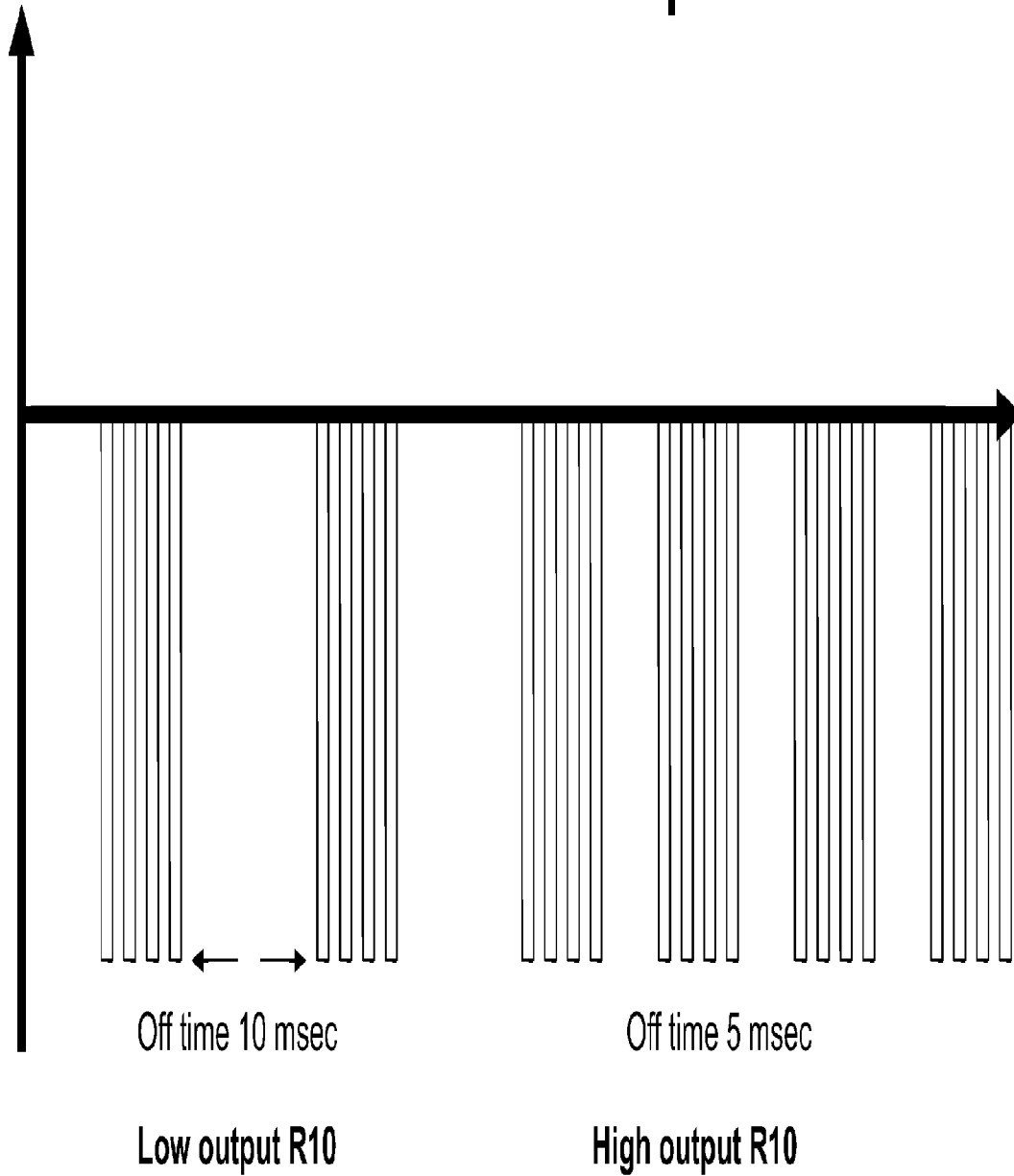


FIG. 5A

FIG. 5B

# Pulser output



**FIG. 6**

# Pulser Circuit

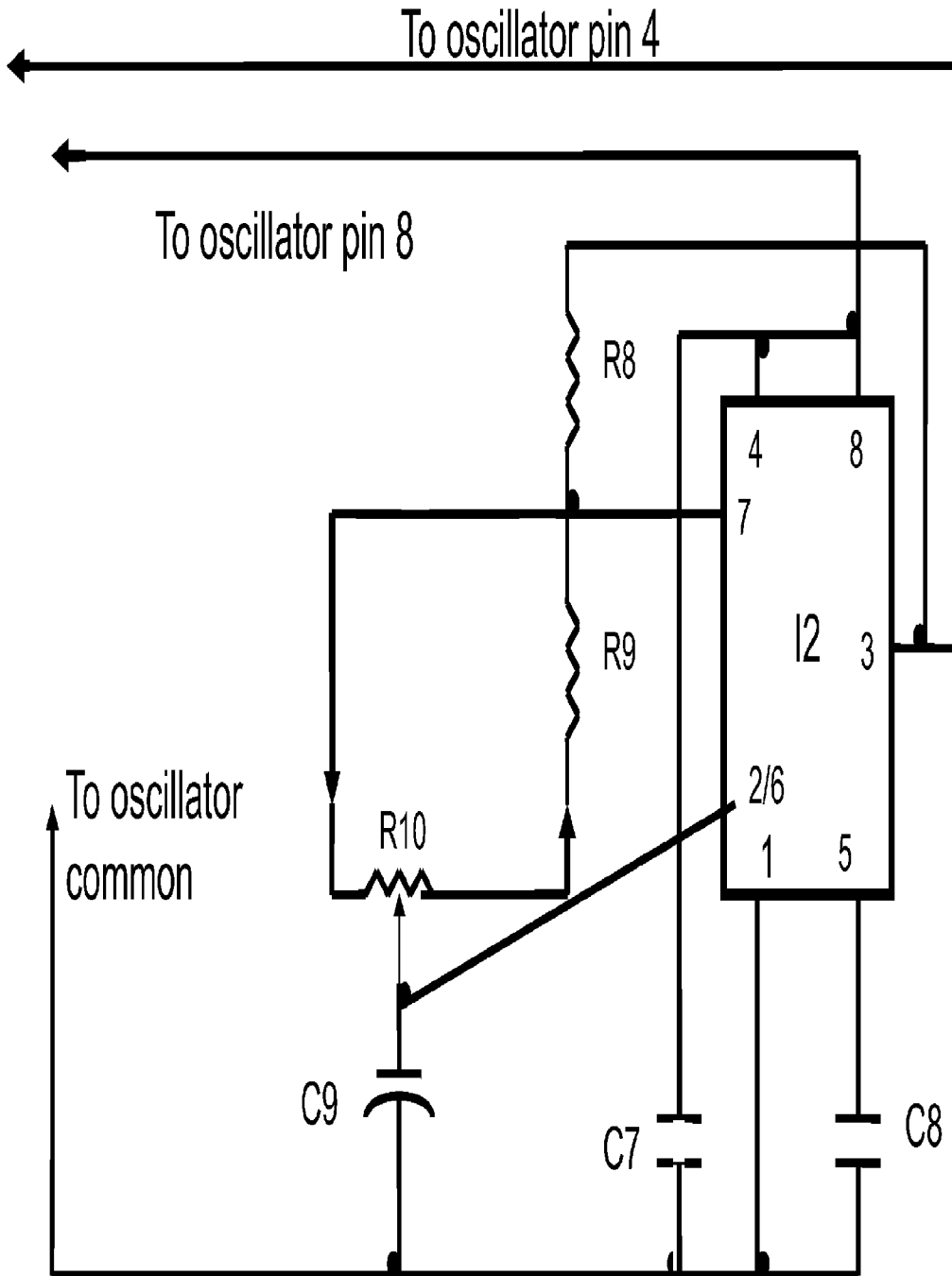


FIG. 7

# Cockcroft-Walton Amplifier

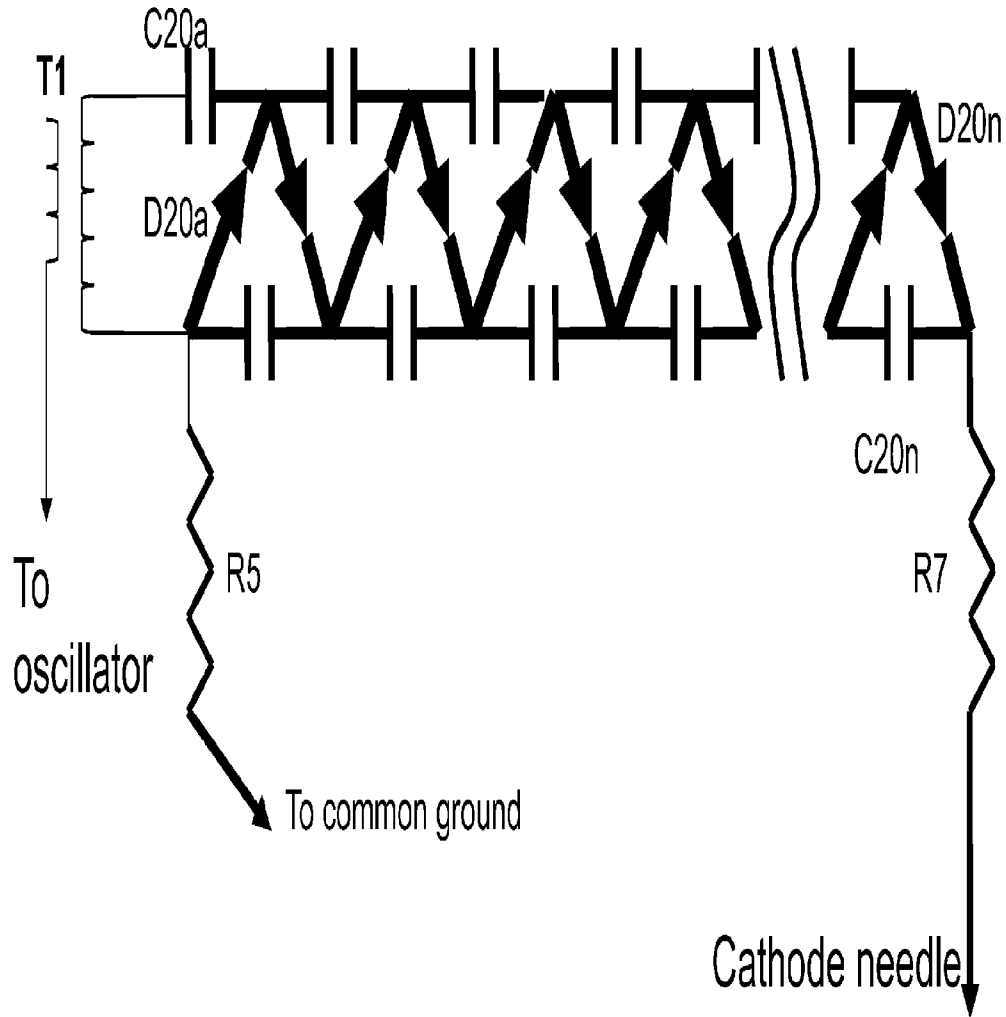


FIG. 8

**INTERNATIONAL SEARCH REPORT**

International application No.  
PCT/US2011/029904

<p><b>A. CLASSIFICATION OF SUBJECT MATTER</b>                  IPC(8) - G21B 1/11 (2011.01)                  USPC - 376/150                  According to International Patent Classification (IPC) or to both national classification and IPC</p>																							
<p><b>B. FIELDS SEARCHED</b></p> <p>Minimum documentation searched (classification system followed by classification symbols)                  IPC(8) - G21B 1/00, 1/15, 1/15, 3/00 (2011.01)                  USPC - 376/107, 108, 144-146, 150; 977/774, 778, 785</p> <p>Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched</p> <p>Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)                  Google Patnets, Patbase</p>																							
<p><b>C. DOCUMENTS CONSIDERED TO BE RELEVANT</b></p> <table border="1"> <thead> <tr> <th>Category*</th> <th>Citation of document, with indication, where appropriate, of the relevant passages</th> <th>Relevant to claim No.</th> </tr> </thead> <tbody> <tr> <td>Y</td> <td>US 2008/0037694 A1 (DEAN, JR et al) 14 February 2008 (14.02.2008) entire document</td> <td>1-18</td> </tr> <tr> <td>Y</td> <td>US 2006/0135669 A1 (RYANG) 22 June 2006 (22.06.2006) entire document</td> <td>1-14, 17-18</td> </tr> <tr> <td>Y</td> <td>US 2007/0284244 A1 (DAVIDSON) 13 December 2007 (13.12.2007) entire document</td> <td>1-12</td> </tr> <tr> <td>Y</td> <td>US 2009/0048094 A1 (RING et al) 19 February 2009 (19.02.2009) entire document</td> <td>5, 10</td> </tr> <tr> <td>Y</td> <td>US 2009/0122940 A1 (BREED) 14 May 2009 (14.05.2009) entire document</td> <td>15-16</td> </tr> <tr> <td>Y</td> <td>US 2010/0065786 A1 (SIMONS) 18 March 2010 (18.03.2010) entire document</td> <td>2, 17-18</td> </tr> </tbody> </table>			Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.	Y	US 2008/0037694 A1 (DEAN, JR et al) 14 February 2008 (14.02.2008) entire document	1-18	Y	US 2006/0135669 A1 (RYANG) 22 June 2006 (22.06.2006) entire document	1-14, 17-18	Y	US 2007/0284244 A1 (DAVIDSON) 13 December 2007 (13.12.2007) entire document	1-12	Y	US 2009/0048094 A1 (RING et al) 19 February 2009 (19.02.2009) entire document	5, 10	Y	US 2009/0122940 A1 (BREED) 14 May 2009 (14.05.2009) entire document	15-16	Y	US 2010/0065786 A1 (SIMONS) 18 March 2010 (18.03.2010) entire document	2, 17-18
Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.																					
Y	US 2008/0037694 A1 (DEAN, JR et al) 14 February 2008 (14.02.2008) entire document	1-18																					
Y	US 2006/0135669 A1 (RYANG) 22 June 2006 (22.06.2006) entire document	1-14, 17-18																					
Y	US 2007/0284244 A1 (DAVIDSON) 13 December 2007 (13.12.2007) entire document	1-12																					
Y	US 2009/0048094 A1 (RING et al) 19 February 2009 (19.02.2009) entire document	5, 10																					
Y	US 2009/0122940 A1 (BREED) 14 May 2009 (14.05.2009) entire document	15-16																					
Y	US 2010/0065786 A1 (SIMONS) 18 March 2010 (18.03.2010) entire document	2, 17-18																					
<p><input type="checkbox"/> Further documents are listed in the continuation of Box C. <input type="checkbox"/></p>																							
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<p>Date of the actual completion of the international search</p> <p>07 June 2011</p>		<p>Date of mailing of the international search report</p> <p><b>16 JUN 2011</b></p>																					
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