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(54) Title: SYSTEM AND METHOD FOR CONTROLLING ACTUATION OF DOWNHOLE TOOLS

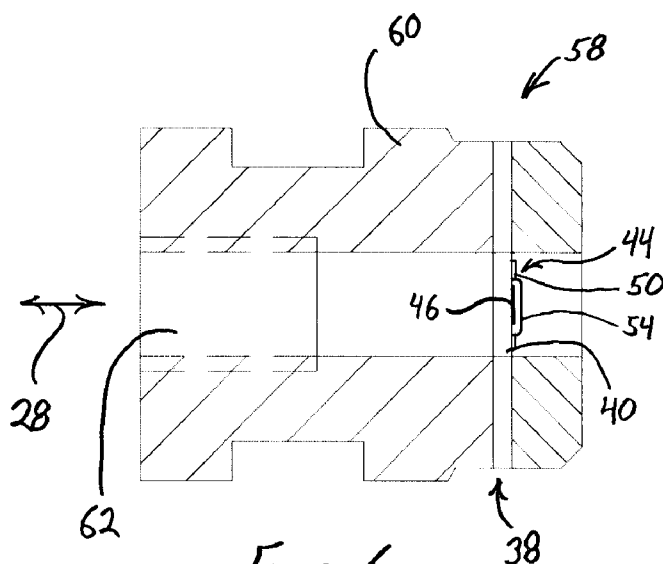


FIG. 6

(57) Abstract: A technique controls the actuation of a downhole tool in a wellbore. The technique utilizes a rupture pressure membrane in a flow path of actuating fluid used to actuate the downhole tool. An energetic material is mounted proximate the rupture disc, and this energetic material may be selectively exploded. The resultant energy is sufficient to initiate rupture of the rupture pressure membrane which enables flow of actuating fluid to the downhole tool.



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SYSTEM AND METHOD FOR CONTROLLING ACTUATION OF DOWNHOLE TOOLS

BACKGROUND

[0001] This application claim priority to U.S. Patent Application No. 12/556,074, filed September 9, 2009, the contents of which are hereby incorporated by reference.

[0002] In a variety of downhole applications, actuating devices are used to control the actuation of downhole tools, such as valves or packers. In some applications, pressure pulse tools are used to recognize unique pressure pulse signatures as commands to activate a given downhole tool. In other systems, rupture discs are used to selectively permit the flow of an actuating fluid upon application of sufficient pressure in a control line, in tubing or in a casing annulus. Once the rupture disc is ruptured, fluid under pressure is directed to the downhole tool to actuate the tool.

SUMMARY

[0003] In general, the present invention provides a system and methodology for controlling the actuation of a tool in a wellbore. The technique utilizes placement of a rupture pressure membrane in a flow path of fluid used to actuate the downhole tool. An energetic material is mounted proximate the rupture disc, and this energetic material may be selectively actuated or exploded. The resultant energy is enough to weaken the rupture disc sufficiently to rupture the pressure membrane, which enables flow of actuating fluid to the downhole tool.

[0004] Other or alternative features will become apparent from the following description, from the drawings, and from the claims.

BRIEF DESCRIPTION OF THE DRAWINGS

[0005] Certain embodiments of the invention will hereafter be described with reference to the accompanying drawings, wherein like reference numerals denote like elements. It should be understood, however, that the accompanying drawings illustrate only the various implementations described herein and are not meant to limit the scope of various described technologies. The drawings are as follows:

FIG. 1 is a schematic view of a well system deployed in a wellbore in which the well system utilizes a small-scale system to selectively enable actuation of a downhole tool, according to an embodiment of the present invention;

FIG. 2 is a front view of a portion of a system designed to enable selective actuation of the downhole tool, according to an embodiment of the present invention;

FIG. 3 is a view similar to that of FIG. 2 but showing additional features of the system designed to enable selective actuation, according to an embodiment of the present invention;

FIG. 4 is a view similar to that of FIG. 3 but showing additional features of the system designed to enable selective actuation, according to an embodiment of the present invention;

FIG. 5 is a view similar to that of FIG. 4 but showing additional features of the system designed to enable selective actuation, according to an embodiment of the present invention;

FIG. 6 is a cross-sectional view of one example of a rupture disc assembly that can be used to enable selective actuation, according to an embodiment of the present invention;

FIG. 7 is an end view of one example of the rupture disc assembly, according to an embodiment of the present invention; and

FIG. 8 is a cross-sectional view of another example of a rupture disc assembly that can be used to enable selective actuation of the downhole tool, according to an embodiment of the present invention.

DETAILED DESCRIPTION

[0006] In the following description, numerous details are set forth to provide an understanding of the present invention. However, it will be understood by those of ordinary skill in the art that the present invention may be practiced without these details and that numerous variations or modifications from the described embodiments may be possible. In the specification and appended claims: the terms “connect”, “connection”, “connected”, “in connection with”, “connecting”, “couple”, “coupled”, “coupled with”, and “coupling” are used to mean “in direct connection with” or “in connection with via another element”; and the term “set” is used to mean “one element” or “more than one element.”

[0007] The present invention generally relates to a system for controlling the actuation of downhole tools that are part of a well system. In a well system having one or more downhole tools actuated via fluid, e.g. hydraulic fluid, a flow control pressure membrane may be deployed in the actuating fluid flow path. The flow control pressure membrane may be selectively activated to open the fluid flow path that allows actuation

of the desired downhole tool. The flow control pressure membrane may be activated via specific operator input and/or upon detection of predetermined well parameters.

[0008] In one embodiment, the flow control pressure membrane is designed with very small packaging to provide a pressure membrane that can be used to replace single shot tools. In some applications, micro electromechanical system technology is employed to facilitate the very small, economical packaging. Examples of the approach are described in greater detail below and are configured to provide consistent, reliable performance as well as low production cost.

[0009] Referring generally to FIG. 1, an example of a well system 20 is illustrated as deployed in a wellbore 22, according to one embodiment of the present invention. The well system 20 comprises downhole equipment 24 that may be in the form of a downhole completion or other equipment. As illustrated, downhole equipment 24 comprises one or more downhole tools 26 that may be actuated by fluid, e.g. hydraulic fluid, delivered along a flow path 28, or down tubing 30, or in the annulus between tubing 30 and the casing lining the wellbore 22. No separate control line is needed to control the pressure membrane in this invention. The flow path 28 may be routed, at least in part, along the interior of a control line. The downhole tool 26 illustrated in FIG. 1 may comprise, for example, a downhole control valve or a packer. However, other types of downhole tools or devices also may be actuated via actuating fluid delivered along flow path 28.

[0010] The configuration of well system 20 can vary substantially depending on the specific well application for which it is designed. Accordingly, the embodiment illustrated is simply an example to facilitate explanation of the present technique for controlling actuation of downhole tools. In the example illustrated, downhole equipment 24 is deployed into wellbore 22 via a conveyance 30, such as production tubing, coiled tubing, cable, or other suitable conveyance. The wellbore 22 extends downwardly from a wellhead 32 positioned at a surface location 34 (either terrestrial or sub-sea). Additionally, an actuating fluid supply system 36 may be used to deliver pressurized fluid

along flow path 28 to downhole tool 26. However, the pressurized actuating fluid also may be supplied from other systems or from the natural pressure within wellbore 22 at depth. Furthermore, well system 20 may be employed in wellbores 22 that are generally vertical and/or in wellbores that are deviated, e.g. horizontal.

[0011] The fluid that flows along flow path 28 to downhole tool 26 is selectively controlled via a control device 38 having a small, economical package size. The control device 38 may comprise a pressure membrane 40 that initially blocks the flow of actuation fluid along flow path 28. For example, flow control pressure membrane 40 may span flow path 28 to block flow of hydraulic fluid or other actuation fluid along flow path 28 until actuation of downhole tool 26 is desired.

[0012] Referring generally to FIG. 2, one embodiment of flow control device 38 is illustrated. In this embodiment, flow control device 38 is illustrated as comprising pressure membrane 40 which, in turn, may comprise a material 42 capable of being selectively ruptured to enable flow along flow path 28 to downhole tool 26 for actuation of the tool. The material 42 may be a membrane or other suitable material formed, for example, as a disc for placement across flow path 28. According to one embodiment, material 42 is formed as a pressure membrane made from nickel alloy metal or other material that is chemically inert to downhole fluids and temperatures. In this example, the membrane is capable of sealing between downhole pressure and an atmospheric or low-pressure chamber. The membrane is designed to be strong enough to withstand ambient differential pressure until rupture of the material is desired and initiated with a specific input.

[0013] In the example illustrated, flow control device 38 may further comprise a micro electromechanical system 44 that enables selective rupture initiation with respect to material 42. In one embodiment, micro electromechanical system 44 comprises a sensor 46 for detecting differential pressure acting on pressure membrane 40. By way of example, sensor 46 may comprise a strain gauge 48 or piezo material applied to the

atmospheric/low-pressure side of pressure membrane 40. The sensor 46 may be designed to generate a signal when the differential pressure is changing. In many applications, absolute pressure accuracy is not required if the sensor has sufficient sensitivity to recognize pressure pulse command signals that may be used to cause initiation of the rupture of pressure membrane 40.

[0014] As illustrated in FIG. 3, the micro electromechanical system 44 may further comprise a layer or pellet of energetic material 50 that may be selectively actuated or exploded. When the energetic material 50 is ignited or detonated, the energetic material has sufficient energy to weaken the pressure membrane 40 and allow the differential pressure acting on pressure membrane 40 to rupture the pressure membrane 40. Alternatively, energetic material 50 may be designed to have energy sufficient to cause complete rupture of pressure membrane 40 without the contribution of differential pressure. The latter option can be used in applications where functionality is desired independent of pressure. Depending on the application and the expected differential pressures, the thickness of pressure membrane 40 may be incrementally increased or decreased. For example, the thickness may be increased for wells with higher expected differential pressures in order to keep the amount of energetic material 50 to a minimum.

[0015] Energetic material 50 may be formed from a variety of explosive materials that explode or detonate, i.e. provide a rapid release of energy, as a result of ignition, chemical reaction, or other processes. For example, energetic material 50 may be formed from explosive materials, such as those used in perforating applications. In one embodiment, the energetic material 50 is deployed in a specific form, e.g. a shape charge, mounted on pressure membrane 40. Furthermore, the energetic material 50 may be stationed at various locations along pressure membrane 40. In the example illustrated, energetic material 50 is applied over sensor 46 (see FIG. 2) such that sensor 46 is sandwiched between energetic material 50 and the surface of pressure membrane 40.

[0016] Referring generally to FIG. 4, one approach for causing explosion of energetic material 50 is illustrated. In this embodiment, an initiator 52 is positioned adjacent energetic material 50 and utilized in initiating explosion of the energetic material 50. By way of example, initiator 52 may comprise an igniter or detonator. The initiator 52 may be designed as an independent component or as an integral part of a micro electromechanical system chip.

[0017] Additionally, circuitry 54 may be operatively coupled between strain gauge 48 (see FIG. 2) and energetic material 50 via, for example, initiator 52, as illustrated in FIG. 5. The circuitry 54 may be designed to process an initiation signal, such as a pressure signal acting on pressure membrane 40, and to initiate explosion of energetic material 50 via initiator 52 in response to the predetermined initiation signal. By way of example, circuitry 54 may be designed to process data related to measurement of differential pressure via strain gauge 48. When the circuitry 54 determines an appropriate command signal has been given, the circuitry 54 may output a signal to initiator 52 to activate energetic material 50. The circuitry 54 may comprise an application-specific integrated circuit (ASIC), an integrated micro electromechanical system (MEMS) chip, or another suitable circuit configured to carry out the measurement and processing functions.

[0018] The circuitry 54 may be powered via an electric power source 56, which may be in the form of a battery or other suitable power source. In some applications, electric power source 56 is part of circuitry 54 or built into the overall micro electromechanical system 44. However, in other applications the electric power source 56 may comprise an external power source, such as external batteries connected with circuitry 54.

[0019] Because control device 38 is small in size, the control device 38 can be adapted for use with a variety of structures. For example, control device 38 may be incorporated into a rupture disc assembly 58, as illustrated in FIG. 6. In this example,

pressure membrane 40 comprises a rupture disc disposed in a surrounding rupture disc housing 60. The rupture disc housing 60 may comprise an internal flow passage 62 to accommodate the flow of actuating fluid along flow path 28 during actuation of the downhole tool 26. The external size and configuration of rupture disc housing 60 may be designed according to the corresponding mounting structure found in downhole tool 26 or other adjacent structures to which control device 38 is mounted along flow path 28.

[0020] Initially, rupture disc 40 spans flow passage 62 and prevents flow therethrough until rupture disc 40 is ruptured via activation of energetic material 50, as described above. By way of example, the micro electromechanical system 44 may comprise energetic material 50 in the form of a nanoenergetic material installed on the rupture disc 40, as illustrated in FIG. 7. Depending on size constraints, an external power source 56 (see FIG. 5) may be used to provide sufficient power to activate the initiator 52, e.g. igniter, and cause explosion of the nanoenergetic material 50. As described above, the energy from material 50 is used to initiate rupture of pressure membrane 40 by either directly rupturing the pressure membrane 40 or by weakening the pressure membrane 40 sufficiently to enable differential pressure to complete the rupture.

[0021] In another embodiment, a single micro electromechanical system chip 64 is employed, as illustrated in FIG. 8. In this embodiment, the single micro electromechanical system chip 64 may comprise all of the previously described system components, including strain gauge 48, energetic material 50, initiator 52, circuitry 54 and power source 56 (see previous FIGS.). The single chip 64 simply is adhered or otherwise attached to the pressure membrane 40. In some examples, the single micro electromechanical system chip 64 is constructed with an adhesive surface 66 that may be exposed for adherence to a membrane surface, for example, in the event pressure membrane 40 is formed as a membrane spanning flow path 28.

[0022] The circuitry 54 is designed, e.g. programmed, to recognize specific inputs, e.g. pressure differentials, pressure inputs, combinations of downhole parameters, or

other inputs, that cause the circuitry 54 to initiate explosion of the energetic material 50 (see FIG.3). The explosion, in turn, initiates rupture of pressure membrane 40 to enable flow of actuating fluid to downhole tool 26. The circuitry 54 may be designed to recognize inputs that are specifically input by a well operator via, for example, pressure inputs, and/or the circuitry may be designed to recognize specific parameters that occur downhole.

[0023] System 20 can be constructed in a variety of configurations for use in many types of wells. For example, the downhole equipment 24 may comprise many types of production components, service components, and other well related components depending on the specific operations to be carried out by the well system. An individual downhole tool or a plurality of downhole tools of similar or different types may incorporate control devices 38 to control actuation. Additionally, each control device 38 may be designed to operate in response to a corresponding, unique signature or other input. In other applications, however, the plurality of control devices 38 may be designed to respond simultaneously to a single type of control input.

[0024] Additionally, the pressure membrane 40 may be designed from a variety of materials in a variety of shapes and thicknesses. The components mounted on pressure membrane 40 also may be designed in many shapes and configurations for mounting on either side of pressure membrane 40. For example, micro electromechanical system chips may be used to assemble some or all of the components into a cooperating assembly. By way of further example, the amount and type of energetic material 50 may be adjusted for specific applications and environments.

[0025] In some embodiments, either a downhole device or a surface located device may provide an electrical signal to the micro electromechanical system to indicate initiation of the energetic material. For example, a surface device such as a simple switch, micro-processor running a modeling algorithm, or a signal generating device, could send an initiation signal to the micro electromechanical system. In other cases, a

downhole device or sensor could generate an initiation signal due to downhole parameters such as water cut, flow rate, temperature, or other fluid composition. In still other cases, a signal generated by a pump down device such as an RF tag, radioactive tracer, mechanical switch, or magnetic signal could be received by the micro electromechanical system.

[0026] The signal may be communicated via a variety of wired and wireless methods. For example, a non-limiting list of wireless methods may include pressure pulses, electromagnetic signals, radio signals, or acoustic signals. A combination of wired and wireless communication techniques may be employed.

[0027] Even though the micro electromechanical system is shown in many of the figures as being mounted on the pressure membrane, other embodiments may have some or all of the components mounted proximate or near the pressure membrane. For example, the strain gauge may be on the pressure membrane but the other micro electromechanical system components may be near the pressure membrane, such as coupled to a surface of the rupture disc housing. The energetic material may be provided around the circumference of the pressure membrane or mounted just upstream of the pressure membrane in a case in which the energetic material initiates a chemical reaction when actuated.

[0028] Although only a few embodiments of the present invention have been described in detail above, those of ordinary skill in the art will readily appreciate that many modifications are possible without materially departing from the teachings of this invention. Accordingly, such modifications are intended to be included within the scope of this invention as defined in the claims.

CLAIMS

What is claimed is:

- 1 1. A system for actuating tools downhole, comprising:
2 a downhole tool that is actuated by flow of hydraulic fluid along a flow
3 path;
4 a pressure membrane spanning the flow path to block flow of hydraulic
5 fluid along the flow path until actuation of the downhole tool is desired; and
6 a micro electromechanical system comprising an energetic material
7 mounted on or near the pressure membrane;
8 wherein the energetic material may be selectively actuated to initiate
9 rupture of the pressure membrane.
- 1 2. The system as recited in claim 1, wherein the downhole tool comprises a packer.
- 1 3. The system as recited in claim 1, wherein the downhole tool comprises a valve.
- 1 4. The system as recited in claim 1, wherein the pressure membrane comprises a
2 rupture disc.
- 1 5. The system as recited in claim 1, wherein the micro electromechanical system
2 comprises a strain gauge to detect a differential pressure acting on the pressure
3 membrane.
- 1 6. The system as recited in claim 5, wherein the energetic material explodes or sets
2 off a chemical reaction when actuated to initiate rupture of the pressure
3 membrane.
- 1 7. The system as recited in claim 6, wherein the energetic material is arranged into a
2 specific form to facilitate rupture of the pressure membrane.

- 1 8. The system as recited in claim 5, wherein the micro electromechanical system
2 comprises circuitry coupled with the strain gauge to cause the energetic material
3 to explode upon determining occurrence of a specific differential pressure.
- 1 9. The system as recited in claim 8, wherein the micro electromechanical system
2 further comprises an electric power source mounted on or near the pressure
3 membrane.
- 1 10. The system as recited in claim 8, wherein the micro electromechanical system
2 further comprises an electric power source mounted separately from the pressure
3 membrane.
- 1 11. A method for controlling actuation of a tool in a wellbore, comprising:
2 initially blocking hydraulic flow of actuating fluid to a downhole tool with
3 a pressure membrane positioned along a flow path of the actuating fluid; and
4 selectively causing an explosion or ignition of energetic material
5 proximate the pressure membrane to initiate rupture of the pressure membrane to
6 enable flow of actuating fluid to the downhole tool.
- 1 12. The method as recited in claim 11, further comprising employing a strain gauge
2 proximate to the membrane to detect a pressure signal.
- 1 13. The method as recited in claim 12, further comprising coupling circuitry to the
2 strain gauge to process the pressure signal and initiate the explosion.
- 1 14. A method, comprising:
2 providing a rupture disc assembly with a rupture disc disposed in a
3 surrounding rupture disc housing;
4 mounting an energetic material on or proximate to the rupture disc; and
5 coupling the energetic material to circuitry that responds to a desired
6 signal to cause explosion of the energetic material.

- 1 15. The method as recited in claim 14, further comprising placing a strain gauge on or
2 proximate to the rupture disc to detect the desired signal.
1
- 1 16. The method as recited in claim 15, wherein placing comprises placing the strain
2 gauge against the rupture disc and beneath the energetic material.
- 1 17. The method as recited in claim 14, further comprising mounting the circuitry on
2 the rupture disc.
- 1 18. The method as recited in claim 14, further comprising mounting the rupture disc
2 assembly in a downhole tool.
1
- 1 19. A system, comprising:
2 a rupture assembly having a rupture pressure membrane disposed in a
3 surrounding housing; and
4 an energetic material mounted on or near the rupture pressure membrane,
5 where the energetic material may be selectively exploded to initiate rupture of the
6 rupture pressure membrane.
1
- 1 20. The system as recited in claim 19, further comprising a micro electromechanical
2 system mounted on the rupture assembly and configured to actuate the energetic
3 material.
1
- 1 21. The system as recited in claim 20, wherein the micro electromechanical system
2 comprises a strain gauge mounted on the rupture pressure membrane.
1
- 1 22. The system as recited in claim 21, wherein the micro electromechanical system
2 comprises circuitry coupled between the strain gauge and the energetic material.
- 1 23. The system as recited in claim 19, wherein the energetic material is initiated by an
2 electrical signal communicated from a separate location.

1 24. The system as recited in claim 23, wherein the separate location is provided by a
2 pump down RF tag.

1 25. The system as recited in claim 23, wherein the separate location is provided by a
2 downhole sensor.

FIG. 1

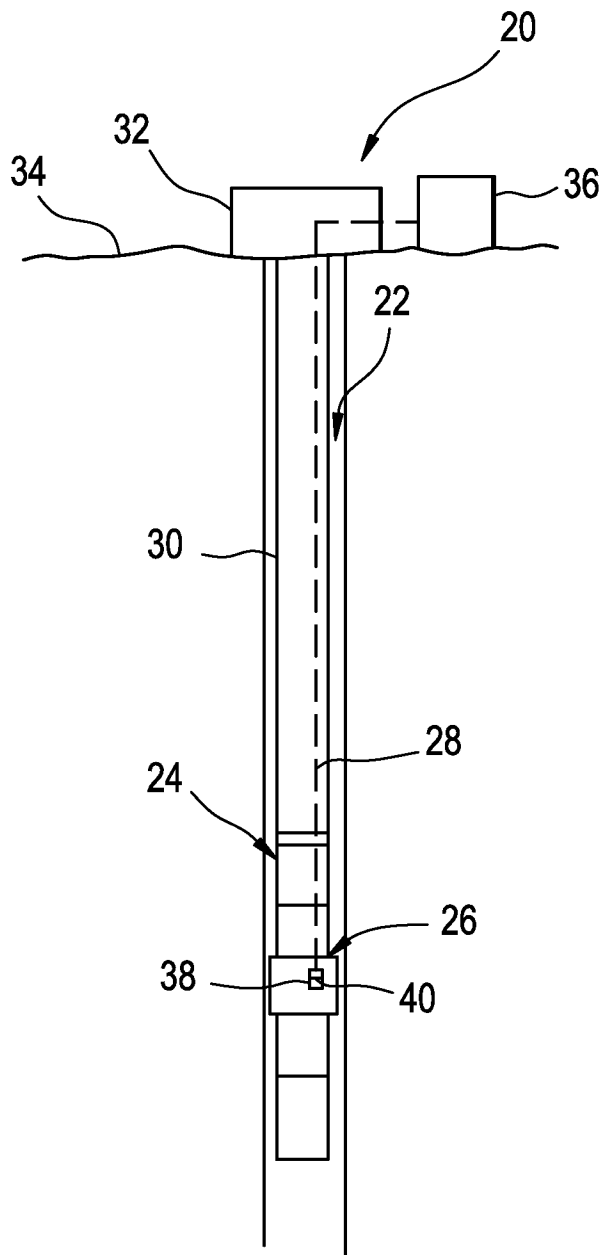


FIG. 2

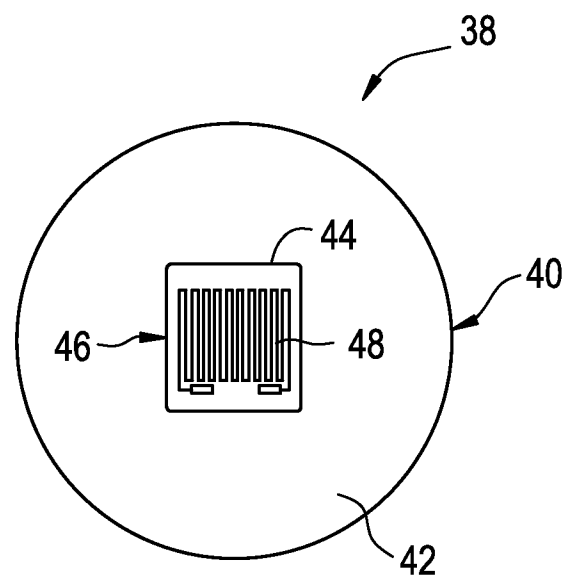


FIG. 3

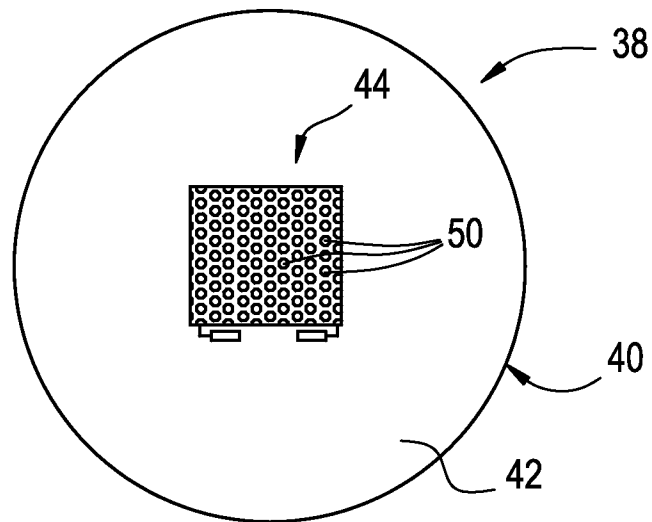
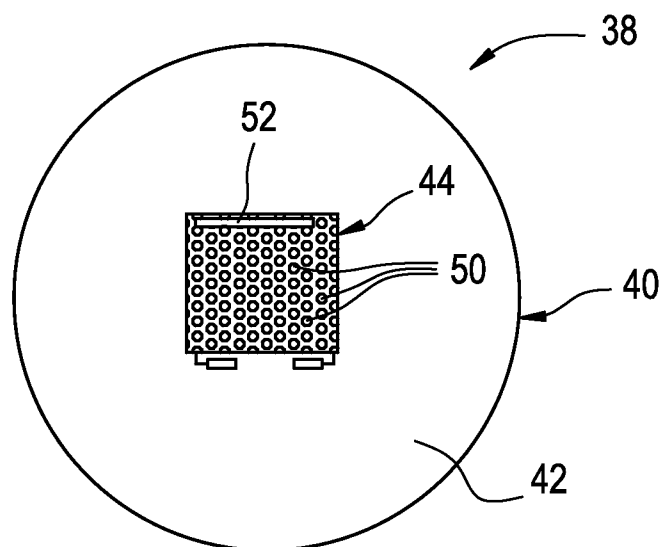


FIG. 4



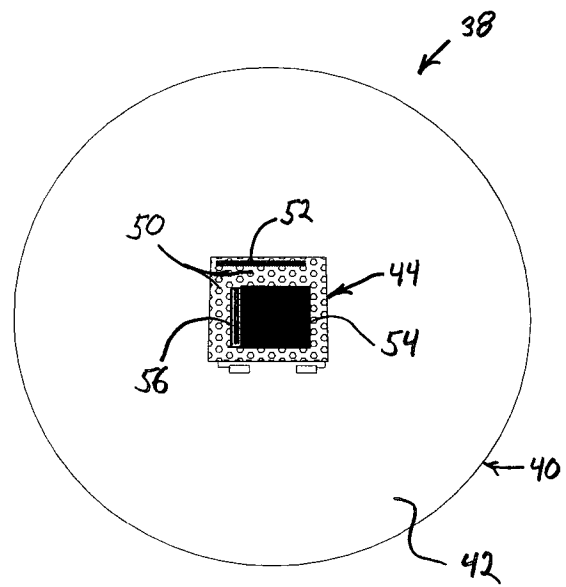


FIG. 5

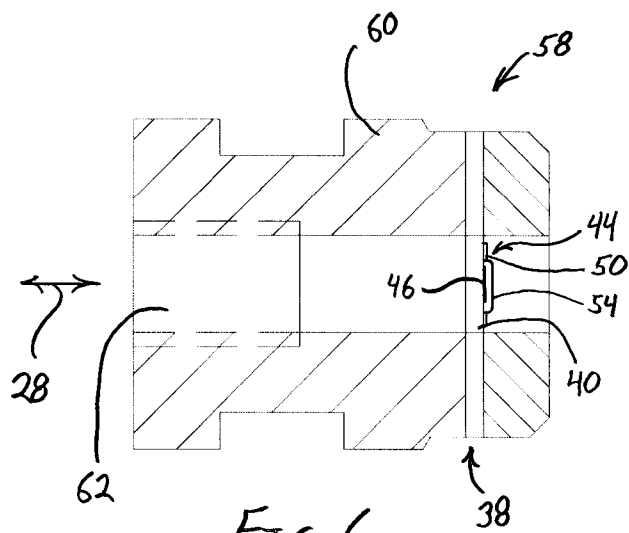


FIG. 6

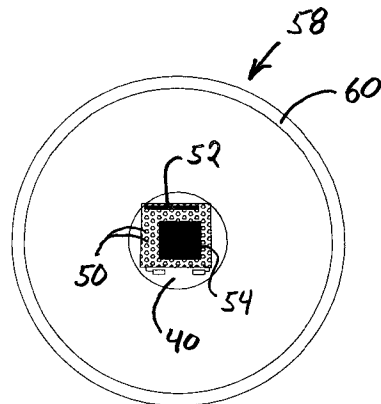


FIG. 7

FIG. 8

