result, the pin count impacts the cost of the feedthrough, and that cost increases as the number of feedthrough pins increases in the implantable device. Consequently, due to this complex design requirement, the resulting manufacturing, and the required acceptance tests, the feedthrough is an expensive component.

**[0005]** Moreover, conventional implantable device designs based on a feedthrough or header attached to housing components disadvantageously have an overall volume of the resulting device that is larger than desired, because several discrete components make up the assembly.

**[0006]** The devices shown in FIG. 1 contains control electronics, a power source, and wireless communication capabilities. The benefit of these internal functions is that the device can be programmed to automatically release discrete doses at specific time points, and the dosing schedule can be updated or modified wirelessly at any time. The patient therefore can automatically receive his or her medication without having to take any action. A disadvantage to this automatic drug delivery implant is that all of these functions require a finite volume. There is a clear desire, however, to reduce the volume of the device in order to i) reduce the incision required to implant the device under the skin, ii) increase the possible locations in the body that the device can be implanted, and iii) make the device less intrusive for the patient. In particular, it would be desirable to provide a smaller overall device volume without sacrificing functionality, simplicity, and/or hermeticity.

[0006a] According to a first aspect of the present invention, there is provided a containment device, comprising: a microchip element comprising one or more containment reservoirs that are configured to be electrically activated to open; an electronic printed circuit board (PCB) fixed to the microchip element, wherein the PCB comprises an alumina or other biocompatible ceramic substrate; one or more electronic components associated with the microchip element or the PCB; and a first inductive coupling device incorporated into the microchip element or the ceramic PCB, wherein the first inductive coupling device is in communication with the one or more electronic components.

[0006b] According to a second aspect of the present invention, there is provided a medical implant system comprising: the above containment device, which is configured for implantation in a patient; and an external communicator comprising a second inductive coupling device configured to form an inductive coupling circuit with the first inductive coupling device when brought within proximity of the containment device.

[0006c] According to a third aspect of the present invention, there is provided a method of assembling a containment device, comprising: providing an elongated microchip element comprising one or more containment reservoirs that are configured to be electrically activated to open; fixing the elongated microchip element to an electronic printed circuit board (PCB) which comprises a biocompatible substrate; electrically connecting the elongated microchip element to one or more electronic components;

and incorporating a first inductive coupling device into the microchip element or the PCB, wherein the first inductive coupling device is in communication with the one or more electronic components.

**[0006d]** According to a fourth aspect of the present invention, there is provided a system for drug delivery, biosensing, or both drug delivery and biosensing, comprising: an implantable component which comprises: a microchip element comprising one or more containment reservoirs that are configured to be electrically activated to open, the one or more containment reservoirs containing at least one of a drug, a biosensor, or a combination thereof, an electronic printed circuit board (PCB) fixed to the microchip element, one or more electronic components associated with the microchip element or the PCB, and a first inductive coupling device incorporated into the microchip element or the PCB, wherein the first inductive coupling device is in communication with the one or more electronic components; and an external component which comprises a second inductive coupling device configured to form an inductive coupling circuit with the first inductive coupling device when brought within proximity of the implantable component.

**[0006e]** According to a fifth aspect of the present invention, there is provided a containment device, comprising: a microchip element comprising one or more containment reservoirs that are configured to be electrically activated to open; a silicon substrate positioned adjacent to the microchip element; one or more electronic components disposed within the silicon substrate, wherein the one or more electronic components are in communication with the microchip element; and a first inductive coupling device associated withincorporated into the microchip element or the silicon substrate, wherein the first inductive coupling device is in communication with the one or more electronic components.

**[0006f]** According to a sixth aspect of the present invention, there is provided a medical implant system comprising: the above containment device, which is configured for implantation in a patient; and an external communicator comprising a second inductive coupling device configured to form an inductive coupling circuit with the first inductive coupling device when brought within proximity of the containment device.

**[0006g]** According to a seventh aspect of the present invention, there is provided a system for drug delivery, biosensing, or both drug delivery and biosensing, comprising: an implantable component which comprises: a microchip element comprising one or more containment reservoirs that are configured to be electrically activated to open, the one or more containment reservoirs containing at least one of a drug, a biosensor, or a combination thereof, a silicon substrate positioned adjacent to the microchip element, one or more electronic components disposed within the silicon substrate, wherein the one or more electronic components are in communication with the microchip element, and a first inductive coupling device associated withincorporated into the microchip element or the silicon substrate, wherein the first inductive coupling device is in communication with the one or more electronic components; and an external

component which comprises a second inductive coupling device configured to form an inductive coupling circuit with the first inductive coupling device when brought within proximity of the implantable component.

[0006h] According to an eight aspect of the present invention, there is provided a method of assembling a containment device, comprising: providing an elongated microchip element comprising one or more containment reservoirs that are configured to be electrically activated to open; positioning the elongated microchip element adjacent to a silicon substrate; electrically connecting the elongated microchip element to one or more electronic components; and incorporating a first inductive coupling device into the microchip element or the silicon substrate, wherein the first inductive coupling device is in communication with the one or more electronic components.

[0006i] According to a ninth aspect of the present invention, there is provided a method of operating a containment device, comprising: determining a location of the containment device, wherein the containment device comprises: a microchip element comprising one or more containment reservoirs that are configured to be electrically activated to open; an electronic printed circuit board (PCB) fixed to the microchip element; one or more electronic components associated with the microchip element or the PCB; and a first inductive coupling device incorporated into the microchip element or the PCB, wherein the first inductive coupling device is in communication with the one or more electronic components; positioning an external communicator comprising a second inductive coupling device configured to form an inductive coupling circuit with the first inductive coupling device within proximity of the containment device; and activating the one or more containment reservoirs to open.

## SUMMARY

**[0007]** Some or all of the above needs and/or problems may be addressed by certain embodiments of the disclosure. In one embodiment, a containment device is provided that includes an elongated microchip element comprising one or more containment reservoirs that are configured to be electrically activated to open. The containment device may also include an elongated electronic printed circuit board (PCB) comprising a biocompatible substrate. The elongated PCB also may include a first side on which one or more electronic components are fixed and an opposed second side on which the elongated microchip element is fixed in electrical connection to the one or more electronic components. Further, the containment device may include an elongated housing fixed to the elongated PCB. The elongated housing is configured to hermetically seal the one or more electronic components of the elongated PCB within the elongated housing.

**442**. The grooves **450** may be etched in the silicon and then coated with a metallized layer of the same material as the metal ring. Variations of this embodiment are envisioned, for example, where other positive and negative bonding features are provided in/on either or both interfacing surfaces of the silicon substrate **442** and the primary substrate **440**.

**[0050]** The primary substrate **440** is generally relatively thicker than the silicon substrate **442**, and all or at least a majority (greater than 50%) of the reservoir sidewall height (or depth) is defined by the primary substrate **440**. In an embodiment, the silicon substrate **442** has thickness that is between 5% and 50% of the thickness of the primary substrate **440** at the bonded interfaces of the substrates.

**[0051]** Although not shown in ~~the~~ **FIG. 4** or **FIG. 5A**, the reservoirs **344** and **444**, respectively, include reservoir contents positioned therewithin. The reservoirs can be configured to store essentially any substance or device component in need of hermetic containment and subsequent release or exposure at a selected time. The reservoir content may be, for example, a chemical reagent, a drug formulation, or sensor or component thereof, such as an electrode. In an embodiment, a single device includes at least one containment reservoir containing a biosensor and at least one reservoir containing a drug formulation. Examples of various reservoir contents are described for example in U.S. Patent No. 7,510,551; U.S. Patent No. 7,497,855; U.S. Patent No. 7,604,628; U.S. Patent No. 7,488,316; and PCT WO 2012/027137.

**[0052]** An exemplary embodiment of a containment device **600** including a microchip element **612** is illustrated in **FIG. 6**. The containment device **600** includes a ceramic PCB **614** which has via **630** electrically connecting electronic component **618** to the microchip element **612**. The electronic component **618** is secured on a first side of the ceramic PCB **614**, and the microchip element **612** is secured on the opposing second side of the PCB **614**. The via **630** electrically connects to a metallized conductive surface **632** on the first side of the PCB **614**. The electrical circuitry **635** of the microchip element **612** is electrically connected to the metallized surface **632** by a wirebond **634**. An epoxy **633** coats the wirebond **634** and at least a portion of the microchip element **612**, the ceramic PCB **614**, and a housing **620**. In this manner, the epoxy **633** ensures that the containment device **600** is void of any atramatic surfaces. The second side of the ceramic PCB **614** also includes a metallized conductive surface **637**, which is electrically connected to the electronic component **618**. Although not shown in this illustration, the containment device **600** may include multiple microchip elements, as well as multiple vias, electronic

components, and wirebonds. Moreover, the containment device **600** may be completely or partially coated by the epoxy **633**.

**[0053]** The microchip element **612** includes a primary substrate **640** and a silicon substrate **642**. The primary substrate **640** and silicon substrate **642** are bonded together by compression cold welding at/adjacent the interface of a ring structure and groove structure tongue **650/652**. Reservoirs **644** are defined in the primary substrate **640** with the open end in fluid communication with apertures **646** defined through the silicon substrate ~~612~~642. Electrically conductive reservoir caps **648** sealingly cover the apertures **646** and reservoirs **644**.

**[0054]** An exemplary embodiment of a containment device **700** is illustrated in **FIG. 7**. The containment device **700** includes a microchip element **712** and a ceramic PCB **714**, which is fixed to the microchip element **712**. Electrical circuitry **735** of the microchip element **712** is electrically connected to the metallized surface **732** by a wirebond **734**. An epoxy **733** coats the wirebond **734** and at least a portion of the microchip element **712**, the ceramic PCB **714**, and/or the metallized surface **732**. In this manner, the epoxy **733** ensures that the containment device **700** is void of any atramatic surfaces. Although not shown in this illustration, the containment device **700** may include multiple microchip elements, as well as multiple vias, electronic components, and wirebonds. Moreover, the containment device **700** may be completely or partially coated by the epoxy **733**. In some instances, the containment device **700** may be relatively thin and the epoxy coating may be omitted. The containment device **700** may include any length, to width, to thickness ratio. That is, the containment device **700** may be any suitable size.

**[0055]** In some instances, the PCB **714** may comprise a silicon material that is manufactured using a MEMS manufacturing process. In other instances, the PCB **714** may comprise a multilayer low temperature co-fired ceramic (LTCC). In yet other instances, the PCB **714** may comprise a substrate other than a printed circuit board that is capable of performing the functionality described herein. For example, element **714** may comprise a silicon substrate or the like that is configured to house one or more electric components **718** therein. In turn, the electrical components **718** may be in communication with the microchip element **712**.

**[0056]** The microchip element **712** includes a primary substrate **740** and a silicon substrate **742**. The primary substrate **740** and silicon substrate **742** are bonded together by compression cold welding at/adjacent the interface of a ring structure and groove structure

I claim:

1. A containment device, comprising:

a microchip element comprising one or more containment reservoirs that are configured to be electrically activated to open;

an electronic printed circuit board (PCB) fixed to the microchip element, wherein the PCB comprises an alumina or other biocompatible ceramic substrate;

one or more electronic components associated with the microchip element or the PCB; and

a first inductive coupling device incorporated into the microchip element or the ~~ceramic~~ PCB, wherein the first inductive coupling device is in communication with the one or more electronic components.

2. A medical implant system comprising:

the containment device of claim 1, which is configured for implantation in a patient; and

an external communicator comprising a second inductive coupling device configured to form an inductive coupling circuit with the first inductive coupling device when brought within proximity of the containment device.

~~3. The containment device of claim 1, wherein the PCB comprises a biocompatible substrate.~~

~~4. The containment device of claim 3, wherein the biocompatible substrate comprises alumina.~~

~~5~~3. The containment device of claim 1, wherein the PCB comprises at least one via configured to electrically connect at least one of the one or more electronic components to the ~~elongated~~ microchip element.

~~6~~4. The containment device of claim 1, wherein the microchip element is ~~wirebonded~~ connected via a wire bond to a metallized conductive surface on the PCB.

~~7~~5. The containment device of claim ~~6~~4, wherein a biocompatible coating substance is positioned over the wire bond to secure and protect the connection of the wire bond and to create an atraumatic surface about the containment device.

~~8~~6. The containment device of claim 1, wherein the one or more containment reservoirs comprise microreservoirs containing a drug formulation or a sensor element.

~~9~~7. The containment device of claim 1, wherein the microchip element comprises:

a silicon substrate having a first side, an opposed second side, and at least one aperture extending therethrough, wherein the first side of the silicon substrate comprises an electrically conductive reservoir cap which closes off the at least one aperture;

a primary substrate which is formed of silicon or other metalloid, a polymer, or a glass or other ceramic material, wherein the primary substrate has at least one of the one or more reservoirs which is defined by a closed end wall, an open end, and at least one sidewall extending between the closed end wall and the open end; and

reservoir contents positioned within the at least one reservoir,

wherein the second side of the silicon substrate is hermetically bonded to the primary substrate such that the open end of the reservoir is in fluid communication with the at least one aperture for controlled release or exposure of reservoir contents.

~~10~~8. The containment device of claim ~~9~~7, wherein the primary substrate comprises a metal coating over at least a part of the polymer, glass or other ceramic material of the primary substrate.

~~11~~9. The containment device of claim ~~10~~8, wherein the metal coating coats the at least one sidewall and/or the closed end wall of the at least one reservoir.

~~12~~10. The containment device of claim ~~9~~7, wherein the second side of the silicon substrate comprises at least one ring structure formed thereon.

~~13~~11. The containment device of claim ~~12~~10, wherein the at least one ring structure comprises gold or another metal.

~~14~~12. The containment device of claim ~~12~~10, wherein the primary substrate comprises at least one groove structure, wherein the at least one ring structure and the at least one groove structure are configured to form a hermetic bond.

~~15~~13. The containment device of claim ~~14~~12, wherein the surface of the primary substrate in and/or adjacent to the at least one groove structure comprises a metal coating.

~~16~~14. The containment device of claim ~~15~~13, wherein the metal coating comprises gold.

~~17~~15. The containment device of any one of claims 1 to ~~16~~14, further comprising at least one drug payload disposed in the one or more containment reservoirs for actively controlled release.

~~18~~16. The containment device of claim ~~17~~15, wherein a ratio of a volume of the at least one drug payload to a total volume of the containment device is from about 75 μL/cc to about 150 μL/cc.

~~19~~17. The containment device of claim ~~17~~15, wherein a ratio of a volume of the at least one drug payload to a total volume of the containment device is from about 85 μL/cc to about 120 μL/cc.

~~20~~18. A method of assembling a containment device, comprising:

providing an elongated microchip element comprising one or more containment reservoirs that are configured to be electrically activated to open;

fixing the elongated microchip element to an electronic printed circuit board (PCB) which comprises a biocompatible substrate;

electrically connecting the elongated microchip element to one or more electronic components; and

incorporating a first inductive coupling device into the microchip element or the PCB, wherein the first inductive coupling device is in communication with the one or more electronic components.

2119. The method of claim 2018, wherein providing the elongated microchip element further comprises:

microfabricating a silicon substrate having a first side, an opposed second side, and at least one aperture extending therethrough, wherein the first side comprises an electrically conductive reservoir cap which closes off the at least one aperture;

casting or molding a polymer or a glass or other ceramic material to form a primary substrate having at least one of the one or more reservoirs which is defined by a closed end wall, an open end, and at least one sidewall extending between the closed end wall and the open end;

providing reservoir contents within the at least one reservoir; and

bonding the silicon substrate to the primary substrate such that the open end of the reservoir is in fluid communication with the at least one aperture.

2220. The method of claim 2119, wherein the microfabricating step further comprises forming at least one ring structure on the second side of the silicon substrate.

2321. A system for drug delivery, biosensing, or both drug delivery and biosensing, comprising:

an implantable component which comprises:

a microchip element comprising one or more containment reservoirs that are configured to be electrically activated to open, the one or more containment reservoirs containing at least one of a drug, a biosensor, or a combination thereof,

an electronic printed circuit board (PCB) fixed to the microchip element,

one or more electronic components associated with the microchip element or the PCB, and

a first inductive coupling device incorporated into the microchip element or the PCB, wherein the first inductive coupling device is in communication with the one or more electronic components; and

an external component which comprises a second inductive coupling device configured to form an inductive coupling circuit with the first inductive coupling device when brought within proximity of the implantable component.

2422. The system of claim 2321, wherein the implantable component is configured for subcutaneous insertion into a patient in need thereof.

2523. A containment device, comprising:

a microchip element comprising one or more containment reservoirs that are configured to be electrically activated to open;

a silicon substrate positioned adjacent to the microchip element;

one or more electronic components disposed within the silicon substrate, wherein the one or more electronic components are in communication with the microchip element; and

a first inductive coupling device ~~associated with~~incorporated into the microchip element or the silicon substrate, wherein the first inductive coupling device is in communication with the one or more electronic components.

2624. A medical implant system comprising:

the containment device of claim 2523, which is configured for implantation in a patient; and

an external communicator comprising a second inductive coupling device configured to form an inductive coupling circuit with the first inductive coupling device when brought within proximity of the containment device.

2725. A system for drug delivery, biosensing, or both drug delivery and biosensing, comprising:

an implantable component which comprises:

a microchip element comprising one or more containment reservoirs that are configured to be electrically activated to open, the one or more containment reservoirs containing at least one of a drug, a biosensor, or a combination thereof,

a silicon substrate positioned adjacent to the microchip element,

one or more electronic components disposed within the silicon substrate, wherein the one or more electronic components are in communication with the microchip element, and

a first inductive coupling device ~~associated with~~incorporated into the microchip element or the silicon substrate, wherein the first inductive coupling device is in communication with the one or more electronic components; and

an external component which comprises a second inductive coupling device configured to form an inductive coupling circuit with the first inductive coupling device when brought within proximity of the implantable component.

~~28~~26. The system of claims ~~23~~21, ~~24~~22, or ~~27~~25, wherein the external component comprises a power source and the implantable component does not contain a power source.

~~29~~27. A method of assembling a containment device, comprising:

providing an elongated microchip element comprising one or more containment reservoirs that are configured to be electrically activated to open;

positioning the elongated microchip element adjacent to a silicon substrate;

electrically connecting the elongated microchip element to one or more electronic components; and

incorporating a first inductive coupling device into the microchip element or the silicon substrate, wherein the first inductive coupling device is in communication with the one or more electronic components.

28. A method of operating a containment device, comprising:

determining a location of the containment device, wherein the containment device comprises:

a microchip element comprising one or more containment reservoirs that are configured to be electrically activated to open;

an electronic printed circuit board (PCB) fixed to the microchip element;

one or more electronic components associated with the microchip element or the PCB; and

a first inductive coupling device incorporated into the microchip element or the PCB, wherein the first inductive coupling device is in communication with the one or more electronic components;

positioning an external communicator comprising a second inductive coupling device configured to form an inductive coupling circuit with the first inductive coupling device within proximity of the containment device; and

activating the one or more containment reservoirs to open.