Summary of the Invention

~~In one aspect,~~ compression cold welding methods and structures are provided for hermetically sealing at least two substrates together. This advantageously can provide a hermetic seal without heat input to the sealing process, which may be desirable in many applications where such additional heat could be detrimental to devices, formulations, or materials in close proximity to the bonding area.

According to a first aspect, there is provided a method of forming an electrical via connection comprising: providing a first non-conductive substrate having an aperture therethrough, wherein the interior surface of said first substrate defining said aperture comprises a layer of a first electrically conductive material; providing a second non-conductive substrate having a projecting member extending from a surface of said second substrate, wherein said projecting member is formed of or coated with a second electrically conductive material; and compressing the projecting member of said second substrate into the aperture of said first substrate, to locally deform the first and second electrically conductive layers, in an amount effective to form a cold weld and electrical connection between the first and second electrically conductive layers.

According to a second aspect, there is provided a device including at least one electrical via connection comprising: a first non-conductive substrate having an aperture therethrough, wherein the interior surface of said first substrate defining said aperture comprises a layer of a first electrically conductive material; a second non-conductive substrate having a projecting member extending from a surface of said second substrate, wherein said member is formed of or coated with a second electrically conductive material; and wherein the projecting member of said second substrate is compressed into the aperture of said first substrate such that the first and second electrically conductive layers are cold welded and electrically connected.

In an ~~preferred~~ embodiment, the method includes providing a first substrate having at least one first joint structure which comprises a first joining surface, which surface comprises a first metal; providing a second substrate having at least one second joint structure which comprises a second joining surface, which surface comprises a second metal; and compressing together the at least one first joint structure and the at least one second joint structure to locally deform and shear the joining surfaces at one or more interfaces in an amount effective to form a metal-to-metal bond between the first metal and second metal of the joining surfaces. In one embodiment, the method further includes aligning the at least one first joint structure above the at least one second joint structure before the compressing step so as to impart one or more overlaps of the at least one first joint structure over the at least on second joint structure, wherein the one or more overlaps create the one or more interfaces of the joining surfaces during the compressing step. In an~~preferred~~ embodiments, the one or more overlaps are effective to displace surface contaminants and facilitate intimate contact between the joining surfaces without heat input. In a particular embodiment, the at least one first joint structure comprises at least one tongue structure and the at least one second joint structure comprises at least one groove structure, and the step of compressing together the at least one first joint structure and the at least one second joint structure includes compressing the at least one tongue structure at least partially into the at least one groove structure. In one embodiment, the at least one tongue structure has a tongue height ranging from 1 micron to 100 microns and a tongue width ranging from 1 micron to 100 microns, and the at least one groove structure has a groove depth ranging from 1

step may occur substantially simultaneously. In one embodiment, the heating of the joining surfaces occurs with a microheater.

In another embodiment, the sealing method further includes applying an ultrasonic energy to the joining surfaces at the one or more interfaces.

In yet other embodiments, the sealing method further includes clamping or soldering together the first substrate and the second substrate.

In one ~~a preferred~~ embodiment of the method, the bonded substrates comprise at least one cavity defined therein. In one embodiment, the at least first substrate comprises a plurality of discrete reservoirs containing reservoir contents, each reservoir being hermetically sealed from each other and from an exterior environment. In one example, the reservoir contents comprise a biosensor or other secondary device. In another example, the reservoir contents comprise a drug formulation. In still another example, the reservoir contents comprise fragrance or scent compounds, dyes or other colorants, sweeteners, or flavoring agents. In one embodiment, the first substrate comprises a cavity in which a third substrate is located before the first and second joint structures are compressed together. The third substrate may, for example, comprises a sensor, a MEMS device, or combination thereof.

In one embodiment, the deformation step in the process is conducted under vacuum or in an inert gas atmosphere effective to reduce oxidation of the joint structure relative to that which would occur if conducted in atmospheric air.

In one embodiment, a method is provided for hermetically sealing at least two substrates together, which includes the steps of providing a first substrate having at least one first joint structure which comprises a first joining surface, which surface comprises a first compliant polymer, which has been metallized with a thin layer of a metal; providing a second substrate having at least one second joint structure which comprises a second joining surface, which surface comprises a second compliant polymer, which has been metallized with a thin layer of a metal; and compressing together the at least one first joint structure and the at least one second joint structure to locally deform the joining

surfaces at one or more interfaces in an amount effective to form a bond between the first and second the joining surfaces. In one embodiment, the layer of metal of the first or second metallized polymer, or both, comprises gold, platinum or a combination thereof.

In another embodimentaspect, a containment device is provided which includes a first substrate having a front side and a back side, and including at least one first joint structure which comprises a first joining surface, which surface is a first metal; a second substrate having at least one second joint structure which comprises a second joining surface, which surface is a second metal; a hermetic seal formed between and joining the first substrate and the second substrate, wherein the hermetic seal is made by compression cold welding the first joining surface to the second joining surface at one or more interfaces; and at least one containment space being defined between the first substrate and the second substrate within the hermetic seal such that the containment space is hermetically sealed an exterior environment. In one embodiment, the at least one containment space comprises a plurality of discrete reservoirs in the at least first substrate positioned between the front side and the back side. In various embodiments, the at least one containment space comprises a sensor, a MEMS device, a drug formulation, or a combination thereof, contained in said containment space. In onea preferred embodiment, the joining surfaces are joined together by a metal-to-metal bond formed without heat input. In one embodiment, the at least one first joint structure and the at least one second joint structure comprise a tongue and groove joint.

In various embodiments, the first metal, the second metal, or both, metals may comprise gold, platinum, or a combination thereof, and the substrates may comprise a material selected from the group consisting of silicon, metals, ceramics, polymers, glasses, and combinations thereof. In one embodiment, a pre-form structure is deformed between the first and second joint structures. In another embodiment, the first joint structure or the second joint structure comprises a microheater. Optionally, an intermediate layer may be provided adjacent to the microheater. In one embodiment, the first joint

structure or second joint structure may comprise a magnetic material effective to heat the structure via an external induction heater.

The device may further include other securement means, for example, a clamp may be included for joining the substrates together, or a solder material may be used to secure the first substrate and the second substrate together.

In one embodiment, the first substrate further comprises a plurality of discrete openings in communication with the at least one containment space, and said openings are closed by a plurality of discrete reservoir caps. In one embodiment, the reservoir caps comprise a metal film and the device includes means (e.g., control circuitry and power source) for selectively disintegrating the reservoir caps.

In one embodimentaspect, an implantable medical device is provided for the controlled exposure or release of contents located in hermetically sealed reservoirs. In one embodiment, the device includes a first substrate; a plurality of discrete reservoirs disposed in the first substrate, the reservoirs having first openings and second openings distal the first openings; reservoir contents located inside the reservoirs, wherein the reservoir contents comprises a drug or a biosensor; a plurality of discrete reservoir caps closing the first openings; means for selectively disintegrating the reservoir caps; and a second substrate and a hermetic joint sealing and closing the second openings, wherein the hermetic joint is made by compression cold-welding. In one embodiment, the the hermetic joint comprises a tongue and groove interface.

In another embodimentaspect, a method is provided for forming an electrical via connection comprising: providing a first non-conductive substrate having an aperture therethrough, wherein the interior surface of said first substrate defining said aperture comprises a layer of a first electrically conductive material; providing a second non-conductive substrate having a projecting member extending from a surface of said second substrate, wherein said member is formed of or coated with a second electrically conductive material; and compressing the projecting member of said second substrate into the aperture of said first substrate, to locally deform and shear the first and/or second