CLAIMS

1. An implantable medical device for monitoring mechanical stress from within a host, comprising:

a hermetically sealed housing; and

a physical stress sensor encased within the housing and configured to receive an internal mechanical energy signal that emanates from within the host from an internal body structure and to transduce the received internal mechanical energy signal to an electrical signal indicative of a physiological function by the internal body structure,

wherein the physical stress sensor is a unimorph piezoelectric sensor having a rigid unimorph piezoelectric structure that does not deflect greater than 10 nm when exposed to the internal mechanical energy signal, the rigid unimorph piezoelectric structure comprising a piezoelectric transducer coupled to a biocompatible stress absorption material and to an electrode, wherein the biocompatible stress absorption material is operable to receive the internal mechanical energy signal for the unimorph piezoelectric sensor and transfer the internal mechanical energy signal to the piezoelectric transducer, and wherein the electrode is operable to receive the electrical signal transduced by the piezoelectric transducer.

2. The device of claim 1, wherein the rigid unimorph piezoelectric structure includes a thickness in a range of 300 μm to 750 μm.

3. The device of claim 2, wherein the piezoelectric transducer includes lead zirconate titanate (PZT), the biocompatible stress absorption material includes titanium, and the electrode includes one or more of titanium, gold, platinum, silver, copper, nickel, aluminum, palladium, or combination thereof.

4. The device of claim 1, wherein the biocompatible stress absorption material constitutes a portion of the hermetically sealed housing.

5. The device of claim 1, wherein the unimorph piezoelectric sensor comprises:

a piezoelectric material layer operable as the piezoelectric transducer;

a first layer coupled to a first side of the piezoelectric material layer and configured in the hermetically sealed housing to face outward of the implantable medical device, the first layer comprising a biocompatible, electrically conductive, non-piezoelectric material having a Young's modulus within 2X – 3X of a Young's modulus of the piezoelectric material layer, wherein the first layer is operable as the biocompatible stress absorption material; and

a second layer coupled to a second side of the piezoelectric material layer opposite the first side, the second layer comprising an electrically conductive, non-piezoelectric material, wherein the second layer is operable as the electrode,

wherein the first layer is configured to receive an applied force caused from the internal mechanical energy signal emanated from the internal body structure within the host, such that stress caused by the applied force on the biocompatible, electrically conductive, non-piezoelectric material is transferred through the first layer and into the piezoelectric material to transduce the stress into electrical energy corresponding to the electrical signal indicative of the physiological function by the internal body structure,

wherein the first layer and the second layer are electrically addressable to detect the electrical signal by an electrical circuit.

6. The device of claim 5, wherein the second layer of the unimorph piezoelectric sensor is configured to have a length or a diameter that is equal to the length or the diameter of the piezoelectric material layer of the unimorph piezoelectric sensor.

7. The device of claim 1, wherein the unimorph piezoelectric sensor comprises:

a piezoelectric material layer operable as the piezoelectric transducer;

a first layer configured in the hermetically sealed housing to face outward of the implantable medical device, the first layer comprising a biocompatible, electrically insulative, non-piezoelectric material, wherein first layer is operable as the biocompatible stress absorption material;

a second layer coupled to a first side of the piezoelectric material, the second layer comprising an electrically conductive, non-piezoelectric material, wherein second layer is operable as the electrode; and

a third layer coupled to a second side of the piezoelectric material layer opposite the first side and coupled to a side of the first layer, the third layer comprising an electrically conductive, non-piezoelectric material,

wherein the first layer is configured to receive an applied force caused from the internal mechanical energy signal emanated from the internal body structure within the host, such that stress caused by the applied force on the biocompatible, electrically insulative, non-piezoelectric material is transferred through the first layer and through the third layer and into the piezoelectric material to transduce the stress into electrical energy corresponding to the electrical signal indicative of the physiological function by the internal body structure,

wherein the second layer and the third layer are electrically addressable to detect the electrical signal by an electrical circuit.

8. The device of claim 1, wherein the hermetically sealed housing includes titanium (Ti).

9. The device of claim 1, wherein the internal mechanical energy signal includes a transmission of mechanical energy that propagates in an in vivo medium including one or more of a gas, liquid, or solid, wherein:

the transmission of mechanical energy includes sound energy associated with one or both of blood flow in a blood vessel or a heart of the host and an airflow in an airway or a lung of the host, and wherein the physical stress sensor is operable to detect the sound energy at a distance of at least 0.5 cm from a source of the sound energy, and/or

the unimorph piezoelectric sensor is configured to detect the transmission of mechanical energy in a frequency range of 10 Hz to 1,000 Hz indicative of one or both of blood flow in a blood vessel or a heart of the host and an airflow in an airway or a lung of the host.

10. The device of claim 1, comprising:

an electronics unit in electrical communication with the physical stress sensor, wherein the electronics unit is in a hermetically sealed casing,

wherein the electronics unit comprises:

a power supply, and

a signal processing unit and a wireless communications unit configured to process electrical signals associated with the internal mechanical energy signal as data and wirelessly transmit the data to an external processor.

11. The device of claim 10, comprising:

at least one secondary sensor in communication with the electronics unit and operable to measure a secondary measurement in compilation with an internal mechanical energy signal measurement by the physical stress sensor, wherein the secondary measurement includes one or more of a biological parameter, a physiological parameter, an electrophysiological parameter, or a physical parameter of the host within which the implantable medical device is deployed.

12. The device of claim 11, wherein the at least one secondary sensor includes one or more of the following:

an inertial measurement unit (IMU) configured to detect motion of the implantable medical device in multiple degrees of freedom,

an electrophysiological sensor configured to detect an electrophysiological signal of an anatomic structure of the host, wherein the electrophysiological sensor includes an electrocardiogram (ECG) sensor,

a step counter comprising one or more of at least one accelerometer or at least one rotational rate sensor to detect a quantity of steps moved by the host over a period of time,

an analyte sensor configured to detect an analyte of a biological fluid of the host in a region where the implantable medical device is deployed,

a pH sensor configured to detect a pH level of a biological fluid of the host in a region where the implantable medical device is deployed,

a temperature sensor configured to detect temperature of a tissue structure or an area within the host in a region where the implantable medical device is deployed, or

an ultrasound sensor configured to detect one or more of a vascular blood flow, a vessel wall thickness, and/or a vessel diameter at a reference point in a cardiac cycle of the host or as a function of time during the cardiac cycle.

13. The device of claim 12, wherein the at least one secondary sensor includes (a) an electrophysiological sensor including an electrocardiogram (ECG) sensor, (b) an inertial measurement unit (IMU), and (c) a temperature sensor, and wherein the implantable medical device is configured to:

simultaneously detect (i) the internal mechanical energy signal detectable by the physical stress sensor and (ii) a plurality of secondary signals comprising (a) an electrophysiological energy signal associated with a physiological phenomenon of at least one internal body structure, from within the host, detectable by the ECG sensor, (b) a position, orientation, and/or a movement of the host detectable by the IMU, and (c) a core body temperature of the host detectable by the temperature sensor.

14. The device of claim 13, wherein the implantable medical device is configured to:

process the detected internal mechanical energy signal, the detected electrophysiological energy signal, the detected position, orientation, and/or a movement of the host, and the detected core body temperature of the host to produce biomedical data; and

use the biomedical data to determine a health and/or disease state of the host,

wherein position, orientation, and/or movement of the host detected by the IMU is used to determine whether the host is (1) awake and at rest, (2) undergoing activity, or (3) is sleeping.

15. A system for in vivo monitoring of internal mechanical energy associated with physiological phenomena originating from an anatomic structure, comprising:

the implantable medical device of any of claim 1; and

a data processing system, comprising a processor and a memory, in data communication with the implantable medical device and configured to receive the data from the implantable medical device and process the received data to determine an internal mechanical energy signal parameter associated with a physiological function of the anatomic structure.