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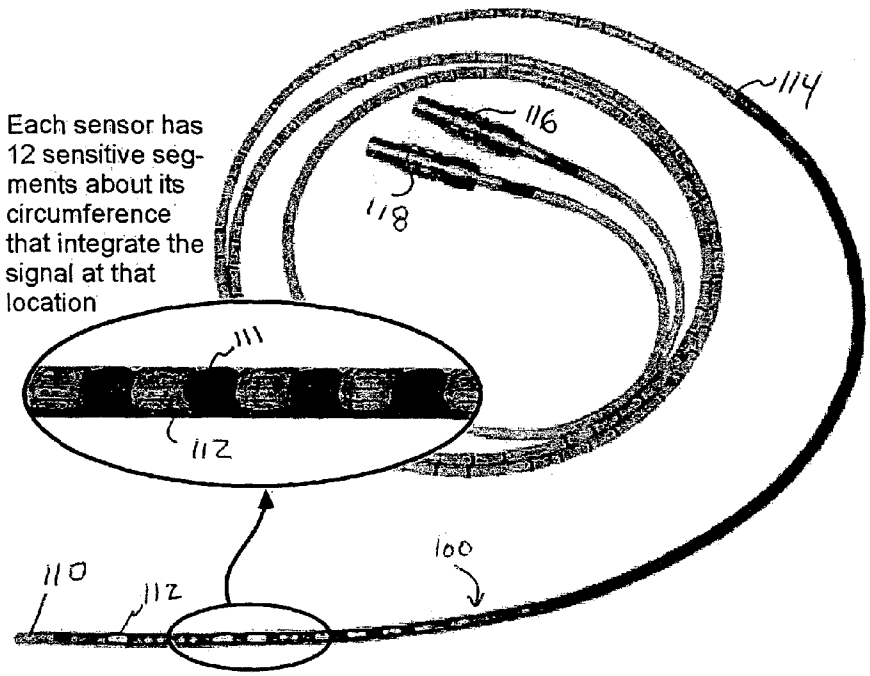
Declarations under Rule 4.17:

— *as to applicant's entitlement to apply for and be granted a patent (Rule 4.17(ii))*

— *as to the applicant's entitlement to claim the priority of the earlier application (Rule 4.17(iii))*

[Continued on next page]

(54) Title: HIGH RESOLUTION SOLID STATE PRESSURE SENSOR



(57) Abstract: A pressure sensor and pressure-sensing catheter in which a deformable pressure sensing membrane is separated from an inner metalized surface on a rigid support by an air gap. An input allows a voltage to be applied to an electrode on the sensing membrane and an output allows reading of the signal modulation from the support surface. An outer sleeve overlays the membrane and a wire bus transmits the signals to a terminal connector. The catheter may include a vented air gap, a multiplexing wire bus, and an internal cable to maintain tension.

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AMENDED CLAIMS
received by the International Bureau on 21 May 2007 (21.05.2007)

1. A pressure sensing catheter comprising:

a plurality of tubular pressure sensors having a deformable outer membrane with an electrically conductive inner surface, spaced apart from a rigid, electrically conductive inner surface by a gap, said pressure sensors spaced within a catheter tube, wherein each pressure sensor is configured to produce an electrical signal in response to pressure external to the catheter tube; and

a signal bus extending through the plurality of sensors and electrically connected to the electrically conductive inner surface of each pressure sensor and each of the rigid electrically conductive inner surface of each pressure sensor, said signal bus extending to terminal connectors at a terminal end of said catheter, said terminal connectors configured to allow access to signals from said pressure sensors.

2. The catheter of claim 1 wherein said pressure sensors are capacitive transducers.

3. The catheter of claim 2 wherein said pressure sensors include a deformable membrane having a metalized inner surface and a rigid metalized surface separated from said deformable membrane by an air gap.

4. The catheter of claim 1 wherein said signal bus comprises a first group of input lines and a second group of output lines.

5. The catheter of claim 4 wherein said first group of input lines is connected to a first terminal of the pressure transducers and said second group of output lines is connected to a second terminal of the pressure transducers.

6. The catheter of claim 5 wherein the input lines are configured to supply an A.C. signal voltage.

7. The catheter of claim 6 wherein said A.C. signal has a frequency below 250kHz.

8. The catheter of claim 1 wherein said signal bus is carried in a flexible wire harness.

9. The catheter of claim 1 further including a non-rigid support tube.

10. The datheter of claim 9 wherein said support tube is 0.050 to 0.001 inch thick.

11. The catheter of claim 1 including pressure sensors spaced 1.2 cm or less center to center.

12. The catheter of claim 1 wherein the pressure sensors have a coaxial tubular deformable outer electrode membrane having a plurality of longitudinal lengthwise slits.

13. The catheter of claim 4 wherein said input lines and said output lines are both disposed on layers of a single, shielded ribbon cable.

14. A tubular capacitive pressure sensor comprisin a pair of spaced apart, co-axially align surfaces including an outer tubular, deformable, electrically conductive membrane surface, and an inner axially aligned non-deformable electrically conductive surface separated from the deformable membrane by an air gap having a characteristic gap dimension; and electrical signal leads positioned proximate to said membrane surface, making separate contact with the deformable conductive membrane surface and the non-deformable conductive surface, whereby when a signal source having a frequency establishing a measurable capacitive impedance across the electrical signal leads, the capacitive impedance varies as pressure changes the dimension of the gap.

15. The sensor of claim 14 wherein said inner surface is a surface on a spool, said spool having annular raised structures for positioning said outer surface.

16. The sensor of claim 15 wherein said outer surface is comprised of a polyimide membrane having a patterned conductive area.

17. The sensor of claim 16 wherein the electrical signal leads are positioned on an arm that extends from a side of the spool.

18. The sensor of claim 14 wherein the deformable outer membrane has a plurality of longitudinal slits.

19. The sensor of claim 17 further including a ground on said sensor, said ground electrically joined to said spool.

20. A pressure sensing catheter comprising:

a longitudinally extending tube, said tube having an internal lumen and an external wall;

a plurality of solid state pressure sensors inside said tube, each pressure sensor having an input and an output; and

an interconnect bus connecting each sensor input and output to an input line and an output line, wherein m x n sensors connect in a m x n matrix to m input lines and n output lines.

21. Cancelled.

22. Cancelled.

23. The catheter of claim 20 wherein said pressure sensors are air gap pressure sensors.

24. The catheter of claim 23 wherein said air gap pressure sensors include an air gap region in gas communication with a vent tube, said vent tube venting to atmospheric pressure.

25. The catheter of claim 20 wherein said plurality of pressure sensors includes 36 pressure sensors.

26. The catheter of claim 20 wherein six sensors share an input line and six sensors share an output line.

27. The catheter of claim 25 wherein said pressure sensors are spaced 1.2 cm or less center to center.

28. The catheter of claim 20 wherein said input lines and said output lines are both disposed on layers of said ribbon wherein said input lines are shielded from said output lines, and both input lines and output lines are shielded from an outside of said ribbon.

29. An elongate pressure sensing device including:

a longitudinally extending non-rigid external tube;

a plurality of capacitive pressure sensors inside said tube; and

a multiplexing means for providing an input and an output to each sensor and transmitting said output to a terminal connector, wherein a number of wires required for the input and the output to each sensor is less than a total number of sensors in the plurality of capacitive sensors.

30. The device of claim 29, wherein said device is a catheter.

31. The device of claim 29, wherein said pressure sensors are capacitive transducers.

32. Cancelled.

33. Cancelled.

34. A pressure sensor comprising:

an outer, flexible member;

an outer electrode positioned on an inside surface of said flexible membrane;

a rigid mounting structure onto which said outer flexible membrane is annularly mounted;

an inner electrode positioned on an surface of said rigid mounting structure such that said outer electrode and said inner electrode are coaxial such that said outer electrode and said inner electrode are separated by an air gap; and

wherein said rigid mounting structure acting to shunt axial and bending loads.

35. A capacitive pressure sensing catheter comprising:

a plurality of pressure sensors, each pressure sensor having an input and an output; and

a flexible ribbon cable extending through said pressure sensors, said flexible ribbon cable containing a plurality of wires, said input and output from each sensor connected to at least one wire in said cable, wherein said ribbon cable includes a plurality of layers onto which a plurality of shielded input wires and a plurality of output wires are connected, wherein said input wires and said output wires are both shielded from each other and are shielded from an area outside the ribbon cable.

36. A pressure sensor comprising:

an outer, flexible membrane;

an outer electrode positioned on an inside surface of said flexible membrane;

a rigid mounting structure onto which said outer flexible membrane is annularly mounted;

an inner electrode positioned on an surface of said rigid mounting structure such that said outer electrode and said inner electrode are coaxial such that said outer electrode and said inner electrode are separated by an air gap; and

a vent extending though said rigid mounting structure into an internal space in said sensor, said vent allowing connection to a vent line to vent said air gap to an external pressure.

37. A pressure sensing catheter comprising:

a plurality of solid state pressure sensors;

a wire bus electronically connected to each pressure sensor such that said bus is configured to provide an input signal to each sensor and an out put signal from each sensor, said wire bus extending from a most distal pressure sensor to a terminal connector; and

a disposable sheath extending over said plurality of sensors.

38. Cancelled.

39. A capacitive pressure sensor comprising:

a circumferential outer sensing membrane having a metalized inner surface;

a circumferential inner rigid structure having at least two spaced rigid spacer elements supporting said outer sensing membrane, said rigid spacer elements creating an inner air gap between said outer sensing membrane and an underlying metalized layer on said inner rigid structure;

a first conductive trace leading to a deformable outer electrode;

a second conductive trace allowing connection to an underlying second electrode surface.

40. A capacitive pressure sensor comprising:

a circumferential outer deformable membrane having a metalized inner surface;

an input on said deformable membrane to allow a voltage to be introduced onto an electrode on said outer deformable membrane;

a rigid inner structure;

a metalized surface on said rigid structure, said metalized surface coaxial with the metalized inner surface on said outer deformable membrane.

41. The catheter of claim 1, wherein said pressure sensors are attached to a support cable.

42. The catheter of claim 13, wherein said shielded ribbon cable includes a first insulating layer, a first layer of conductive wires a second insulating layer, a second layer of insulating wires, and a third insulating layer.

43. The pressure sensor of claim 40, further including a ground on said deformable membrane, said ground allowing connection to a ground wire to allow shielding of said sensor from ambient dielectric charges.

STATEMENT UNDER ARTICLE 19 (1)

The applicant's claim 1 has been amended to require a plurality of tubular pressure sensors and to specify that the terminal connectors are at the end of the pressure sensing catheter. Claim 35 has been amended to require that the ribbon cable include layers onto which input wires and output wires are positioned.

Claims 1-13, 16, 20, 27, 28, 29, 31, 34-37, 39 and 40 have all been amended. Claims 21, 22, 32, 33 and 38 have all been canceled. New claims 41-43 have been added.

With respect to the cited references, Wise et al. teaches a pressure sensor that is planar and detects from a single direction. The sensor disclosed in this reference requires exposure to the ambient pressure of the sensor surface, which extends from the ends of the catheter tube containing the wiring for the device. This cited reference does not teach a membrane, which when deformed allows pressure detection. In addition, the pressure sensor of Wise et al. utilizes a silicon diaphragm, not a metalized inner surface as claimed by the applicants.

Holmes et al., like Wise et al., do not teach a pressure sensor, which includes a deformable membrane. In addition, this reference would fail to function if the device used longitudinal slits for construction of the pressure sensors. Neither Holmes et al. or Wise et al. disclose a pressure sensor in which the pressure from the area surrounding the pressure sensors is vented to outside the pressure sensing device. With respect to Wise et al. in combination with Iwata et al., the claims have been amended to specify that the input and output wires are not bundles of wires, but instead are arranged in shielded layers on a ribbon cable.