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(54) **NON-INVASIVE MULTIPARAMETER SENSOR**

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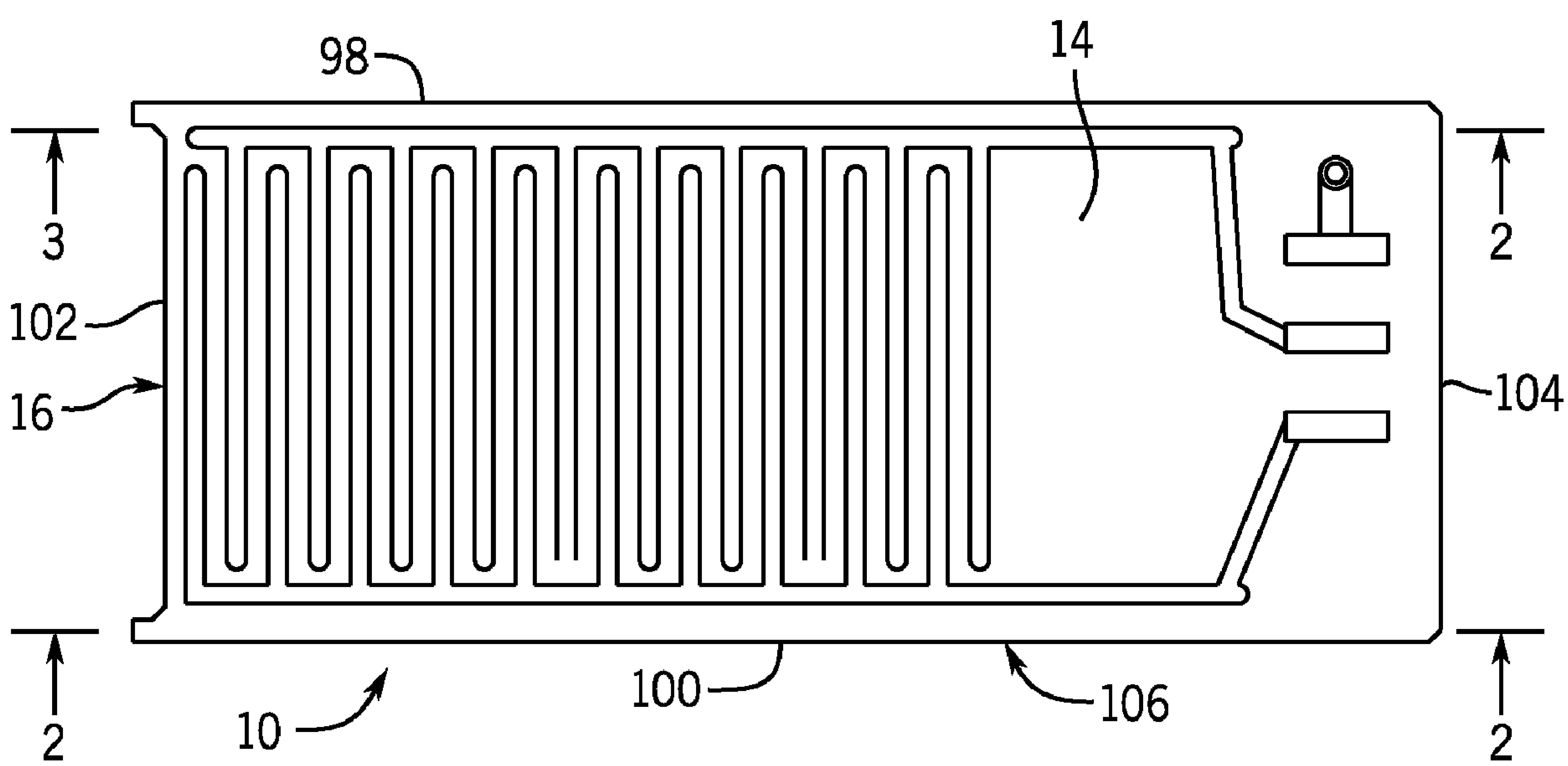
(57) **ABSTRACT**

A sensor and method of interrogating a fluid for multiple parameters is provided. An AC signal is applied to a first electrode in proximity to a fluid so as to induce an electric field to interact with the fluid. A reflected AC signal is measured at a second electrode in response to the interaction of the electric field with the fluid and various parameters of the fluid may be determined in response to the reflected AC signal.



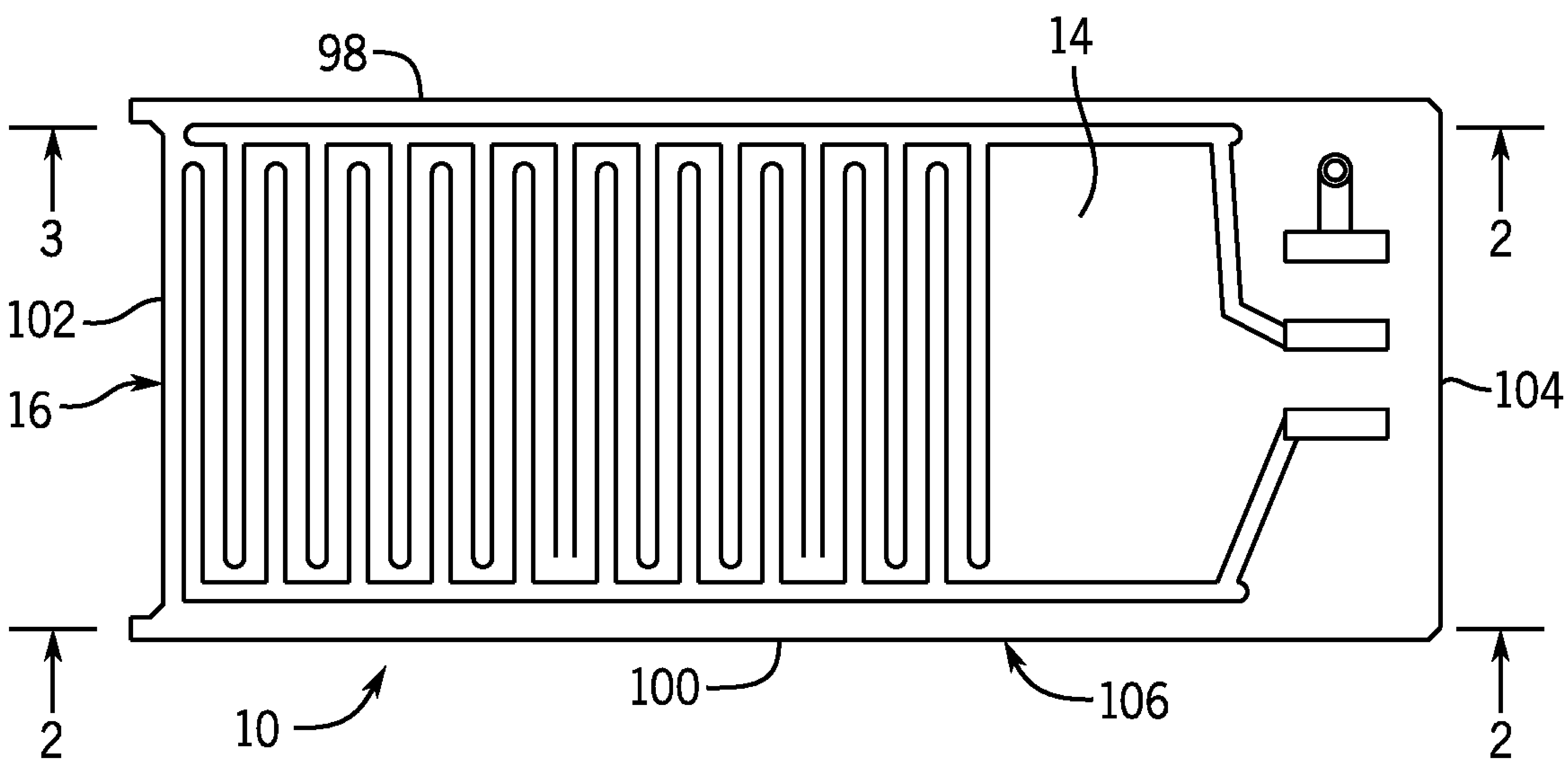


FIG. 1

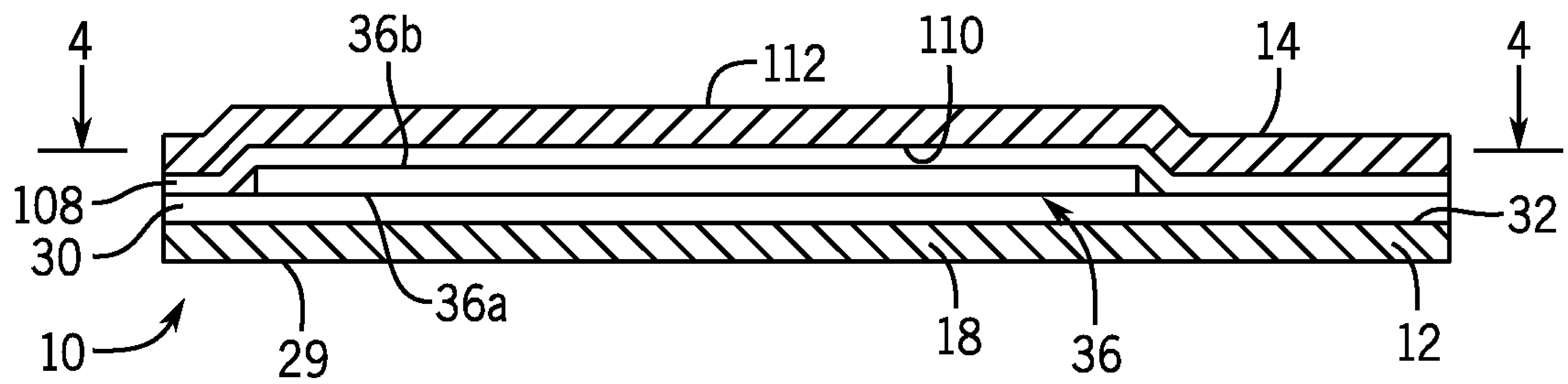


FIG. 2

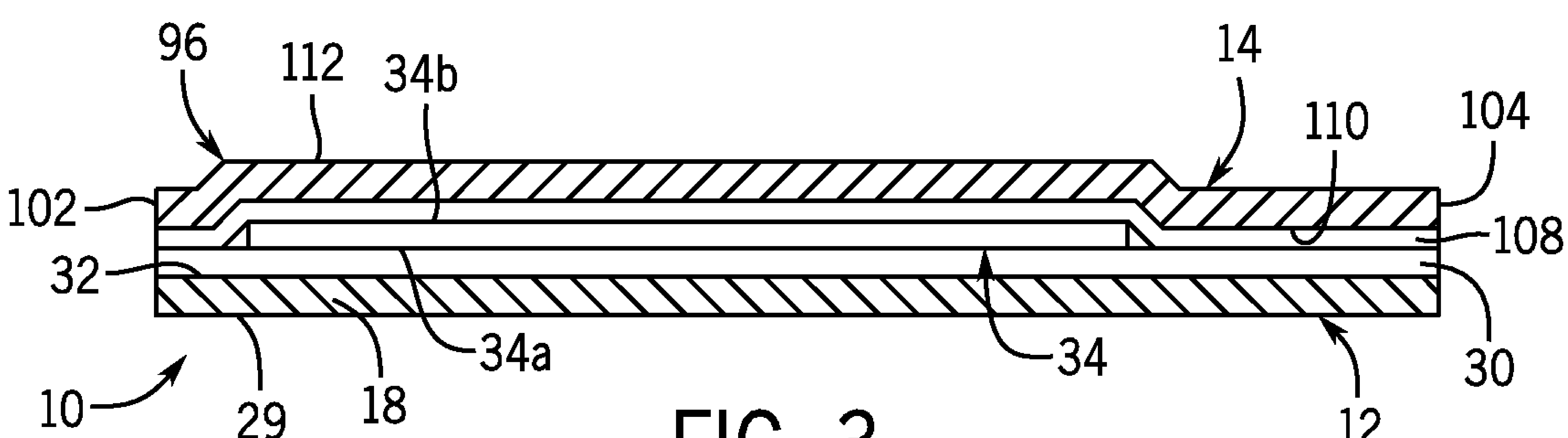


FIG. 3

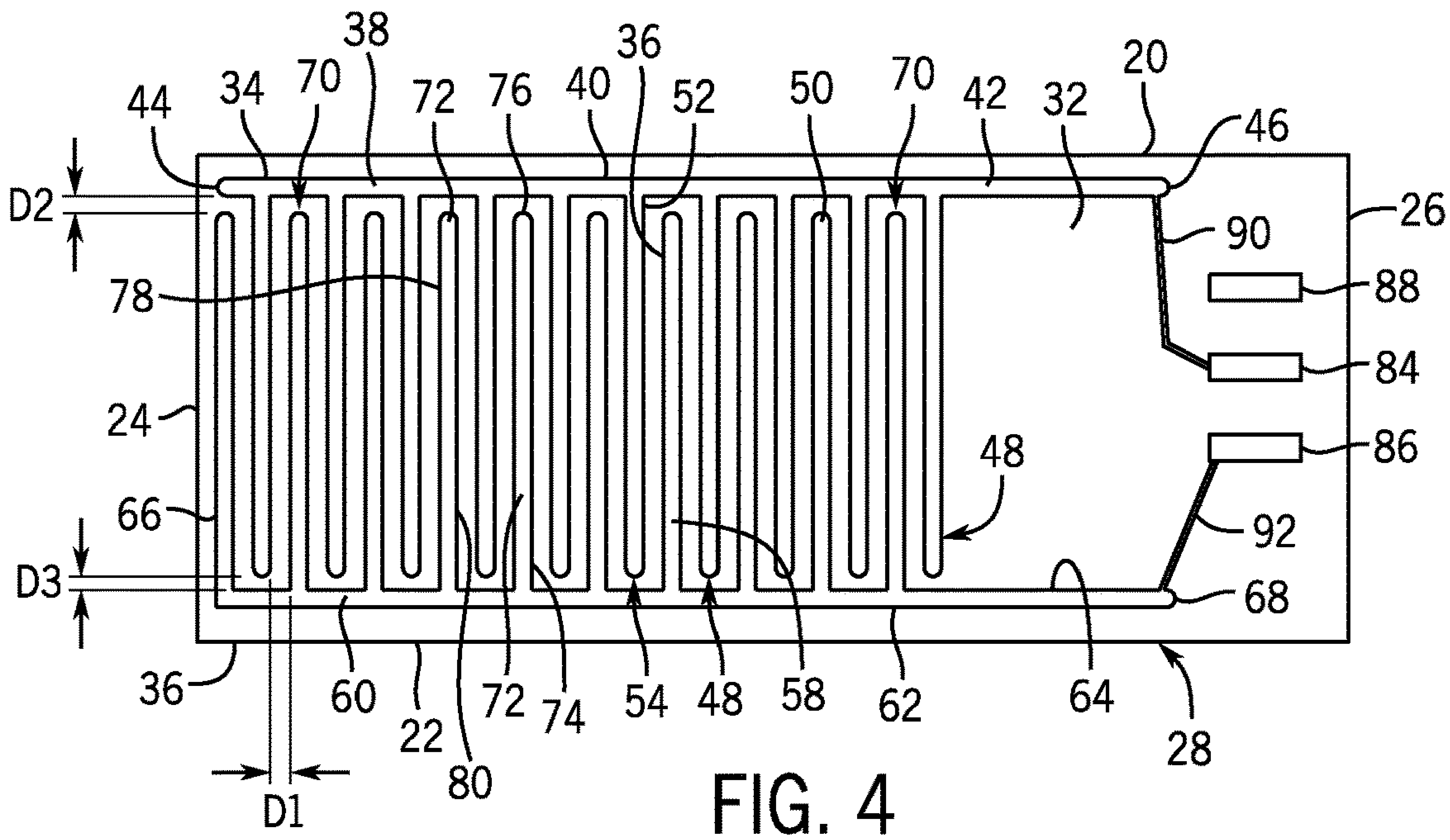

38
36
44
34
70
72
76
40
52
50
70
42
32
20
46
D2
90
26
88
78
84
24
86
48
66
92
D3
68
36
60
22
80
72
74
54
48
58
62
64
28
D1

FIG. 4

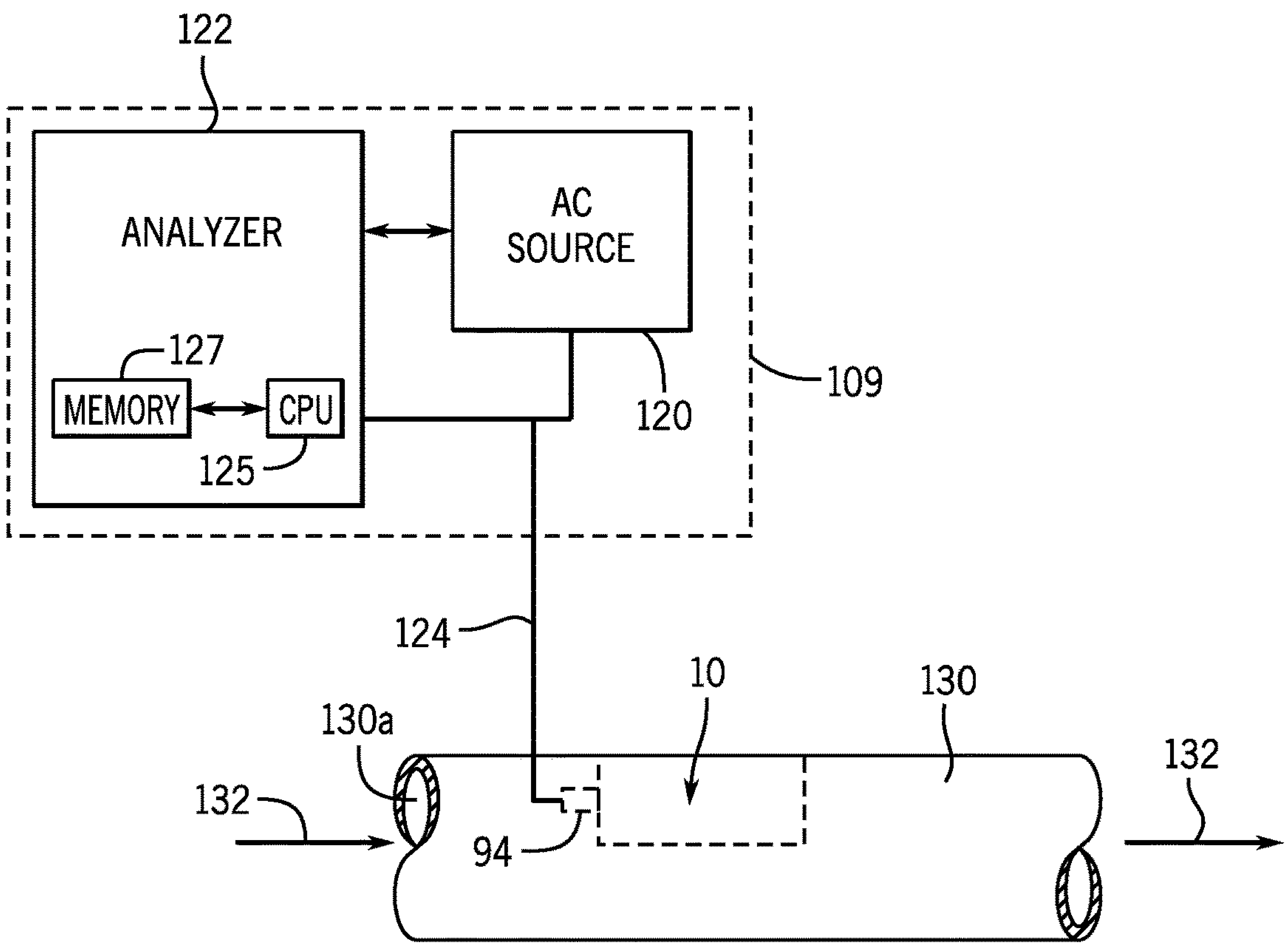

122
ANALYZER
AC
SOURCE
127
MEMORY
CPU
125
120
109
124
10
130
130a
132
132
94

FIG. 5

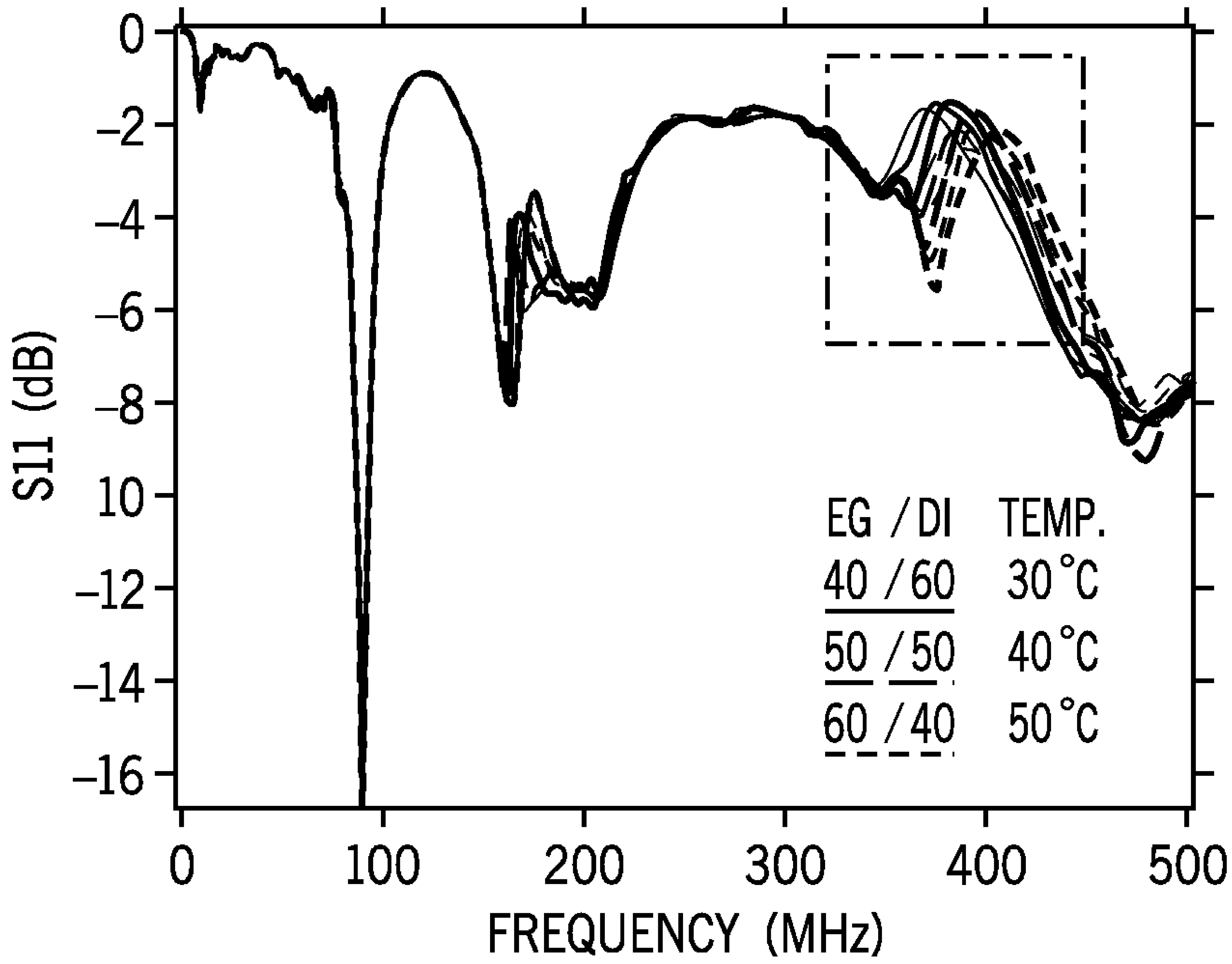

S11 (dB)
0
-2
-4
-6
-8
10
-12
-14
-16
0
100
200
300
400
500
FREQUENCY (MHz)
EG / DI TEMP.
40 / 60 30°C
50 / 50 40°C
60 / 40 50°C

FIG. 6

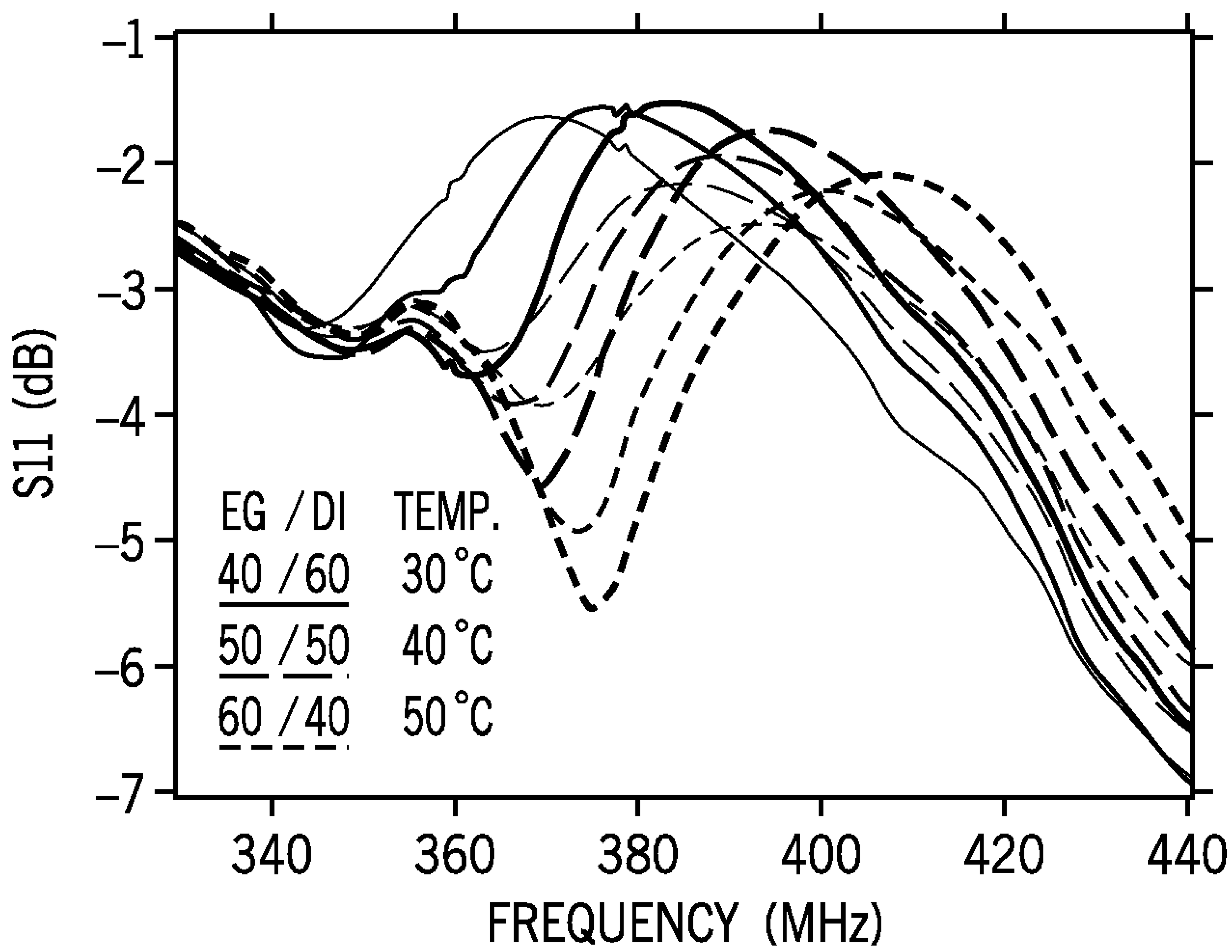

S11 (dB)
-1
-2
-3
-4
-5
-6
-7
340
360
380
400
420
440
FREQUENCY (MHz)
EG / DI TEMP.
40 / 60 30°C
50 / 50 40°C
60 / 40 50°C

FIG. 7

NON-INVASIVE MULTIPARAMETER SENSOR

FIELD OF THE INVENTION

[0001] The present invention relates generally to sensor technology, and in particular, to a sensor and method for interrogating a fluid for multiple parameters simultaneously.

BACKGROUND AND SUMMARY OF THE INVENTION

[0002] It has been estimated that in 2022 alone, the global total emission of CO_2 from the burning of fossil fuels and the production of cement products exceeded 36 billion metric tons (36 metric gigatons) with ground transportation accounting for nearly 18% of this total. In an attempt to curb carbon emissions, governments and industries have turned their attention to the reduction or elimination of carbon pollution by 2050 by mandating the production and sale of zero carbon emission light passenger vehicles by 2035. Currently, the most popular form of vehicle meeting this definition is a battery electric vehicle (BEV).

[0003] These rechargeable BEV applications typically rely on the electrical energy stored and delivered using reversible chemical reactions within individual battery cells. The temperature of these batteries and the thermal gradient during operation within the individual cells must be well controlled to optimize charging/discharging performance, extend the useful life of the battery, and avoid excessively high temperatures that could result in a catastrophic thermal run-away event.

[0004] Although there are many different battery thermal management techniques, the growing majority of these involve the utilization of ethylene glycol/water coolant mixtures to transfer heat. Accurate measurement of a variety of different fluid intrinsic physical properties has become increasingly important when attempting to optimize the performance of modern thermal management systems that utilize aqueous ethylene glycol mixtures as heat transfer media. These fluid physical properties are traditionally measured independently using multiple discrete sensors which rely on a variety of sensing techniques. As the number of measured parameters increases, the cost, system complexity, packaging space, and control system inputs and outputs increase for discrete sensors. Consequently, it can be appreciated that it would be desirable to provide a single sensor technology that has the ability to interrogate a fluid used as a heat transfer media for multiple parameters simultaneously.

[0005] Therefore, it is a primary object and feature of the present invention to provide a sensor and method for interrogating a fluid for multiple parameters simultaneously.

[0006] It is further object and feature of the present invention to provide a sensor and method for interrogating a fluid for multiple parameters non-invasively from a location in proximity to the fluid.

[0007] It is a still further object and feature of the present invention a sensor and method for interrogating a fluid for multiple parameters that is simple and inexpensive.

[0008] In accordance with the present, a sensor is provided for interrogating a fluid for multiple parameters. The sensor includes first and second electrodes positionable in proximity to the fluid. An AC source is operatively connected to the first electrode. The AC source is configured to selectively apply an AC signal to first and second electrodes thereby inducing an electric field to interact with the fluid. An analyzer is operatively connected to the second electrode and is configured to measure a reflected AC signal in response to the interaction of the electric field with the fluid.

[0009] It is contemplated for each of the first and second electrodes to include a base portion having a plurality of legs projecting therefrom. The plurality of legs of the first electrode are interdigitated with the plurality of legs of the second electrode. The sensor also includes a flexible first layer having a first face positionable adjacent to fluid and a second face. The first and second electrodes are bonded to the second face. A flexible second layer may be bonded to the first layer and the first and second electrodes. A Sub-Miniature version A (SMA) connecter may be operatively connected to the first and second electrodes.

[0010] The analyzer is configured to determine a temperature of the fluid in response to the reflected AC signal. The temperature of the fluid is determined by comparing to a signal reflectance of the reflected AC signal to a map. In addition, the analyzer is configured to determine a composition of the fluid in response to the reflected AC signal. The composition of the fluid is determined by comparing to a signal reflectance of the reflected AC signal to a map. The AC source is configured to selectively apply the AC signal to first and second electrodes at a plurality of frequencies.

[0011] In accordance with a further aspect of the present invention, a method of interrogating a fluid for multiple parameters is provided. The method includes the step of applying an AC signal to a first electrode in proximity to a fluid so as to induce an electric field to interact with the fluid. A reflected AC signal is measured at a second electrode in response to the interaction of the electric field with the fluid. A first parameter of the fluid is determined in response to the reflected AC signal. In addition, a second parameter of the fluid may be determined in response to the reflected AC signal.

[0012] The first and second electrodes include a base portion having a plurality of legs projecting therefrom. The plurality of legs of the first electrode are interdigitated with the plurality of legs of the second electrode. The first and second electrodes are bonded to a flexible layer and the flexible layer is positioned adjacent to a conduit carrying the fluid. The first parameter may be temperature or a composition of the fluid. The first parameter is determined by comparing a signal reflectance of the reflected AC signal to a map. The AC signal may be selectively applied to first and second electrodes at a plurality of frequencies.

[0013] In accordance with a still further aspect of the present invention, a method is provided for interrogating a fluid having a plurality of parameters. Each parameter has a plurality of values. The method includes the step of applying AC signals in proximity to a fluid at a plurality of frequencies while maintaining a first parameter of the fluid at a first value of the plurality of values. Each AC signal generates a corresponding electric field which interacts with the fluid. The AC signals are reapplied at the plurality of frequencies while maintaining the first parameter of the fluid at a second value of the plurality of values. Reflected AC signals generated in response to the interaction of the electric field with the fluid in response to the application of the AC signals are measured and a map is generated in response to the reflected AC signals. An interrogating AC signal is applied in proximity to the fluid so as to induce an interrogating electric field to interact with the fluid. A reflected interrogating AC signal in response to the interaction of the interrogating electric field with the fluid is measured and a signal reflectance of the reflected interrogating AC signal is compared to the map to determine a value of the first parameter of the fluid.

[0014] A second set of AC signals may be applied in proximity to the fluid at a plurality of frequencies while maintaining a second parameter of the fluid at a first value of a plurality of values. Each AC signal of the second set of AC signals generates a corresponding electric field which interacts with the fluid. The second set of AC signals is reapplied at the plurality of frequencies while maintaining the second parameter of the fluid at a second value of the plurality of values of the second parameter. Reflected second set of AC signals generated in response to the interaction of the electric field with the fluid is measured in response to the application of the second set of AC signals and a second map is generated in response to the reflected second set of AC signals.

[0015] The signal reflectance of the reflected interrogating AC signal may be compared to the second map to determine a value of the second parameter of the fluid. The interrogating AC signal may applied in proximity to the fluid at a plurality of frequencies. It is contemplated to apply the interrogating AC signals to a first electrode and measure the reflected the interrogating AC signals at a second electrode. The first and second electrodes include a base portion having a plurality of legs projecting therefrom. The plurality of legs of the first electrode are interdigitated with the plurality of legs of the second electrode. The first and second electrodes are bonded to a flexible layer and the flexible layer is positioned adjacent to a conduit carrying the fluid.

[0016] The flexible layer may be a first flexible layer and the method further include the additional step of bonding a second flexible layer to the first flexible layer and to the first and second electrodes so as to capture the first and second electrodes therebetween.

BRIEF DESCRIPTION OF THE DRAWINGS

[0017] Preferred exemplary embodiments of the invention are illustrated in the accompanying drawings in which like reference numerals represent like parts throughout, and in which:

[0018] FIG. **1** is a top plan view of a sensor in accordance with one embodiment of the present invention;

[0019] FIG. **2** is a cross-sectional view of the sensor of the present invention taken along line **2-2** of FIG. **1**;

[0020] FIG. **3** is a cross-sectional view of the sensor of the present invention taken along line **3-3** of FIG. **1**;

[0021] FIG. **4** is a cross-sectional view of the sensor of the present invention taken along line **4-4** of FIG. **2**;

[0022] FIG. **5** is a schematic view showing the sensor of the present in operation;

[0023] FIG. **6** is a graph showing signal reflectance in decibels of three fluid mixtures at three distinct temperatures versus frequency;

[0024] FIG. **7** is an enlarged portion of the graph of FIG. **6**.

BRIEF DESCRIPTION OF THE DRAWINGS

[0025] Referring to FIGS. **1-3**, a sensor in accordance with the present inventions is generally designated by the reference numeral **10**. In the depicted embodiment, sensor **10** has a generally rectangular configuration having includes first and second faces **12** and **14**, respectively, interconnected by outer periphery **16**. However, it can be appreciated that sensor **10** may have other configurations without deviating from the scope of the present invention.

[0026] Referring to FIGS. **2-4**, sensor **10** includes first layer **18** fabricated from a flexible material, e.g. polyimide, having a thickness, e.g. 25 micrometers. First layer **18** has a generally rectangular configuration and is defined by first and second sides **20** and **22**, respectively, and first and second ends **24** and **26**, respectively, which define outer periphery **28** thereof. First face **29** of first layer **18** defines first face **12** of sensor **10**. An adhesive **30** of a desired thickness, e.g. 13 micrometers, is deposited on second side **32** of first layer **18**. First and second interdigitated electrodes **34** and **36**, respectively, having corresponding first sides **34*a*** and **36*a***, respectively, bonded to the second side **32** of first layer **26** by adhesive **30**. It is contemplated for interdigitated, first and second electrodes **34** and **36**, respectively, to be fabricated from copper. However, it can be understood that first and second electrodes **34** and **36**, respectively, may be fabricated from other materials without deviating from the scope of the present invention.

[0027] In the depicted embodiment, first and second electrodes **34** and **36**, respectively, have a generally comb-like shape. More specifically, first electrode **34** includes an elongated base portion **38** having a first side **40** spaced from and generally parallel to first side **20** of first layer **18**, a second side **42** spaced from and generally parallel to second side **22** of first layer **18**, a first end **44** spaced from first end **24** of first layer **18** and a second end **46** spaced from second end **26** of first layer **18**. A plurality of spaced legs **48** project from second side **42** of first electrode **34** along corresponding axes toward second side **22** of first layer **18**. Each leg **50** of the plurality of spaced legs **48** is defined by a first end **52** integral with second side **42** of base portion **38** of first electrode **34** and an opposite, terminal end **54**. First end **52** and terminal end **54** of each leg **50** are interconnected by first and second parallel sides **56** and **58**, respectively, which are perpendicular to second side **42** of base portion **38** of first electrode **34** and parallel to first and second ends **24** and **26**, respectively, of first layer **18**.

[0028] Similarly, second electrode **36** includes an elongated base portion **60** having a first side **62** spaced from and generally parallel to second side **22** of first layer **18**, a second side **64** spaced from and generally parallel to second side **42** of base portion **38** of first electrode **34**, a first end **66** spaced from first end **24** of first layer **18** and a second end **68** spaced from second end **26** of first layer **18**. A plurality of spaced legs **70** project from second side **64** of second electrode **36** along corresponding axes toward second side **42** of base portion **38** of first electrode **34**. The plurality of spaced legs **70** of second electrode **36** are interdigitated with the plurality of spaced legs **48** of first electrode such that each leg **72** of the plurality of spaced legs **70** of first electrode **34** is spaced from an adjacent leg **50** of the plurality of spaced legs **48** of second electrode by a distance D**1**, e.g. 1 millimeter (mm).

[0029] Each leg **72** of the plurality of spaced legs **70** of first electrode **34** is defined by a first end **74** integral with second side **64** of base portion **60** of second electrode **36** and an opposite, terminal end **76**. Terminal end **76** of each leg **72** of the plurality of spaced legs **70** of second electrode **36** is spaced from second side **42** of base portion **38** of first electrode **34** by a distance D**2**, e.g. 1 mm. Likewise, terminal end **76** of each leg **50** of the plurality of spaced legs **48** of first electrode **34** is spaced from second side **64** of base portion **60** of second electrode **36** by a distance D**3**, e.g. 1 mm. In addition, first end **74** and terminal end **76** of each leg **72** of the plurality of spaced legs **70** of second electrode **36** are interconnected by first and second parallel sides **78** and **80**, respectively, which are perpendicular to second side **64** of base portion **60** of second electrode **36** and parallel to first and second ends **24** and **26**, respectively, of first layer **18**. It is intended for the distances D**1**, D**2** and D**3** to be of such dimension so as to allow the expected height of an electric field generated between first and second electrodes **34** and **36**, respectively, as hereinafter described, to be of sufficient height to extend well past the first layer **18** and interact with a fluid in proximity thereto.

[0030] Sensor **10** further includes signal trace **84** and first and second ground traces **86** and **88**, respectively, bonded to the second side **32** of first layer **26** by adhesive **30** at a location adjacent second end **26** of first layer **18**. It is contemplated for signal trace **84** and first and second ground traces **86** and **88**, respectively, to be fabricated from copper. However, it can be understood that signal trace **84** and first and second ground traces **86** and **88**, respectively, may be fabricated from other materials without deviating from the scope of the present invention. Signal trace **84** is electrically coupled to second end **46** of base portion **38** of first electrode **34** by trace **90**. First ground trace **86** is electrically coupled to second end **68** of base portion **60** of second electrode **36** by trace **92**. SubMiniature version A (SMA) connector **94**. FIG. **5**, includes first and second body connectors electrically coupled to first and second ground traces **86** and **88**, respectively, and a center connector electrically coupled to signal trace **84**.

[0031] Referring back to FIGS. **1-3**, sensor **10** further includes second layer **96** fabricated from a flexible material, e.g. polyimide, having a thickness, e.g. 12.5 micrometers. Second layer **96** has a generally rectangular configuration and is defined by first and second sides **98** and **100**, respectively, and first and second ends **102** and **104**, respectively, which define outer periphery **106** thereof. Second layer **96** further includes first and second faces **110** and **112**, respectively. To assemble sensor **10**, second layer **96** is positioned on first layer **18** such that outer periphery **106** of second layer **96** is aligned with outer periphery **28** of first layer **18**. Adhesive **108** is deposited between first face **110** of second layer **96** and second sides **34***b* and **36***b* of first and second electrodes **34** and **36**, respectively, to bond second layer **96** to second sides **34***b* and **36***b* of first and second electrodes **34** and **36**, respectively. In addition, adhesive **108** is deposited between adhesive **30** and second face **112** of second layer **96** to bond second layer **96** to first layer **18**. It is contemplated for adhesive **108** to have a desired thickness, e.g. 15 micrometers. In its assembled configuration, outer periphery **106** of second layer **96** and outer periphery **28** of first layer define outer periphery **16** of sensor **10**. In addition, second face **112** of second layer **96** defines second face **14** of sensor **10**.

[0032] Referring to FIG. **5**, sensor **10** is intended to be operatively connected to controller **109** including AC source **120** and analyzer **122**. More specifically, it is contemplated to interconnect the central conductor of coaxial cable **124** to AC source **120** and to signal trace **84** via SCA connector **94**. The external conductor of coaxial cable **124** interconnects analyzer **122** to first and second ground traces **86** and **88**, respectively, via SCA connector **94**. As hereinafter described, it is intended for AC source **120** to supply an AC signal, for example, an AC voltage signal having a magnitude and a frequency to first electrode **34**, thereby generating an electric field. Analyzer **122** communicates with AC source **120** and includes a processor **125** and software stored in computer-readable memory **127** for effectuating the methodology of the present invention. More specifically, processor **125** controls the magnitude and frequency of the AC signal provided to sensor **10** by AC source **120**. In addition, it contemplated for analyzer **122** to measure the reflected AC signal at first and second ground traces **86** and **88**, respectively.

[0033] In operation, first face **12** of sensor **10** is positioned on conduit **130** carrying a fluid, generally designated by the reference numeral **132**. Sensor **10** may be retained on conduit **130** in any conventional manner such as by an adhesive, a clamp or the like. An AC signal is applied by AC source **120** to first electrode **34**. It is contemplated to apply an AC voltage at a selected magnitude, e.g. 225 mV, and at a selected frequency, e.g. between 1-500 MHz for a predetermined period of time, e.g. 5.33 milliseconds. An electric field is generated in response to application of the AC signal to first electrode **34**. As described above, the electric field is of sufficient height so as to extend past the first layer **18** and conduit **130** and into interior **130***a* of conduit **130** so as to interact with fluid **132** therein. The process is repeated for multiple frequencies in the noted range (e.g., **8192** data points).

[0034] As is known, the complex permittivity of a fluid, e.g. fluid **132**, is modified by physical parameters, such as temperature or volumetric composition. As such, as hereinafter described, the reflected AC signal measured at first ground trace **86** may be used to determine the change in the permittivity of fluid **132** resulting from changes in the physical parameters thereof. More specifically, analyzer **122** measures the magnitude and frequency of the reflected AC signal at first ground trace **86** at each frequency, or in other words, at each of the above-noted data points. Thereafter, after analyzer **122** calculates the signal reflectance S_{11}. As is known, signal reflectance S_{11} is defined as is defined as the ratio between the reflected AC signal and the applied AC signal and may be calculated according to the expression:

$$S_{11} = -10\log_{10}\left(\frac{P_{ref}}{P_{app}}\right) \qquad \text{Equation (1)}$$

[0035] wherein

[0036] S_{11} is the signal reflectance, P_{ref} is the reflected power, and P_{app} is the applied power.

[0037] Once the signal reflectance S_{11} is determined, analyzer **122** may compare the signal reflectance S_{11} to a previously compiled map of signal reflectance S_{11} for a particular fluid at a particular temperature when the particular fluid interacts with an AC signal of a predetermined magnitude over a range of frequencies, e.g. between 1-500 MHz. By way of example, referring to FIG. **6**, a sample map showing various volumetric mixtures of ethylene glycol (EG) and deionized (DI) water at preselected temperatures is depicted. As noted above, this fluid mixture application relevance for use as vehicular heat transfer media, particularly in BEVs. More specifically, FIG. **6** depicts a spectra of signal reflectance S_{11} three different volumetric compositions (40, 50, and 60% EG by volume) of a fluid at three different temperatures (30, 40, and 50° C.).

[0038] FIG. **7** depicts an enlarged portion of the sample map of FIG. **6** show a spectral region in the frequency regime 300-450 Mhz. It can be appreciated that the differences in the volumetric composition of the fluid and the differences in temperature causes increased spectral separation in the signal reflectance S_{11}. It can be appreciated that two distinctive phenomena are associated with each independent variable, namely the temperature and volumetric composition. First, the temperature increase causes a frequency shift within the data. This corresponds to the decrease in the dielectric constant that occurs within EG/DI mixtures as the temperature is increased. Second, as the magnitude of signal reflectance S_{11} changes as the volume percent of EG is increased. This is due to a combination of the decrease in dielectric constant and increase in loss tangent that is exhibited within higher concentration solutions of EG.

[0039] In view of the foregoing, it can be appreciated that by comparing signal reflectance S_{11} to a previously compiled map of signal reflectance S_{11} for a particular fluid, analyzer **122** may simply and easily determine the physical properties, such as temperature and fluid composition, of fluid **132** in a non-invasive manner with sensor **10** in proximity to fluid **132**.

[0040] Although the best mode contemplated by the inventors of carrying out the present invention is disclosed above, practice of the above invention is not limited thereto. It will be manifest that various additions, modifications and rearrangements of the features of the present invention may be made without deviating from the spirit and the scope of the underlying inventive concept.

[0041] It should be appreciated that such a development effort might be complex and time consuming, but would nevertheless be a routine undertaking of design, fabrication, and manufacture for those of ordinary skill having the benefit of this disclosure. Nothing in this application is considered critical or essential to the present invention unless explicitly indicated as being "critical" or "essential."

We claim:

1. A sensor for interrogating a fluid for multiple parameters, comprising:
- first and second electrodes positionable in proximity to the fluid;
- an AC source operatively connected to the first electrode, the AC source configured to selectively apply an AC signal to first electrode thereby inducing an electric field to interact with the fluid; and
- an analyzer operatively connected to the second electrode and configured to measure a reflected AC signal in response to the interaction of the electric field with the fluid.

2. The sensor of claim **1** wherein each of the first and second electrodes include a base portion having a plurality of legs projecting therefrom, the plurality of legs of the first electrode interdigitated with the plurality of legs of the second electrode.

3. The sensor of claim **1** further comprising a flexible first layer, the first layer having a first face positionable adjacent to fluid and a second face, wherein the first and second electrodes are bonded to the second face.

4. The sensor of claim **1** further comprising a flexible second layer, the second layer bonded to the first layer and the first and second electrodes.

5. The sensor of claim **1** further comprising a SubMiniature version A (SMA) connecter operatively connected to the first and second electrodes.

6. The sensor of claim **1** wherein the analyzer is configured to determine a temperature of the fluid in response to the reflected AC signal.

7. The sensor of claim **6** wherein the temperature of the fluid is determined by comparing to a signal reflectance of the reflected AC signal to a map.

8. The sensor of claim **1** wherein the analyzer is configured to determine a composition of the fluid in response to the reflected AC signal.

9. The sensor of claim **8** wherein the composition of the fluid is determined by comparing to a signal reflectance of the reflected AC signal to a map.

10. The sensor of claim **1** wherein the AC source is configured to selectively apply the AC signal to first and second electrodes at a plurality of frequencies.

11. A method of interrogating a fluid for multiple parameters, comprising the steps of:
- applying an AC signal to a first electrode in proximity to a fluid so as to induce an electric field to interact with the fluid;
- measuring a reflected AC signal at a second electrode in response to the interaction of the electric field with the fluid; and
- determining a first parameter of the fluid in response to the reflected AC signal.

12. The method of claim **11** comprising the additional step of determining a second parameter of the fluid in response to the reflected AC signal.

13. The method of claim **11** wherein the first and second electrodes include a base portion having a plurality of legs projecting therefrom, the plurality of legs of the first electrode interdigitated with the plurality of legs of the second electrode.

14. The method of claim **11** comprising the additional steps of:
- bonding the first and second electrodes to a flexible layer; and
- positioning the flexible layer adjacent to a conduit carrying the fluid.

15. The method of claim **11** wherein the first parameter is temperature.

16. The method of claim **11** wherein the first parameter is a composition of the fluid.

17. The method of claim **11** wherein the first parameter is determined by comparing a signal reflectance of the reflected AC signal to a map.

18. The method of claim **11** comprising the additional step of selectively applying the AC signal to first and second electrodes at a plurality of frequencies.

19. A method of interrogating a fluid having a plurality of parameters, each parameter having a plurality of values, comprising the steps of:
- applying AC signals in proximity to a fluid at a plurality of frequencies while maintaining a first parameter of the fluid at a first value of the plurality of values,
- wherein each AC signal generates a corresponding electric field which interacts with the fluid;

reapplying the AC signals at the plurality of frequencies while maintaining the first parameter of the fluid at a second value of the plurality of values;
measuring reflected AC signals generated in response to the interaction of the electric field with the fluid in response to the application of the AC signals;
generating a map in response to the reflected AC signals;
applying an interrogating AC signal in proximity to the fluid so as to induce an interrogating electric field to interact with the fluid;
measuring a reflected interrogating AC signal in response to the interaction of the interrogating electric field with the fluid; and
comparing a signal reflectance of the reflected interrogating AC signal to the map to determine a value of the first parameter of the fluid.

20. The method of claim **19** comprising the additional steps of:
applying a second set of AC signals in proximity to the fluid at a plurality of frequencies while maintaining a second parameter of the fluid at a first value of a plurality of values, wherein each AC signal of the second set of AC signals generates a corresponding electric field which interacts with the fluid;
reapplying the second set of AC signals at the plurality of frequencies while maintaining the second parameter of the fluid at a second value of the plurality of values of the second parameter;
measuring reflected second set of AC signals generated in response to the interaction of the electric field with the fluid in response to the application of the second set of AC signals; and
generating a second map in response to the reflected second set of AC signals.

21. The method of claim **20** comprising the additional steps of comparing the signal reflectance of the reflected interrogating AC signal to the second map to determine a value of the second parameter of the fluid.

22. The method of claim **19** wherein the interrogating AC voltage signal is applied in proximity to the fluid at a plurality of frequencies.

23. The method of claim **19** wherein the interrogating AC signals are applied to a first electrode and the reflected interrogating AC signal is measured at a second electrode, each of the first and second electrodes include a base portion having a plurality of legs projecting therefrom, the plurality of legs of the first electrode interdigitated with the plurality of legs of the second electrode.

24. The method of claim **23** comprising the additional steps of:

bonding the first and second electrodes to a flexible layer; and

positioning the flexible layer adjacent to a conduit carrying the fluid.

25. The method of claim **24** wherein the flexible layer is a first flexible layer and wherein the method further comprises the additional step of bonding a second flexible layer to the first flexible layer and the first and second electrodes so as to capture the first and second electrodes therebetween.

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