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NASA CASE NO. LAR 14591-1

PRINT FIG. 1

NOTICE

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Serial No.: 07/957,014
08-31/92 LaRC

(NASA-Case-LAR-14591-1) MULTIPLE LAYER DIELECTRICS, HOT FILM SENSORS, AND METHODS OF PRODUCING SAME Patent Application (NASA) 13 p

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Unclas

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NASA Case No. LAR 14591-1

MULTIPLE LAYER DIELECTRICS, HOT FILM SENSORS, AND METHODS OF PRODUCING SAME

AWARDS ABSTRACT

The detection of the transition between laminar and turbulent flow is important in aerodynamics research and it is often desired to detect transition over a wide range of temperatures, e.g., 150°F to -300°F. There is currently no sensor which can obtain data over these temperature extremes. Also, the formation of a dielectric over an electrically conducting layer for use of a wide range of temperatures is desirable.

The invention is a method of forming metal designs such as hot film sensors on a composite surface according to the present invention. The outer composite layer is an epoxy resin which is shaped to a desired surface on an underlying metal layer. The epoxy resin is bombarded with an ion beam for a brief period and then a fused silica layer is simultaneously vapor deposited thereon via an electron beam. The fused silica and epoxy resin form a dielectric over the metal layer. A sensor design mask is then positioned over the newly deposited fused silica. The exposed portion of the fused silica layer is then bombarded with an ion beam for a brief period of time and then a metal layer is simultaneously vapor deposited thereon via an electron beam. Thin film leads leading to a data acquisition system are then connected to the metal sensor and fused silica layer in a similar manner. All operations employing the ion beam and electron beam were conducted in a vacuum environment.

Novel features of the present invention include its use of a fused silica layer to stabilize the resin for further deposition of metal layers.

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MULTIPLE LAYER DIELECTRICS, HOT FILM SENSORS, AND METHOD OF PRODUCING SAME

Origin of the Invention

The invention described herein was made by employees of the United States Government and may be manufactured and used by or for the Government for governmental purposes without the payment of any royalties thereon or therefor.

Background of the Invention

1. Technical Field of the Invention

The present invention relates generally to bonding metal to composites and more particularly to a method of applying a metal design such as a hot film sensor onto a composite surface exposed to cryogenic as well as elevated temperatures.

2. Discussion of the Related Art

The detection of the transition between laminar and turbulent flow is very important in aerodynamic research. A conventional sensor exposed to an airflow comprises leads connected to a constant temperature anemometer circuit, whereby the changing voltage requirements of the circuit are indicative of the flow transition. Current test proposals require applying the sensors to models made of a composite material without damage to or significant alteration of the model surface. In addition, the sensors must be able to detect transition while experiencing cryogenic temperatures of approximately -300°F. Operating conditions of up to approximately 150°F are also experienced. A single sensor

capable of proper attachment and sensing between those two extremes is especially desirable. Also the resulting sensor should not exceed a critical roughness height specification to avoid flow disturbances.

There is currently no known technique for attaching the sensors to composite models that meets these requirement. Proposed alternatives to hot film sensors include various flow visualization techniques, infrared thermography, fluxuation surface pressures, and the use of pressure transducers to determine fluctuating surface pressures. These techniques are intrusive, incompatible with a cryogenic environment, or hampered by poor resolution.

Objects of the Invention

It is accordingly an object of the present invention to provide a method of applying hot film sensors onto a composite surface.

It is another object of the present invention to provide a method of applying hot film sensors onto a composite surface without any damage to or significant alteration of the surface of the model surface.

It is a further object of the present invention to provide a method of applying a hot film sensor to a composite surface which can endure cryogenic conditions.

It is another object of the present invention to provide a method of applying a hot film sensor to a composite surface which can endure elevated temperatures of up to 150°C.

It is a further object of the present invention to provide a method of applying a hot film sensor to a composite which can endure both cryogenic and elevated temperatures.

It is another object of the present invention to accomplish the foregoing objects without interfering with the air flow with excessively thick sensors.

It is a further object of the present invention to accomplish the foregoing objects in a simple, straightforward manner.

Additional objects and advantages of the present invention are apparent from the specification and drawings which follow.

Summary of the Invention

The foregoing and additional objects are achieved by a method of forming metal designs such as sensors on a composite surface according to the present invention. The outer composite layer is an epoxy resin which is shaped to a desired surface. The epoxy resin is bombarded with an ion beam for a brief period and then a fused silica layer is simultaneously vapor deposited thereon via an electron beam. A sensor design mask is then positioned over the newly deposited fused silica. The exposed portion of the fused silica layer is then bombarded with an ion beam for a brief period of time and then a metal layer is vapor simultaneously deposited thereon via an electron beam. Thin film leads leading to a data acquisition system are then connected to the metal sensor and fused silica layer in a similar manner. All operations employing the ion beam and electron beam were conducted in a vacuum environment.

Brief Description of the Drawings

FIG. 1 is an exposed side view of a sensor formed on an epoxy resin surface according to the present invention;

FIGS. 2(a)-(i) are respective graphs for nine sensors formed in an epoxy resin surface according to the present invention, plotting resistance versus temperatures from room temperature to 150°F; and

FIGS. 3(a)-(i) are graphs for the same nine sensors depicted respectively in FIGS. 2(a)-(i), plotting resistance versus temperatures from room temperature to -300°F.

Detailed Description of the Invention

The present invention is directed toward a method of non-invasively applying metal designs such as hot film sensors onto an outer surface for operation in cryogenic and elevated temperatures. Referring now to FIG. 1, a composite model 10 is shown comprising an inner stainless steel hull 12, an intermediate fiberglass layer 14, and an outer epoxy resin layer 16. The resin layer may be any suitable resin such as a bisphenol-A based epoxy resin diluted with butyl glycidyl ether commercially available from Shell Chemical Company under the trademark EPON Resin 815®. The epoxy resin is malleable and permits formation of the desired airfoil surface geometry.

The epoxy resin composite model is first placed in a vacuum chamber. The chamber is evacuated to a pressure of below 2x10-5 Torr. Next, the model is bombarded with an ion beam source for approximately three minutes. The ion beam source employed is a high current/low energy type. It is set to generate an ion beam current of approximately 625mA with an ion energy in the range of 90eV. While the model is bombarded by the ion beam, the electron beam is turned on so that fused silica (SiO_2) layer 18 is simultaneously evaporated onto the composite model surface via vapor deposition. Fused silica layer 18 serves as a surface stabilization for the subsequent deposition steps. The typical thickness of the fused silica layer is in the range of 5,000Å to 10,000Å. The ion source is used to clean the composite model surface as well as reduce the stresses inherent in newly deposited materials, especially metallic materials.

After the fused silica is applied, the model is then removed from the vacuum environment in preparation for the next step. A metal mask is masked down over the newly deposited fused silica layer 18. The mask is used to form the desire sensor patterns and dimensions, as is known in the art. The model is then placed back in the vacuum chamber and the ion beam source is once

again activated with the same operating parameters as above so that the exposed fused silica surface under the mask can be cleaned similarly to the previous step. While the ion beam source is on, the electron beam is activated so that the chosen metal is vapor deposited through the mask to form the metal sensor. The resulting metal layer 20 can be any conventionally used metal such as nickel, platinum or palladium. The thickness of the chosen metal is varied according to the particular intended application. In one particular embodiment used in the tests described below, the metal layer was nickel and the thickness was approximately 2,500Å.

After the metal sensor was formed, the model is removed from the vacuum chamber so that the metal mask can be removed and a predetermined lead pattern for the particular sensor is positioned on the fused silica 18 to expose a portion thereon. The model is placed back in the chamber for the upcoming thin film lead deposition step. The ion beam source, using the same operating parameters as described in previous steps, is turned on again in order to clean the exposed silica surface. The electron beam is then concurrently turned on to vapor deposited a selected metal to form the thin film leads 22. This metal can be any suitable electric conductor such as copper, gold and aluminum. In the particular embodiment discussed below, the leads 22 were copper and had a thickness of approximately 5000 Å.

The resulting sensor and other like sensors are connected to a known anemometer system to detect flow transition under various conditions. The epoxy resin composite and fused silica serve to electrically insulate the metal model from the sensors, i.e., to form a dielectric on the metal model.

The sensor according to the present invention is thus firmly attached to a model having an outer coating of epoxy resin. No significant surface roughness results, thereby avoiding degradation of aerodynamic effects. Also, no messy and thickness increasing glue is required. In addition, the dielectric sensor can be applied to two- or three-dimensional surfaces. Most importantly,

the sensor is firmly applied to the epoxy resin surface and remains so applied over a wide range of temperatures, e.g., -300°F to 150°F, as evidenced below.

FIGS. 2(a)-(i) respectively show the resistances of nine sensors fabricated according to the present invention plotted at room temperature (78.5°F), 100°F, 125°F, and 150°F. Each sensor was operated at a 1.4 overheat ratio at the peak temperature. As shown, each sensor exhibited proportional, approximately linear relationship between the measured resistance and the temperature. The resistances of the sensors accordingly are suitable indicators of temperature in the tested range of room temperature (78.5°F) up to 150°F.

FIGS. 3(a)-(i) respectively show the resistance of the same nine sensors as FIGS. 2(a)-(i) plotted at room temperature (84.5°F), 0°F, -50°F, -100°F, -150°F, -200°F, -250°F, and -300°F. Once again, all of the sensors were operated at a 1.4 overheat ratio at the peak temperature. As shown, each sensor continued to exhibit a proportional, approximately linear relationship between the measured resistance and the temperature. The resistance of the sensors are suitable indicators of temperature in the tested range of room temperature (84.5°F) down to -300°F. The total effective range of the sensors fabricated according to the present invention is thus -300°F to 150°F.

Sensors fabricated according to the present invention were also used to detect boundary layer transition in the 0.3-M Cryogenic Tunnel located at NASA Langley Research Center, Hampton, Virginia. The sensors were operated continuously for a few days at temperatures down to 100K and pressures up to 45 psia, marking the first successful transition detection in a cryogenic tunnel operated near its operational temperature.

The present invention is described with reference to a specific example of forming a sensor. It is understood that it is not limited to the example, but applies to applications wherein a metal design is formed on an epoxy resin substrate which overlies an electrically conducting layer, especially wherein the resulting structure is exposed to wide temperature variations.

Many improvements, modifications and substitutions will be apparent to the skilled artisan without departing from the spirit and scope of the present invention as described herein and defined in the following claims.

MULTIPLE LAYER DIELECTRICS, HOT FILM SENSORS, AND METHODS OF PRODUCING SAME

Abstract of the Disclosure

The invention is a method of forming metal designs such as hot film sensors on a composite surface according to the present invention. The outer composite layer is an epoxy resin which is shaped to a desired surface on an underlying metal layer. The epoxy resin is bombarded with an ion beam for a brief period and then a fused silica layer is simultaneously vapor deposited thereon via an electron beam. The fused silica and epoxy resin form a dielectric over the metal layer. A sensor design mask is then positioned over the newly deposited fused silica. The exposed portion of the fused silica layer is then bombarded with an ion beam for a brief period of time and then a metal layer is simultaneously vapor deposited thereon via an electron beam. Thin film leads leading to a data acquisition system are then connected to the metal sensor and fused silica layer in a similar manner. All operations employing the ion beam and electron beam were conducted in a vacuum environment.

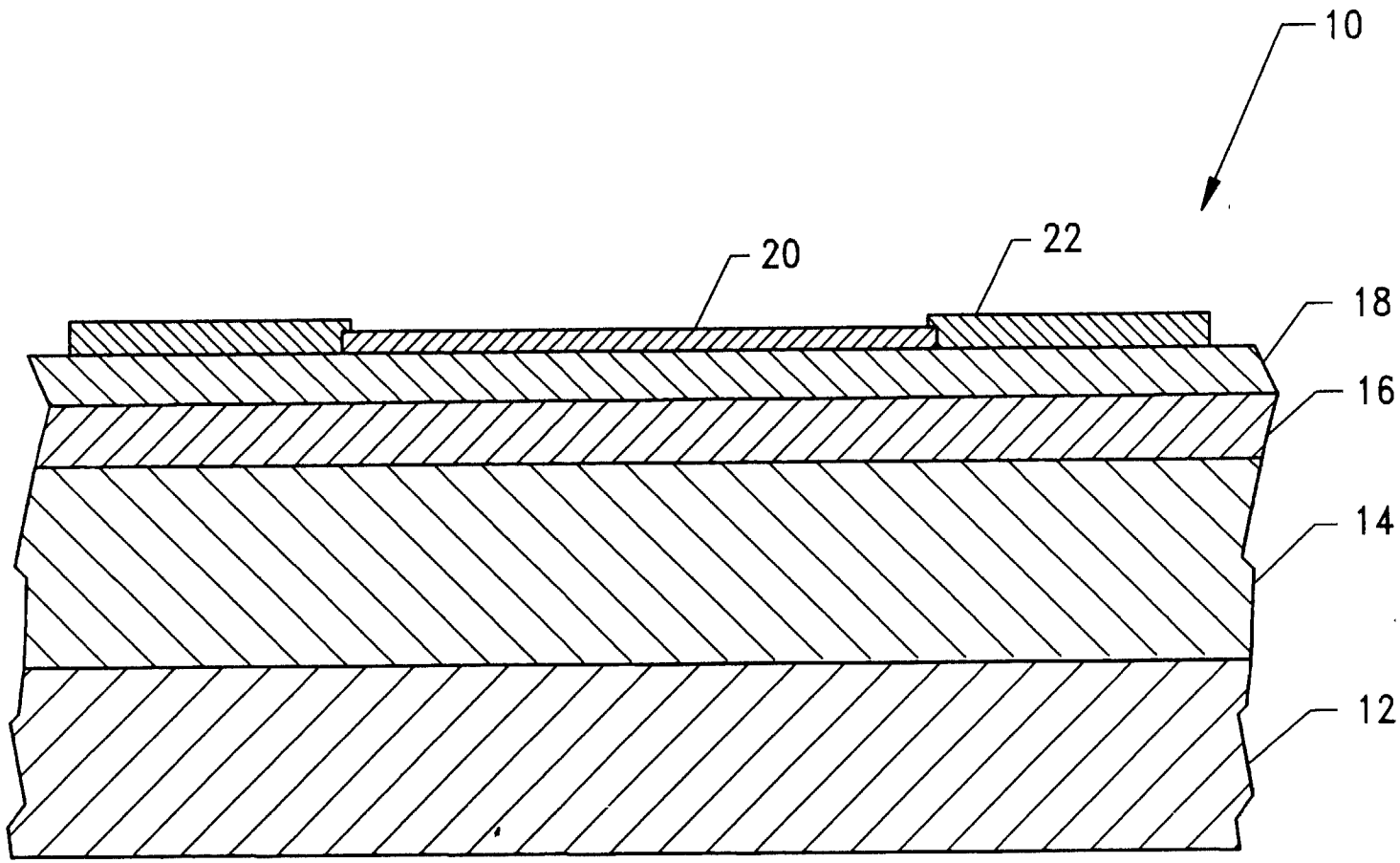

FIG. 1

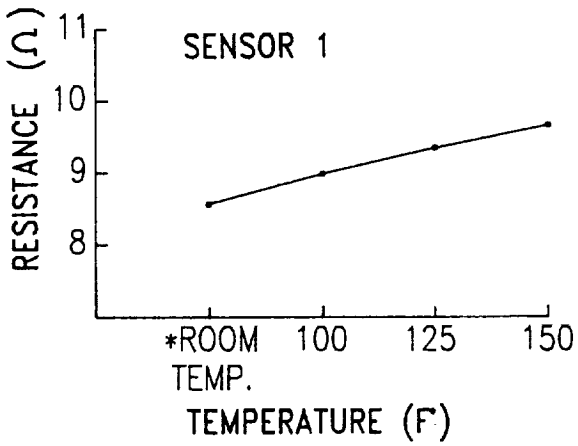

FIG. 2(a)

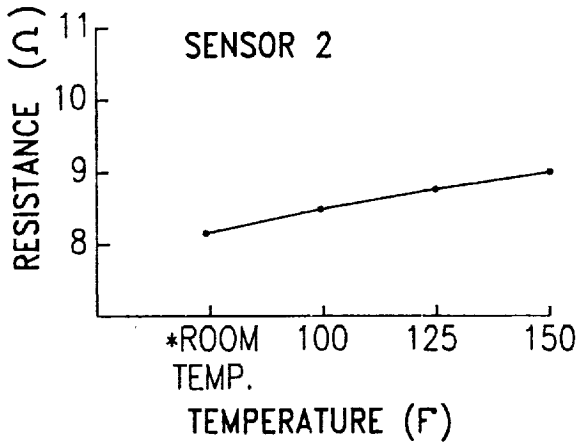

FIG. 2(b)

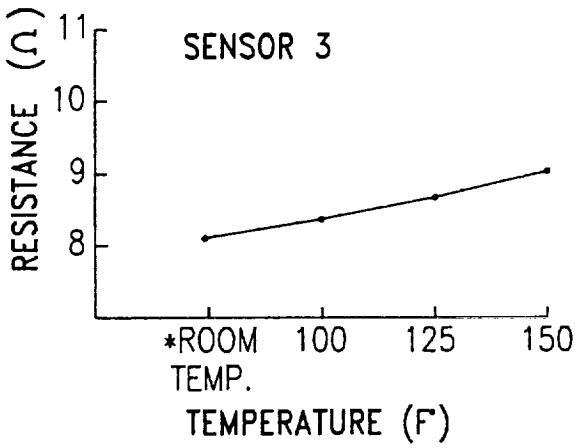

FIG. 2(c)

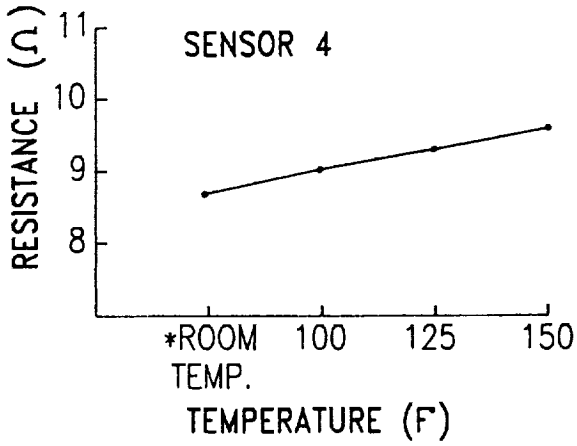

FIG. 2(d)

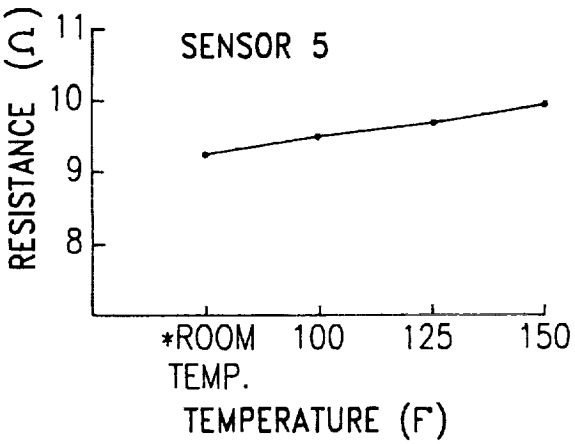

FIG. 2(e)

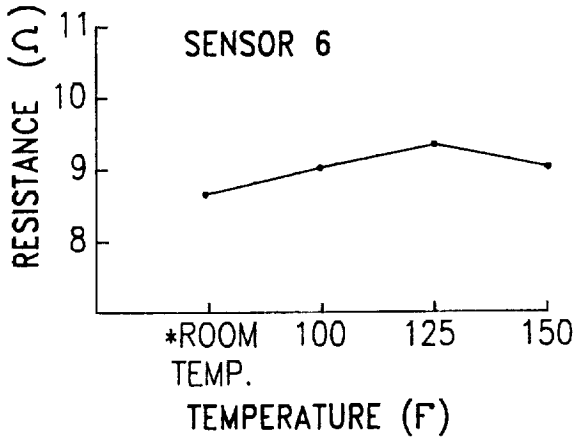

FIG. 2(f)

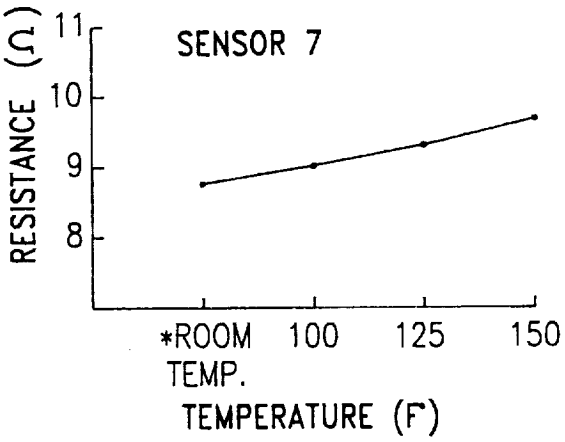

FIG. 2(g)

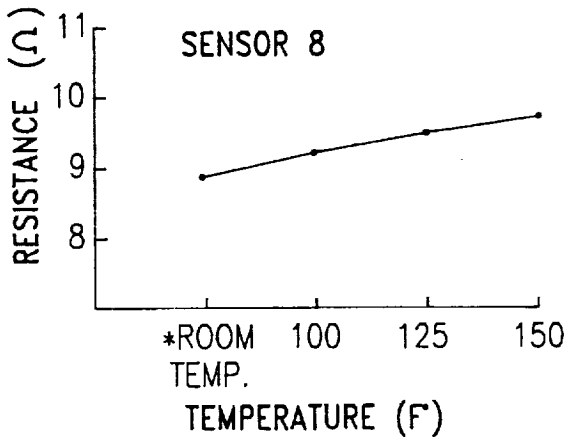

FIG. 2(h)

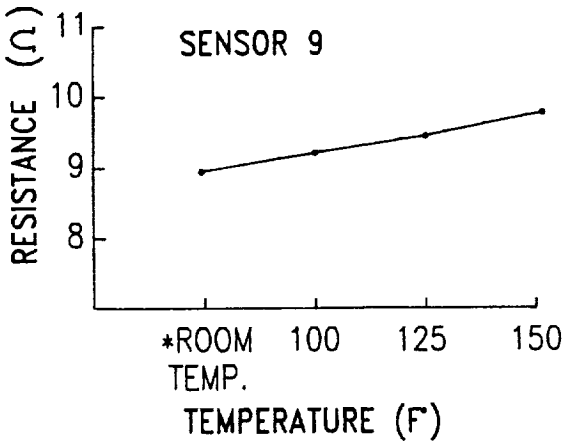

FIG. 2(i)

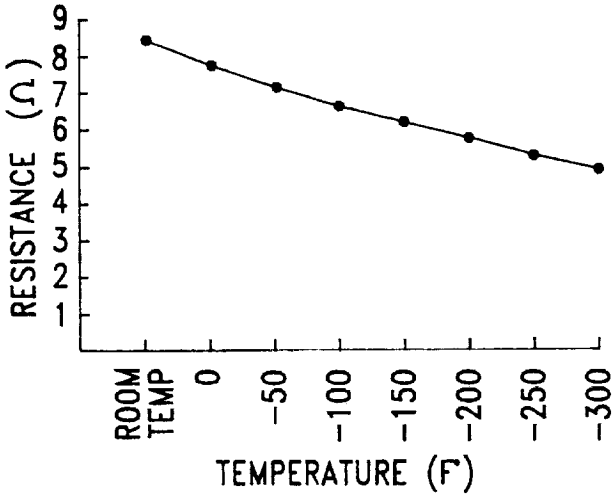

FIG. 3(a)

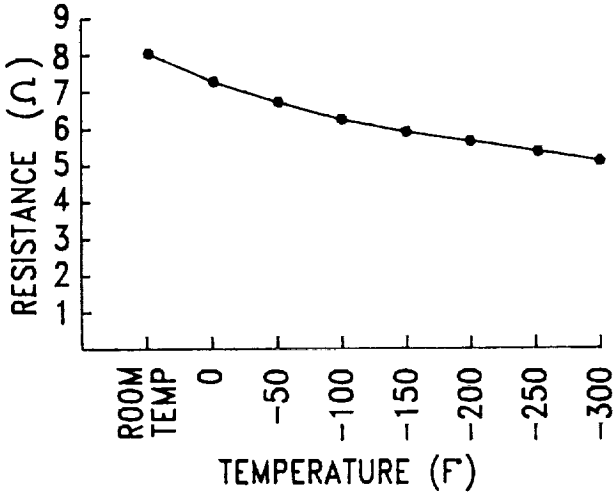

FIG. 3(b)

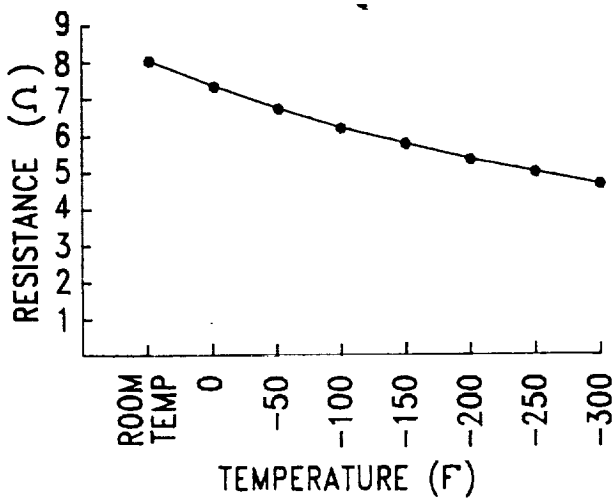

FIG. 3(c)

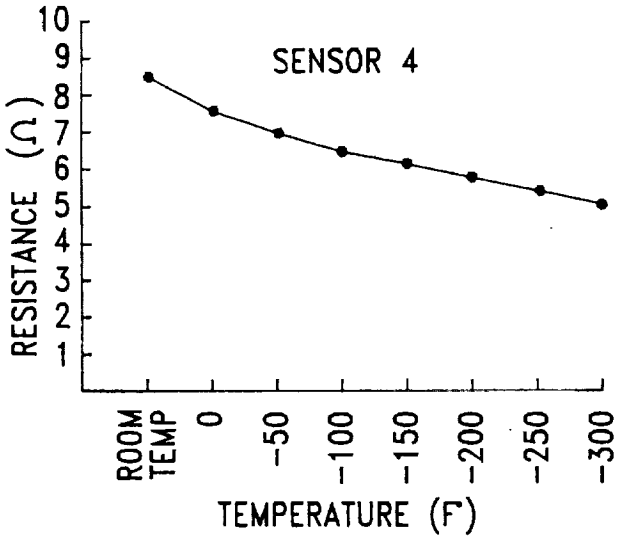

FIG. 3(d)

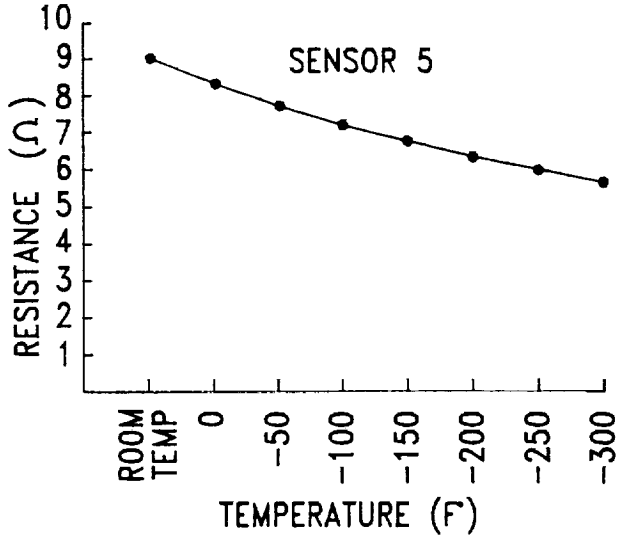

FIG. 3(e)

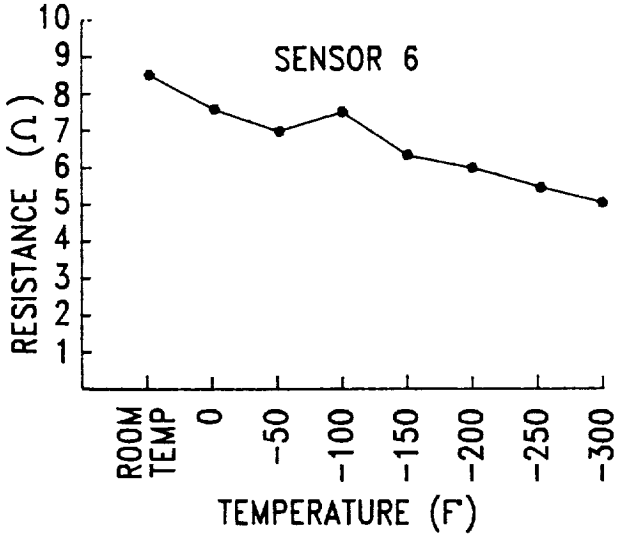

FIG. 3(f)

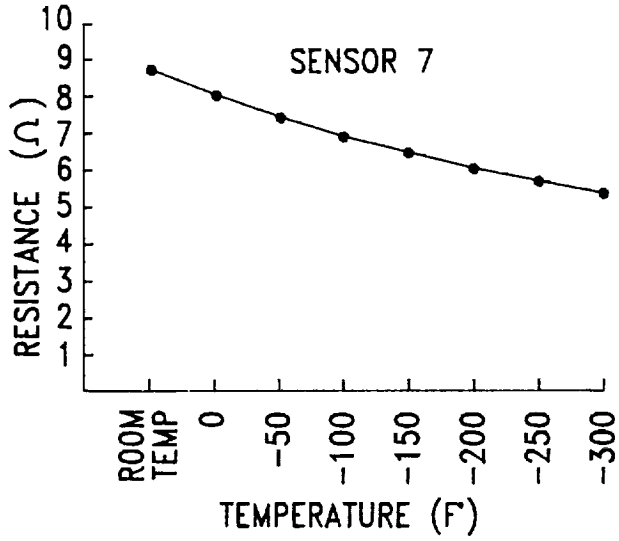

FIG. 3(g)

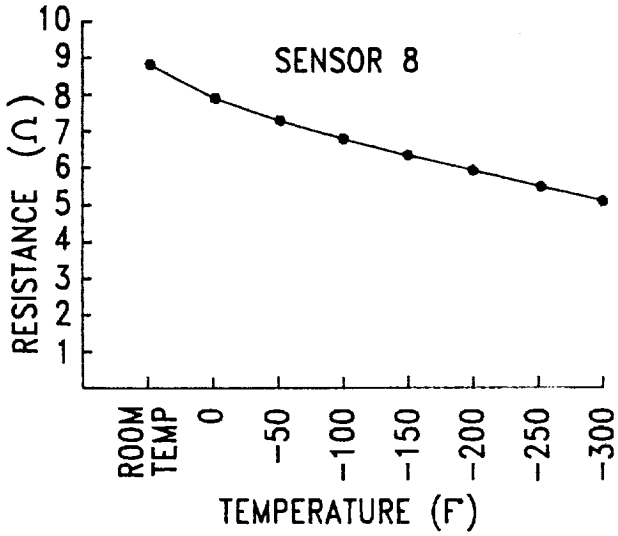

FIG. 3(h)

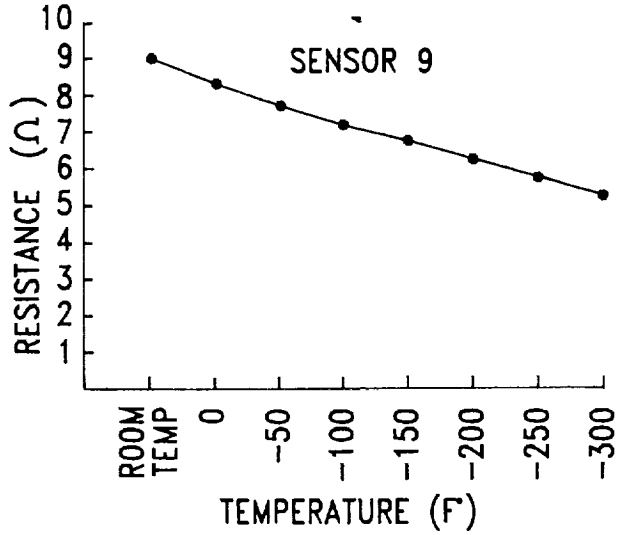

FIG. 3(i)