

**BREATHABLE MOISTURE BARRIER FOR
AN OCCUPANT SENSING SYSTEM**

Background of the Invention

Field of the Invention

5 The present invention relates generally to a breathable, moisture-seal fabric and, more particularly, to a water impervious, breathable moisture barrier enclosing a flexible electrode antenna assembly suitable for use in an occupant sensing system.

Background of the Invention

10 United States Patent Nos. 5,914,610 and 5,936,412 disclose that the ability to determine the position, orientation or presence of a person within a defined space is important in applications ranging from medical treatments to safety and security. For applications where determining the position, orientation or presence of a person within a defined space is important, electrode sensor arrays have been
15 developed to allow automatic monitoring of the defined space. Such sensor arrays and methods for resolving a presence in a defined space are taught in the above-referenced patents.

 Although the method for resolving a presence or activity in a defined space using a sensor array is known, the ability to adapt those sensor arrays to a
20 particular environment is not addressed in the prior art. Specifically, in uses where the sensor array is used to monitor or detect the presence or activity of a person, additional factors come into play which may greatly impact the ability of the sensor array to provide accurate electrical field readings. For example, an expected use of these sensor arrays and methods, as described in United States
25 Patent Nos. 5,914,610 and 5,936,412, is in an automobile seat for regulating the deployment of airbags. Additionally, commonly owned Patent Convention Treaty Application No. PCT/US01/04057 filed on February 8, 2001, incorporated in its entirety herein, sets forth and describes a flexible electrode antenna having sufficient flexibility, comfort and durability for use in close proximity to an
30 individual such as an automobile seat. However, it must be noted that none of these references adequately address the issue of preventing the absorption of

liquids into the sensing system which significantly impairs the ability of the system to make occupant classification determinations.

Therefore, there is a need for a breathable moisture barrier enclosing the sensing system (consisting of electrode antennas, foam substrate and other
5 electrical components) to provide a substantially liquid impervious seal while having a high enough level of breathability so as not to interfere with the readings of a temperature/humidity sensor located inside the seat sensor mat assembly.

Summary of the Invention

The present invention provides a breathable moisture barrier suitable for
10 use in enclosing flexible electrodes, foam substrate and other electrical components within a substantially liquid impervious environment without significantly impairing the ability of electrical sensors to accurately measure temperature and humidity variations within the surrounding environment such as the seating compartment of an automobile. The invention comprises a breathable polymeric
15 material having a sufficiently high moisture vapor transmission rate (MVTR) to permit water vapor to be transported across the barrier and quickly reach equilibrium within the enclosed seat sensor mat assembly and to allow the temperature and humidity compensation of the occupant sensing system to function correctly. The breathable moisture barrier of the present invention
20 provides a sufficiently high MVTR to allow rapid temperature and humidity equilibration within the sensor mat so as to better track rapid changes in the passenger compartment environmental conditions upon starting the car and applying either air conditioning or heating.

In one preferred embodiment, the breathable moisture barrier is a
25 microporous, polypropylene film bonded to a polypropylene nonwoven. In alternative embodiments, other breathable polymeric fabrics or films having a sufficiently high MVTR, a suitable level of durability and other performance attributes required for car seat applications, including comfort, noise, flame retardancy, and thermal stability, may also be used.

As used herein, these terms have the following meanings:

1. The term “breathable” describes a material that is vapor permeable but liquid and particulate impermeable such as films used in garment and diaper applications.

5 2. The term “microporous” describes a material with a structure that enable fluids to flow through them and has an effective pore size that is at least several times the mean free path of the flowing molecules (from several microns down to 100 Angstroms).

Brief Description of the Drawings

10 A more complete understanding of the present invention may be obtained by reference to the following Detailed Description when taken in conjunction with the accompanying drawings in which like reference numerals refer to like parts and wherein:

 Figure 1 is a perspective view of a seat sensor mat assembly featuring a
15 foam mat, a flexible electrode antenna and a humidity/temperature sensing element all enclosed within a breathable moisture barrier constructed in accordance with one embodiment of the present invention;

 Figures 2a-c illustrate a top plan view, a side elevational view and a bottom view, respectively, of the seat sensor mat assembly in accordance with the
20 embodiment of Figure 1;

 Figure 3a is a detailed side elevational view illustrating construction features of the seat sensor mat assembly near a corner of the embodiment shown in Figure 2b;

 Figure 3b is a detailed side elevational illustrating construction features of
25 the seat sensor mat assembly along a bottom portion of the embodiment shown in Figure 2b;

 Figure 4a is a cutaway side view of the seat sensor mat assembly taken along section line A-A;

 Figure 4b is a detailed cutaway side view clearly showing the positioning
30 of the temperature/humidity sensor within the seat sensor mat assembly shown in Figure 4a;

Figure 5 is a series of offset graphs illustrating the effect of varying the breathable area on humidity sensor equilibrium time;

Figure 6 is a series of offset graphs illustrating the effect of using different commercially available polymeric materials having varying levels of MVTR on
5 humidity sensor equilibrium time; and

Figure 7 is a logarithmic chart illustrating the theoretically calculated time required to reach equilibrium at 25°C and 50% relative humidity as a function of the MVTR.

Detailed Description of the Preferred Embodiment

10 Although those skilled in the art will readily recognize that multiple unique constructions may be created for use as a breathable moisture barrier in an occupant sensing system, the present invention is described herein primarily in relation to one preferred construction. In particular, the present invention is described herein as a foam mat having flexible sensor electrodes and a
15 humidity/temperature sensor attached thereto, all enclosed within a breathable polymeric fabric laminate to render the apparatus substantially liquid impervious and having sufficiently high MVTR as to not interfere with the functioning of the sensor apparatus. Alternate constructions in addition to those described herein are considered within the scope and the spirit of the invention.

20 In one example of a seat sensor mat assembly for use in automotive applications, the assembly will consist of a number of electrically conductive sensor strips adhesively attached to the top and bottom surfaces of an open celled, flexible polyurethane foam core. Each sensor strip is connected to an electronic control unit which operates the occupant sensing system by measuring impedance
25 changes in an electric field around each of the sensor strips based on an occupant's size and presence. The seat sensor mat assembly is designed to be incorporated into a hollowed out portion of the bottom cushion of an automobile seat.

Since the occupant sensing system uses electric field sensing technology, water or other liquids spilled on the seat could impair the ability of the sensing
30 system to function properly. Water and other conductive liquids prevent the system from sensing occupant changes accurately because the conductive liquid

creates coupling and shorts between adjacent conductive strips on the seat sensor mat assembly.

One solution to this problem would be to enclose the seat sensor mat assembly entirely within a liquid impervious polymeric film. This is much like wrapping or coating the seat sensor mat assembly with a non-porous, non-breathable polymer film to keep water out. However, this solution presents additional problems by creating very different environmental conditions, namely temperature and humidity, inside the seat sensor mat assembly and in the surrounding passenger compartment of the automobile. The dielectric properties of the materials and gases of the environment surrounding the conductive strips are temperature and humidity dependent. Sealing the entire assembly in a manner which is impervious to both liquids and gases make temperature and humidity compensation of the electric field data significantly more difficult. This solution may ultimately require a temperature and humidity sensor both inside the seat sensor mat assembly and externally within the passenger compartment. Comfortability issues may also arise as air that is trapped inside the sealing material will be unable to escape and will be compressed as the seat is compressed. It is also notable that should any moisture become trapped inside the seat sensor mat assembly, it is quite possible that it will create mildew and other nondesirable conditions inside the assembly. An additional comfort problem may arise from perspiration trapped in the seat trim that is in contact with the occupant.

Accordingly, a breathable moisture barrier would provide a number of advantages in an occupant sensing system. A breathable moisture resistant fabric can be used to create a positive seal of the open celled foam preventing water uptake. Additionally, breathability permits a uniform temperature and humidity environment between the seat sensor mat assembly and the passenger compartment. This uniform environmental condition allows a single temperature/humidity sensor to be incorporated into the seat sensor mat assembly to characterize the environment of both the assembly itself and the passenger compartment. Moreover, temperature and humidity compensation of the electric field data is made easier due to the consistent dielectric properties of the materials and gases within the seat sensor mat assembly, seat trim materials and the

passenger compartment. A breathable moisture barrier should also prevent any moisture from collecting or mildewing in the seat sensor mat assembly, seat trim materials or seat bun. Although a breathable membrane will usually not allow a sufficient amount of air to escape from the seat sensor mat assembly as a passenger sits down, ventilation holes may be easily incorporated on the bottom surface of the assembly and a transfer adhesive, used to adhere the sensor mat to the seat bun may be further utilized at the edges of the ventilation holes to prevent moisture from entering the assembly.

Although any number of breathable moisture barrier films or fabrics are available, one preferred embodiment of the present invention would utilize a microporous polypropylene film laminated to a polypropylene nonwoven and available commercially as PROPORE brand fabric from the Minnesota Mining and Manufacturing Company (3M). See U.S. Patent Nos. 4,539,256, 4,726,989, 4,902,553 and 5,238,623, incorporated herein by reference, for a more complete discussion on the physical properties and the manufacture of microporous polypropylene films. This particular film/nonwoven laminate offers a number of advantageous properties including relatively high moisture vapor transmission rates (MVTR of about 8,000 g/m² 24 hours), 345 kPa (50 psi) water holdout, abrasion resistance due to the presence of the nonwoven layer, good bondability using acrylic transfer adhesives, and relatively low cost due to the use of polypropylenes as the base material in comparison to other moisture resistant breathable fabrics such as GORETEX available from W. L. Gore and Associates and based on polytetrafluoroethylene polymers.

The film may contain adjuvants such as antioxidants, flame retardants and the like, to the extent that such adjuvants do not critically impair the moisture vapor transmission or mechanical properties of the film. Useful antioxidants include phenolic compounds such as pentaerythritol tetrakis(3-(3,5-di-tert-butyl-4-hydroxyphenyl)propionate), available as IRGANOX 1010, from CIBA Specialty Chemicals, and ANOX 20, available commercially from Great Lakes Chemical. Useful flame retardants include halogenated organic compounds, organic phosphorous-containing compounds, and inherently flame retardant compositions. Halogenated organic flame retardants include biphenyls such as 2,2'-

dichlorobiphenyls , octabromodiphenyls ,and halogenated diphenyl ethers containing from 2 to 10 halogen atoms. Useful organic phosphorus additives include phosphorous compounds such as phosphoric acids, phosphorous-nitrogen compounds, halogenated organic phosphorous compounds and the like. These can
5 be used alone or mixed with e.g., chlorinated biphenyls or antimony oxide. Inherently flame retardant polymers are those which do not support combustion or are self-extinguishing. Examples include poly(vinyl choride), poly(vinylidine chloride), polyimides, polyether ketones, and the like. See U.S. Patent 6,171,689, incorporated herein by reference, for further discussion of flame retardants. The
10 adjuvants may be added individually or mixed together, e.g., flame retardant may be mixed with antioxidant and added together for the sake of simplifying process steps during manufacture. The nonwoven layer may also contain adjuvants such as antioxidants, and the like.

In one embodiment of the invention, the composition for the breathable
15 moisture barrier film includes octabromodiphenyl oxide, available commercially from Great Lakes Chemical as DE-79.

Referring now to Figure 1, a perspective view of a seat sensor assembly constructed in accordance with the present invention is shown. The seat sensor assembly **10** comprises a polyurethane foam core **20** a number of electrically
20 conductive sensors **30** and a temperature/humidity sensing element **40** disposed within an opening **25** formed in the foam block **20** for measuring temperature and humidity changes both within the assembly and the interior of the automobile itself. The entire assembly **10** is then covered in a substantially liquid impervious, breathable fabric **50**. Optionally, air ventilation holes **60** may be provided in the
25 bottom of the assembly **10** to allow air to escape from the assembly **10** as an occupant sits on the seat cushion of the automobile. The breathable moisture barrier **50** may be adhered to the foam core **20** of the assembly **10** by an acrylic transfer adhesive, not shown.

Referring now to Figures 2a-2c, a top plan view, a side elevational view
30 and a bottom view, respectively, of the seat sensor assembly of Figure 1 is shown. Note that Figures 2a-2c further illustrate the positioning of the electrically

conductive sensor strips **30**, the temperature/humidity sensor **40** and the air ventilation holes **60** in the seat sensor assembly.

Referring now to Figures 3a-3b, detailed drawings are provided to better illustrate features of the side elevational view shown in Figure 2b. In Figure 3a, a detailed drawing of a corner portion of the seat sensor assembly constructed in accordance with the present invention is shown. Again, as with Figures 1-2c, there is a foam core **20** with electrically conductive sensors **30** and a barrier material **50** attached thereto by a layer of acrylic transfer adhesive **70**. Similarly, Figure 3b shows the foam core **20**, the conductive electrodes **30**, the barrier material **50** and a layer of transfer adhesive **75** on the underside of the barrier material to adhere it to a seat cushion, not shown.

Referring now to Figure 4a, a cutaway side elevational view taken along section line A-A is shown. This figure illustrates the positioning of the foam core **20**, the opening in the foam core **25**, the temperature/humidity sensor **40** and the barrier material **50**. Similarly, Figure 4b shows a detailed drawing of a portion of Figure 4a and better illustrating the positioning of the foam core **20**, the opening in the foam core **25**, the temperature/humidity sensor **40**, the barrier material **50** and the bottom layer of transfer adhesive **75**, again used to attach the seat sensor mat assembly to a seat cushion, not shown.

Referring now to Figure 5, a series of offset graphs are presented to show test cell conditions at 70% relative humidity and then changing to 90% relative humidity at a steady temperature of 40°C. For this figure, the test cells were created by cutting an open celled polyurethane foam mat into a 10.2 cm x 10.2 cm x 1.9 cm (4in x 4in x 0.75in) block having a central opening extending therethrough and fitted with a temperature/humidity sensor. The control test cell did not have any additional coverings. The upper surface of the moisture resistant test cells were covered with a Hytrel 4056 thermoplastic elastomer available from DuPont and having an MVTR value of about 400 g/m² 24 hr. The moisture resistant test cells were then sealed on the sides and bottom with a non-breathable polymer film. Additionally, to better investigate the influence of breathable surface area, it was possible to cover a portion of the top surface of the test cell to

reduce the breathable area from a 10.2 cm x 10.2 cm (4in x 4in) square to a 5.1 cm x 5.1 cm (2in x 2in) square.

As shown in Figure 5, the uncovered foam cell, noted here as environmental chamber conditions, came to equilibrium almost immediately and had a distribution of humidity readings about the set points of 70% and 90% relative humidity. The Hytrel covered foam test cells were then tested in both 5.1 cm x 5.1 cm (2in x 2in) and 10.2 cm x 10.2 cm (4in x 4in) configurations. The 5.1 cm x 5.1 cm (2in x 2in) test cell exhibited large differences from the environmental chamber conditions after the initial change in the relative humidity set points and a long equilibration time to reach the actual environmental conditions. By comparison, the 10.2 cm x 10.2 cm (4in x 4in) test cell exhibited much smaller differences from the environmental chamber conditions after changing the set point and reached equilibrium approximately 4 times faster than the 5.1 cm x 5.1 cm (2in x 2in) test cell. This demonstrates the influence of breathable area on the ability of the humidity sensor to track changes in environmental conditions.

Referring now to Figure 6, another series of offset graphs showing the effects of MVTR on humidity sensor equilibrium time is shown. The test cells were produced much like the Hytrel 4056 cells above with 5.1 cm x 5.1 cm (2in x 2in) breathable surfaces of Macromelt 6239, Tegaderm, and Propore KN-2311 having the properties noted in Table 1.

Table 1

Material	Purpose	Construction	Thickness μm (mil)	MVTR (g/m^2 24 hr)
Hytrel 4056 (DuPont)	Breathable Film	Thermoplastic polyester elastomer	25.4 (1)	400
Propore KN- 2311 (3M)	Breathable Fabric	Microporous polypropylene film/ polypropylene nonwoven	356 (14) (1.5 mil film + 12.5 mil nonwoven)	8,000
Tegaderm (3M)	Breathable Film	Polyethylene	38 (1.5)	90
Macromelt 6239 (Henkel)	Non- breathable Film	Polyamide	152 (6)	less than 10

Note that at 70% relative humidity, the Macromelt covered sample does not appear to reach equilibrium, the Tegaderm covered sample takes about 500 minutes to reach equilibrium whereas the Propore fabric covered material reaches equilibrium in a matter of several minutes and closely tracks the data of the test chamber itself. These results are again mirrored as the relative humidity is increased to 90% at a time of about 800 minutes. Again, it is clear that the Propore fabric having the greatest MVTR most closely tracks the change in environmental chamber conditions.

Referring now to Figure 7, a graph illustrating the theoretically calculated equilibrium time to reach temperature of 25°C and 50% relative humidity inside a 40.6 cm x 40.6 cm x 1.9 cm (16in x 16in x 0.75in) seat sensor mat assembly from various initial environmental conditions as a function of the MVTR is shown. For automotive seat applications, it would be desirable to have equilibration time of less than about five minutes, and more preferably less than about 1 minute, so as to better track rapid changes in the passenger compartment environmental conditions upon starting the car and applying either air conditioning or heating. As shown here graphically, at initial conditions of 80% relative humidity and temperatures of 30°C, 40°C and 50°C, there is a straightforward logarithmic relationship between the MVTR value and the time required for the seat sensor mat assembly to reach equilibrium conditions of 25°C and 50% relative humidity. To reach an equilibrium time goal of less than five minutes, the minimum MVTR value falls somewhere between 100 and 1000 g/m² 24 hours and, more specifically, in a range of about 400 to 600 g/m² 24 hours. Obviously, a material having a particularly high MVTR value of about 8,000 g/m² 24 hours can reach equilibrium in significantly less than five minutes or as shown here, about 0.1 minutes. This theoretical value is based on a calculation using only the 40.6 cm x 40.6 cm (16in x 16in) top surface of the 1.9 cm (0.75in) thick assembly as the breathable area. However, increasing the breathable surface area by, for example, making the bottom surface breathable or increasing the overall volume by, for example, increasing thickness will have a significant impact on the equilibration time. Note that, for ease of comparison, the data shown in Figure 7 have been further summarized in Table 2, as shown below.

Table 2

Equilibration Time to 25C, 50% RH			
Initial Condition:	30C, 80% RH	40C, 80% RH	50C, 80% RH
MVTR (g/m ² /24 hours)	Time (min)	Time (min)	Time (min)
1	399.5	972.0	1877.8
10	39.9	97.2	187.8
100	4.0	9.7	18.8
500	0.8	1.9	3.8
1000	0.4	1.0	1.9
5000	0.1	0.2	0.4
10000	0.0	0.1	0.2

Although preferred embodiments of the invention have been described in the examples and foregoing description, it will be understood that the invention is not limited to the embodiments disclosed, but is capable of numerous rearrangements and modifications of the parts and elements without departing from the spirit of the invention, as defined in the following claims. Therefore, the spirit and the scope of the appended claims should not be limited to the description of the preferred embodiments contained herein.

What is Claimed is:

1. A seat sensor mat assembly comprising:
an insulating foam substrate;
at least one electrically conductive sensing element adhered to the foam
5 substrate;
a humidity sensor disposed within the foam substrate; and
a substantially liquid impervious, vapor permeable material covering at
least a portion of the foam substrate.
2. The seat sensor mat assembly of claim 1, wherein the substantially
10 liquid impervious, vapor permeable material is a microporous film/nonwoven
polymer laminate.
3. The seat sensor mat assembly of claim 1, wherein said vapor
permeable material has a moisture vapor transmission rate of at least 100 g/m^2
24 hours.
- 15 4. The seat sensor mat assembly of claim 3, wherein said vapor
permeable material has a moisture vapor transmission rate of at least 500 g/m^2
24 hours.
5. The seat sensor mat assembly of claim 1, wherein said vapor
permeable material has a moisture vapor transmission rate of at least 1000 g/m^2
20 24 hours.
6. The seat sensor mat assembly of claim 2 wherein microporous
material comprises a polyolefin film.
7. The seat sensor mat assembly of claim 6 wherein said polyolefin is
a polypropylene.
- 25 8. The seat sensor mat assembly of claim 2 wherein said nonwoven
material bonded to said polyolefin film also comprises a polyolefin.

9. The seat sensor mat assembly of claim 8 wherein said nonwoven material is a polypropylene.
10. The seat sensor mat assembly of claim 1, wherein said vapor permeable material covers at least 5% of the surface area of the foam substrate.
- 5 11. The seat sensor mat assembly of claim 10, wherein said vapor permeable material covers at least 25% of the surface area of the foam substrate.
12. The seat sensor mat assembly of claim 1, wherein said vapor permeable material covers an aperture of at least 5 cm x 5 cm.
13. The seat sensor mat assembly of claim 1 wherein said liquid
10 impervious, vapor permeable material further comprises a flame retardant.
14. The seat sensor mat assembly of claim 13 wherein said flame retardant is selected from the group consisting of organic phosphorous materials, halogenated biphenyls, and phenolic compounds.
15. The seat sensor mat assembly of claim 14 wherein said flame
15 retardant is octabromodiphenyl oxide.
16. The seat sensor mat assembly of claim 1 wherein said liquid impervious, vapor permeable material further comprises an antioxidant.
17. The seat sensor assembly of claim 16 wherein said antioxidant is pentaerythritol tetrakis (3,5-di-tert-butyl-4-hydroxyphenyl)propionate).
- 20 18. A sensing system for detecting at least two different conditions having a breathable moisture barrier comprising
at least one electrically conductive sensing element adhered thereto;
a humidity sensor disposed within the foam substrate; and
a substantially liquid impervious, vapor permeable material covering at
25 least a portion of the foam substrate,

wherein said vapor permeable material has a moisture vapor transmission rate of at least 100 g/m^2 24 hours.

19. The sensing system of claim 18, wherein the substantially liquid imperious, vapor permeable material is a microporous film/nonwoven polymer laminate.

20. The sensing system of claim 18, wherein said vapor permeable material has a moisture vapor transmission rate of at least 500 g/m^2 24 hours.

21. The sensing system of claim 18, wherein said vapor permeable material has a moisture vapor transmission rate of at least 1000 g/m^2 24 hours.

22. The sensing system of claim 18, wherein said vapor permeable material covers at least 5% of the surface area of the foam substrate.

23. The sensing system of claim 22, wherein said vapor permeable material covers at least 25% of the surface area of the foam substrate.

24. The sensing system of claim 18 wherein said sensing system is used in a seat.

25. The sensing system of claim 24 wherein said seat is an automotive seat.

26. The sensing system of claim 18 wherein said two conditions are presence of a weight load and absence of a weight load.

27. The sensing system of claim 18 wherein at least one of said two conditions is selected from the group consisting of presence of at least one occupant, size of occupant, location of occupant, motion of occupant, gender of occupant, and presence of more than one occupant.