The Built-in Hybrid Device for Automotive Seat

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Fujikura has developed and manufactured some advanced sensing devices for a seat belt reminder (SBR) to detect a passenger or an object and those to determine the physique and sitting position of a passenger using a membrane circuit technology.

With recent trends in the automotive industry such as the introduction of self-driving systems and electric vehicles (EVs), built-in electronic control systems and sensing devices have been developed rapidly both inside and outside of the car industry. These new products are much more sophisticated than conventional products in ensuring a safe and comfortable driving environment, being expected to be lightweight, space-saving and energy-saving and have multi-functions to enable sensing and monitoring.

Currently, we are developing a hybrid device that combines different functions, in addition to the passenger detection device, including seat heating, radio communication of obtained information, and the detection of biological information (breathing, heart rate) of a driver. This paper describes a hybrid device, which consists of an SBR and a seat heating unit using a new circuit board as the platform.

1. Introduction

To make small-and-mid-sized EVs more affordable for the masses, new powertrains and power systems are expected to be developed. In addition, with automated driving in mind, EVs need to be equipped with an integrated system including hardware and software to enable the exchange of various information between the passengers and vehicles.

Therefore, there are increasing demands for the development and commercialization of new in-car equipment. Through the development of a SBR and force sensing device for a supplemental restraint system (SRS), Fujikura has supplied sensing devices to minimize stress that passengers feel.

In the future, with the expansion of data information of crew status and vehicle inner/outer environments, an increasing number of sensing devices using technologies of sensing methods, data processing and in-vehicle transmission will be mounted on vehicles. In addition, the sensing devices and their system units have been expected to be more integrated to achieve downsizing, energy savings, quick response and multi-functions. To meet these demands, Fujikura has been developing a hybrid device by integrating Fujikura's core technologies such as membrane circuit boards, flexible circuit boards (FPCs), micro wiring, sensors and connectors.

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This paper describes the hybrid device that consists of a new printed circuit board made of glass-woven sheet, on the surface of which an SBR sensor and a sheet heater are arranged, and provides improved performance and passengers comfort.

2. Summary of built-in occupant detection sensor

2.1 SBR occupant detection sensor [1) 2)]

The SBR occupant detection sensor (hereafter SBR sensor) sends a signal when two electrodes facing each other come in contact by the pressure applied to the seat surface.

Upon application of the input signal, an electronic controller unit (ECU) will determine the existence of passengers and, if necessary, gives an alarm and a message for the passenger to fasten seatbelt.

There are two types of SBR sensors. One is placed on the upper seat just under the top surface leather (A-Surface), and the other is placed on the seat forming (B-Surface) as shown in Fig. 1

SBR sensors for the front passenger's seat have come into widespread use. Moreover, further demand for SBR sensors will be expected because the new amendment to the international car safety standards requires the installation of SBR sensors in all of the passenger seats including rear seats.

Figure 2 shows the appearance of a typical A-Surface SBR for occupant detection sensor.

To distinguish between a passenger and luggage,

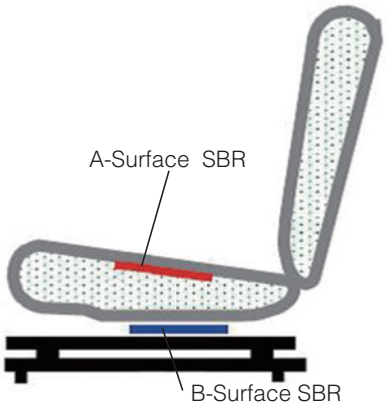

Fig. 1. Position of SBR Sensor.

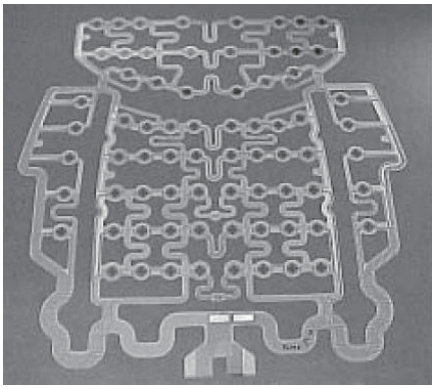

Fig. 3. Photo of Physique Detecting Seat Sensor.

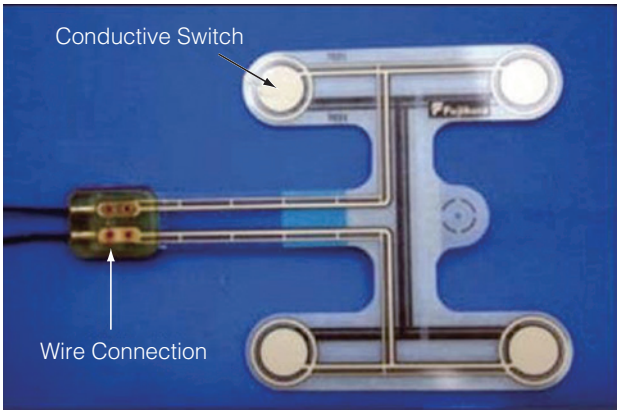

Fig. 2. Photo of A-Surface SBR Sensor.

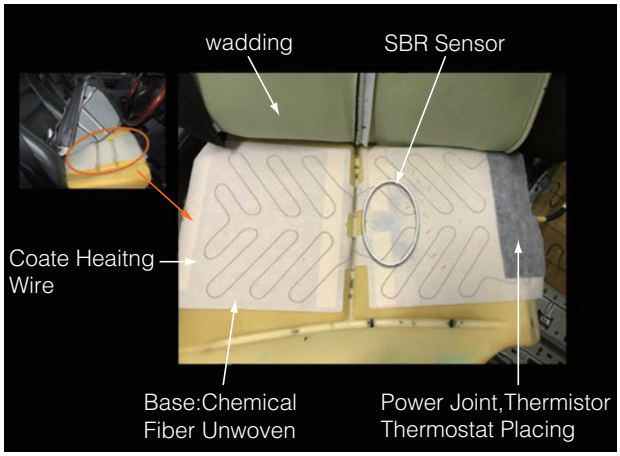

Fig. 4. Photo of Seat Heater in Drivers Seat.

the device has a structure what we call "Dual Cell", in which the system operates only when at least one electrode on each of the left and right side come into contact with the circuit. This reduces detection errors resulting from luggage of a certain weight when only one electrode is brought into contact. In designing an SBR for individual cars, it is important to properly place the electrodes and adjust the load value at which the electrode is brought into conduction taking properties of the cushion into consideration. This will allow the device to implement reliable detection even if the seat occupants change their position or posture in the seat.

2.2 Physique detecting Seat Sensor for Supplemental Restraint System (SRS) [3)]

In addition to the SBR system, a physique detection seat sensor for supplemental restraint system (SRS) has been developed. This sensor is used for a smart airbag system, which provides advanced airbag collision time control (Fig. 3).

The basic sensor electrode structure and the position in the seat are similar to those of the A-Surface SBR sensor. However, the SBR detects on/off signals through the contact of electrodes. On the other hand, the physique detecting sensor detects changes in pressure values on many pressure-sensitive electrodes placed on the seat and the back rest. The physique detection sensor can collect the information about the passengers such as build (adult / child), sitting position, and the posture by mapping pressure values of sensing points.

Both the A-Surface SBR sensor and physical detecting seat sensor has the same characteristics of lightweight, low-cost, a thickness around 0.3 (sace) mm. They also has a common simple laminated structure.

The A-Surface SBR sensor is placed under the surface of the seat or back rest and so close to a passenger or some object. This sensor has the best position to obtain stable and reliable data because of relatively large pressure load. On the other hand, there are issues of man-hours needed, for example, to fix the sensor with precise positioning between the surface leather and cushion foam in the seat. and uncomfortable feeling, unnatural hardness and some unusual sound.

3. Summary of conventional built-in seat heater

Some vehicles are equipped with built-in seat heaters, which are mounted on car seats to warm the passengers (Fig. 4).

The contact heating system on the seat surface has high efficiency to warm the passenger's body and is expected to reduce infection risk by less dry air, compared to the air under conventional air conditioning.

In addition, this heating system provides the occupant with comfort, keeping the head cool and the feet warm and reducing low back pain.

This product also contributes to saving energy consumption in EVs compared to ordinary air conditioning systems.

Especially, some reports on thermal comfort by warming passenger's buttocks have been published [4) 6) 7)].

The current seat heating device is made of one long electric heating wire (continuous stroke design) with a diameter of around 1.0 (space) mm, and arranged on the surface of 2.0 mm-thick flexible non-woven cloth.

The heating operation is controlled across the whole wire by supplying electric power at a fixed voltage and using the above-mentioned occupant detection sensor to turn the device on/off. However, the current seat heating device above require some thick buffer material (wadding in Figure 4) between the leather seat covering and the cushion form to expand heated area along the wire and to reduce projections created by heating wire. Because of the buffer material (wadding), the current seat heating device needs to address energy issues at a time of raising and keeping the heating level and difficulties to design a precise heating area shape and island layout on the seat surface.

4. The hybrid concept

To achieve safety and comfort of passengers, various sensing devices attached to vehicle seats, which are in close contact with occupants, have been developed for practical use.

The concept of hybrid is to integrate more than one of these devices into one device and make it more sophisticated, which enables the device to achieve miniaturization, lower power consumption, reduction in total cost including man-hours, and improvements in installation and accuracy (Fig. 5).

Regarding the hybrid of SBR sensor and heater introduced in this paper, the proper temperature environment around the sensor area for stable sensing is kept as an additional function. Therefore, improvement and stability of detection accuracy is expected for sensors of a low elasticity material, which present variable sensing accuracy depending on environmental temperature particularly at low temperatures.

As shown in Fig. 4, the SBR sensor and the heater have conventionally been designed as separate devices with different functions and fixed underneath the leather seat covering individually.

Because the hybrid device can accommodate the devices on the same flat face in optimal arrangement for sensing and heating, this device has obtained some complex functions shown in the following list.

- 1. Flexible, soft and fit like woven cloth, easy to sew on the leather
- 2. Flexibility in installation, shape and control for heating device
- 3. Flexibility in selecting conductive layer materials

5. Structure of hybrid device and its features

5.1 Basic structure of hybrid device

The appearance of hybrid device prototype is shown in Fig. 6 and its structure diagram is shown in Fig. 7.

By integrating some of Fujikura's core technologies, this device has enough softness and flexibility to fit the base seat cushion form with a printed conductive circuit. This allows the device to carry both the SBR sensor device and heating device on the same plane.

5.2 Platform printed circuit woven

To arrange both the SBR sensor and the seat heater on the same plane, we have developed a new printed

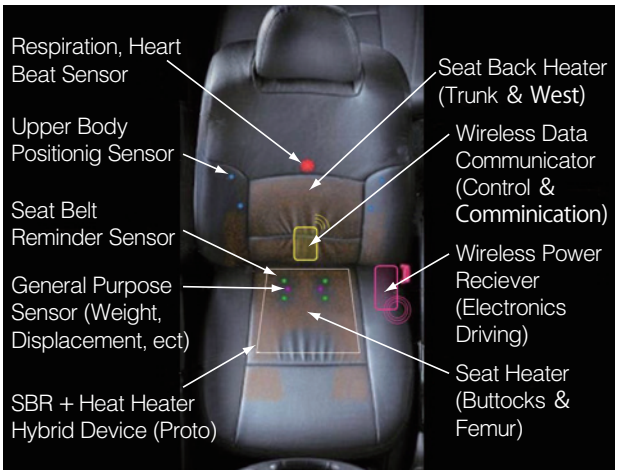

Fig. 5. Concept Design Image of Hybrid Devices.

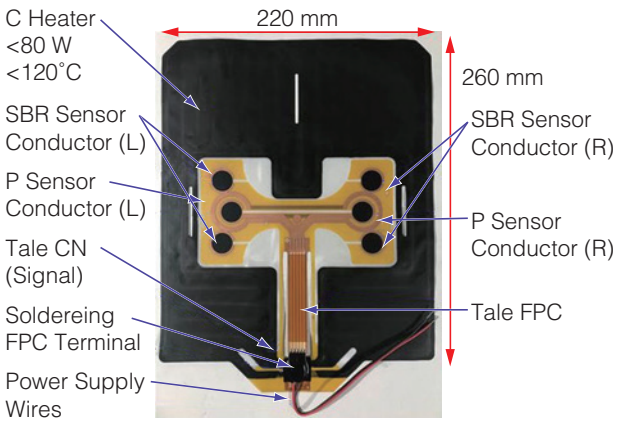

Fig. 6. Photo of Hybrid Device Prototype Model.

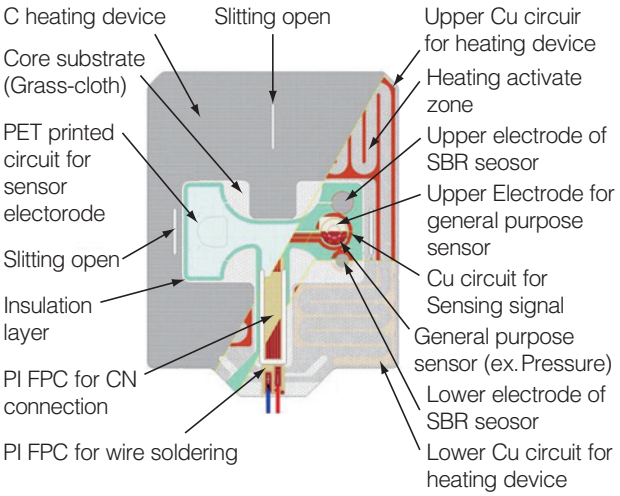

Fig. 7. Structure of Hybrid Device Prototype Model.

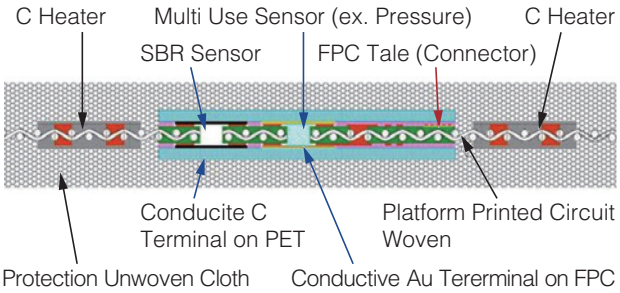

Fig. 8. Process of platform PCW sheet.

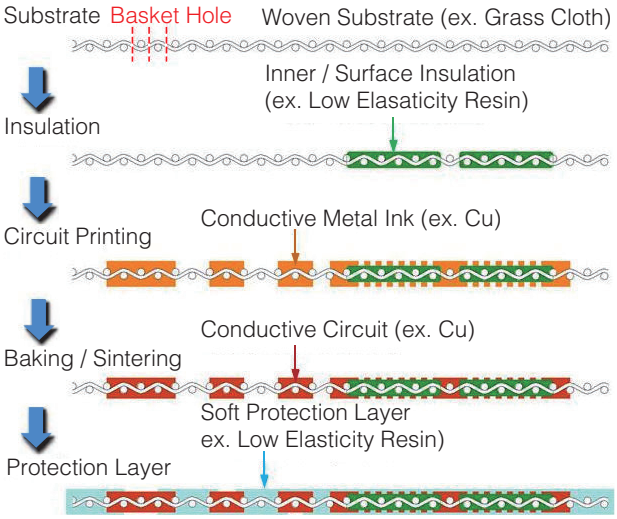

Fig. 9. Cross Section Image of Hybrid Device.

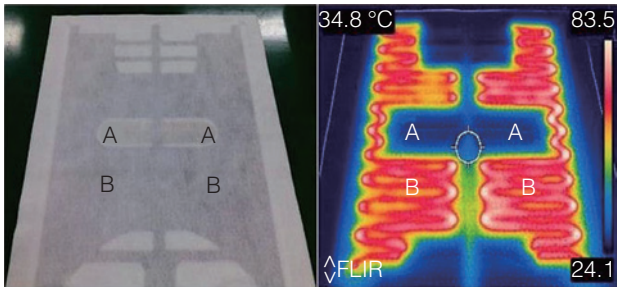

Fig. 10. Appearance and infrared thermography on heating activation.

circuit woven (PCW) sheet, which is composed of copper circuit printed on the glass cloth (GC) substrate [5].

The electrode is formed by screen-printing copper on the GC, which is 0.1 mm in thickness, and is resistant to heat up to 300 degrees Celsius (Fig. 8).

Although the copper printed circuit itself has a slightly rigid feel, the majority area of the PCW sheet keeps a flexible feel and allows hybridization for different devices by taking advantage of technical features below.

- The electric circuits facing each other on both sides of the GC are connected through the GC basket holes and make ease of 0.1-0.2 (space) mm-thick printed circuit formation. (EICISS: Embedded Integrate Conductor in Skelton Substrate)
- Forming resin insulation on a desired area of the GC substrate before printing copper ink allows coexistence of different types of circuits such as fine printed circuits, single and double sided circuits, and circuits having stiffness partially.
- Connecting an FPC made by etching to printed copper allows coexistence of different types of circuits such as ones that need to have specific electric properties or ones to which electronic devices are soldered.
- Physical and mechanical properties, appearance, and environmental resistance of the PCW sheet can be finally adjusted through resin coating, impregnation, and forming processes.

5.3 SBR sensor

The new SBR sensor and conventional one have a common switch structure, in which the upper and lower electrodes face each other. On the other hand, the new sensor uses a GC substrate in the clearance instead of conventional double-sided adhesive PET film substrate.

The use of SBR film electrodes in a small area can minimize the rigid area in the whole device. (Fig. 9).

In addition, because the sensor electrodes and transmission are formed separately there are choices of conductor materials for the electrodes of the sensor. For example, the use of gold-plated FPC electrodes instead of conventional SBR electrodes enables some analog sensors, such as for determining pressure, temperature, humidity, and shock, to be equipped.

5.4 Seat heater

Figure 10 shows the appearance of the seat heater and its infrared thermography at the time of heating, and Fig. 11 shows the graph (T/W) showing the

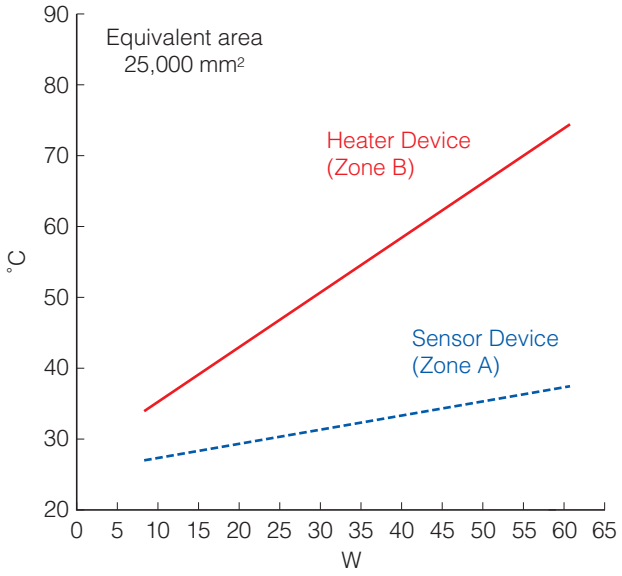

Fig. 11. The heating future (T/W) for both of heating zone and sensor zone.

relationship between temperature and power in the heating zone and the sensor zone.

Less than 0.15-mm-thick flat heating device is configured with a copper feeder circuit on the platform PCW sheet and a printed high-resistance heating carbon film. The carbon film is formed by printing a high-resistance heating carbon ink on the both sides fully overlapping copper feeder circuit of the platform PCW sheet.

Because the heating carbon ink is not only printed on the surface but absorbed into the platform PCW sheet through basket holes to join both sides together. The heater has a front-back symmetric structure to meet functional requirements for both flexibility and durability.

The input voltage of the heater can be selected from 12 V or 24 V, and the maximum temperature limit can be easily adjusted by the gap between electrodes. For a conventional seat heater with a heating cable, placing heating and non-heating areas separately is difficult because the heater needs continuous stroke wiring.

On the other hand, the hybrid heater device allows isolated layout of heating and non-heating areas regardless of the location or shape on the platform PCW, by not applying carbon ink for heating onto undesirable heating area.

The sensor arranged closely with a 3.0 mm gap between the devices to the heating device that generates a temperature of approx. 80 degrees Celsius ("B" position in Fig. 10) keep a temperature up to around 40 degrees Celsius. ("A" position in Fig. 10)

The features of the hybrid device mentioned above include thinness, flatness and flexibility to fit on the seat cushion form and flexibility in designing different temperature areas, shapes and locations of devices as well as heating and non-heating areas in one device. This hybrid device has been greatly improved so as to be mounted onto a solid support such as a lumber support in the backrest.

The surface protection material of the hybrid device can be selected from non-woven or needle-punched fabrics, which offer an option of sewing them directly on the back side of the seat.

An extensive choice of surface protection materials according to the seat leather material, enables the hybrid device not only to be used in leather seat but fabric seat for lower-priced and commercial vehicles.

6. Conclusion

In this paper, the hybridization of the SBR sensor with the seat heater built into the vehicle seat is introduced as a sample of a complex and application of Fujikura's existing core technologies in the development of automotive electronics.

We expect this hybrid device to spread into broad applications such as vehicle interior equipment for temperature comfort and seatbelt reminders. The hybrid sheet heater, especially, is expected to be installed not only in EV vehicles or ordinary vehicles as an optional equipment but in general grade vehicles as standard equipment.

The platform PCW sheet in 5.2 has originally been developed for wearable application. This product has the potential to realize various new electronics solutions for comfort and convenience in human life, which exist in diverse markets such as health care, child care, environment, education and culture.

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