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A device for skin moisture and environment humidity detection

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ABSTRACT

Water content detection is important for our daily life. For environmental detection, the relative humidity is an index for comfortable living atmosphere. For skin health, the water content in stratum corneum is a parameter to diagnose the skin condition. This paper mainly describes a moisture sensor for determination of human skin moisture. The skin moisture sensor is based on the conventional humidity sensor structure (interdigital capacitance, IDC), and the moisture sensor is also sensitive to the environmental humidity. Therefore, the effects of the environment, temperature and humidity, are discussed to find the appropriate operation conditions for skin moisture detection. Besides, the application of the moisture sensor for the environment detection is also described. The IDC structure is fabricated by using printed circuit board (PCB) technology which simplifies the bonding technique and reduces the cost.

1. Introduction

The relative humidity (RH) is a quantity that indicates the water content in air and it is an important parameter, which must be controlled to keep a comfortable living condition in buildings and to maintain the characteristics of production in industry. Hence, humidity sensors are applied in many fields [1]. However, besides surrounding air, an interesting issue is that any creature holds water within itself.

Nowadays bioengineering applications develop soon and dermatocosmetic research follows to develop. The detection of water content of the skin becomes more important for skin diagnosis. Hence, it is valuable and feasible to investigate skin moisture sensors based on the structure of humidity sensors. In recent years, several techniques have been developed to measure the skin properties objectively [3–11], and a few of commercially available instruments are used in dermatocosmetic research, e.g. the conductance-based instrument: Nova DPM 9003® and the capacitance-based instrument: Coorneometer CM820 PC® [11,12]. The functions of the diagnostic instruments are measuring the water content of the stratum corneum.

In 2001, Sekiguchi et al. [13] presented a skin moisture sensor made by using a sputter system and pointed out that the measuring frequencies influenced the output capacitance obviously. In the same year (2001), Hanreich et al. [20] provided a kind of bonding technique for human skin humidity sensors to make the sensor surface absolutely flat. The technique makes the sensor contact with skin surface uniformly to reduce measuring errors. Besides, a further possibility to investigate the skin health is the measurement of the transepidermal water loss (TEWL) expressed in grams per square meter and per hour. In 2006, Valentin et al. [24] presented a novel TEWL sensor to collect the water vapor emitted from the skin. The vapor fills the measuring chamber and causes an increasing relative humidity inside the chamber. By calculating the growing rate of the vapor condensing on the comparable cold humidity sensor surface, the water barrier function of the skin can be evaluated.

According to the output form, there are two types of humidity sensors in common. One is resistive type and another is capacitance type [2]. In this study, a capacitive-type sensor based on interdigital electrodes covering a polyimide (PI) film prepared by a hot press method is described. The polyimide film in this case is used for adsorbing water molecules from the stratum corneum or the surrounding air. The permittivity of water molecules is about 80 and the permittivity of polyimide material is about 2–3, so water molecules adsorbed into the polyimide film can increase the permittivity of the polyimide sensing layer obviously. The humidity-sensitive device presented in this paper has a function for diagnosing the water content of the stratum corneum. According to the capacitance variation, the skin moisture can be evaluated.

Interdigital capacitance (IDC) is conventionally applied to humidity and gas sensors in the environmental detection field,

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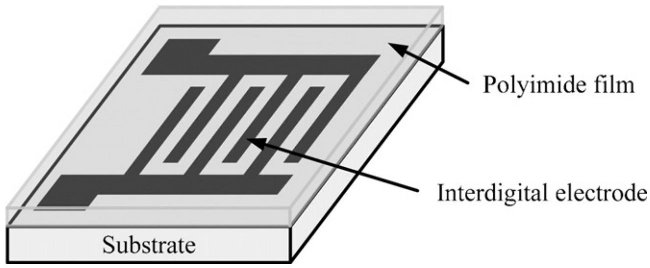

Fig. 1. Basic structure of a humidity sensor based on interdigital capacitors.

and the interdigital electrodes have been used as transducers for many years [14–19,21]. According to the previous research, the IDC is extended to use for recognizing water content of the human skin and environmental humidity in this study. Moreover, for human skin moisture measurement, the active sensing area that contacts directly with the skin must be maintained flat [20]. In order to complete the requirement, this study presents a printed circuit board (PCB) technique which provides an interconnection method between front and back electron pathways of the PCB laminate to solve the bonding problems for the skin moisture sensor. The PCB technology is a convenient method to realize the conductive pathway on a non-conductive substrate by etching the copper sheet. In consequence, the sensor based on IDC structure and fabricated by PCB technology is an inexpensive and simple method for sensor fabrication. The advantage of this structure is that the skin moisture sensor can be integrated with another humidity sensor for environmental moisture on the same printed circuit board. Furthermore, the sensors can be integrated with the readout circuit and the single chip to establish a portable skin moisture sensing system on the PCB laminate. The interdigital capacitance is fabricated by PCB technique to reduce the fabrication process and makes the sensors be low cost and capable for mass production.

2. Experimental

2.1. Sensor structure

Fig. 1 indicates the basic structure of a humidity sensor with IDC structure. A skin moisture sensor is based on a conventional capacitive-type humidity sensor with IDCs. It consists of three main elements: an interdigital capacitor, a polyimide moisture-sensitive layer, and a non-conductive substrate. The polyimide is a sensing material which is widely used for humidity detection [22,23]. Furthermore, this study applied a polyimide membrane to establish a human skin moisture sensor to detect water content of stratum corneum. A polyimide cover layer (CA335) is obtained from Topco Scientific Co., Taiwan. The cover layer with a film thickness of 60 μm is a PI material coated with a thin thermoplastic resin. By heating process to harden the PI thermoplastic resin and applying the high temperature and high pressure, the PI thermoplastic can be coated on the copper material. The lamination process needs following conditions: (1) temperature: 160 °C; (2) pressure: 50 kgf/cm^2; (3) operating time: 30 min.

2.2. Skin moisture measurement

For human skin moisture measurement, the active sensing area that contacts directly with the skin must be flat. In order to complete the necessary, the connection between the active sensing area and the soldering pad must be modified to reduce towering above the active sensing area. Fig. 2 shows the PCB bonding technique for the skin moisture sensor. It is required to drill a via (diameter: 1 mm) and around the via a metal is attached. The soldering pad is behind the active sensing area, and using the conventional tin solder can immobilize the conduction wire on the soldering pad.

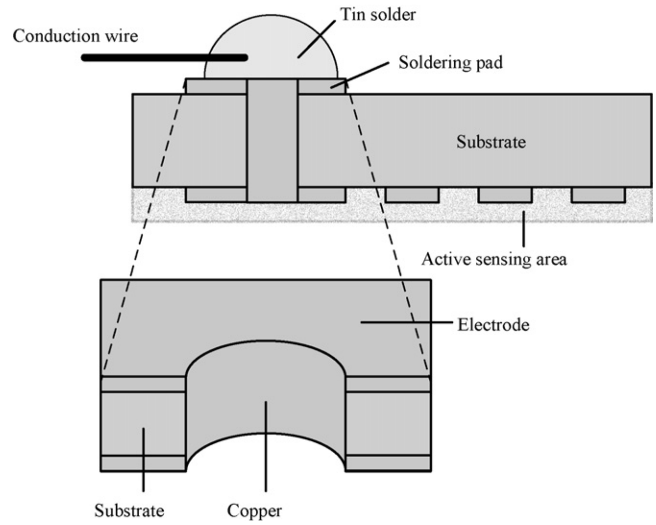

Fig. 2. Interconnection method between front and back electron pathway of PCB laminate.

Moreover, in order to reduce the error of skin humidity measurements, the pressure applied on the skin must be controlled. Fig. 3 shows the probe for detecting the skin moisture. A spring system, which can offer a constant force of 1.96 N, is connected with a skin moisture sensor. When the sensor is pressed on the skin, the spring can maintain the force applied on the skin to reduce the error of measurement. For stability measurements, identical areas of normal skin and hydrated skin were measured three times each and the capacitance variations of the sensors were monitored.

All measurements were achieved in a controlled environment at 25 ± 1 °C, 45 ± 2%RH. Before measuring, samples were adjusted in the controlled environment for 20 min to make sure that the samples were in steady states. The skin moisture sensor was pressed onto the human skin surface and the capacitance signal of the sensor was obtained by an LCR meter (HP 4284A) with a constant frequency of 100 kHz and an applied voltage of 300 mV. The water contents of the skin were identified in percentage units (%) by commercial skin moisture diagnostic instrument (MoistSense, from Moritex Corporation, Japan). Furthermore, the experimental results were compared to the commercial skin diagnostic instrument.

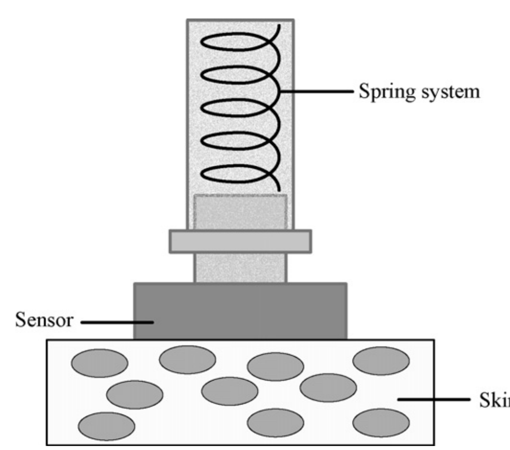

Fig. 3. Probe for detecting the skin moisture with a spring system.