Microsensor for the Measurement of the Transepidermal Water Loss of Human Skin

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We have developed a novel microsensor to measure the emission of water from human skin. Measurement of the transepidermal water loss (TEWL) is used for studying the water barrier function of the skin. The microsensor consists of a ceramic substrate carrying a thin film interdigital electrode system covered with a highly hygroscopic salt film. The change of capacitance of the electrode system per unit of time is a measure for the TEWL value. We demonstrate the different measuring results with normal skin and atopic skin.

Introduction

The protective function of the human skin shields the body not only from external influences (e.g. germs) but also prevents it from drying up. The stratum corneum (outer part of the skin) is flexible as long as it contains more than 10% water, but it becomes hard and brittle when dehydrated. Dermatologists universally recognize the unaffected skin of patients with atopic dermatitis by the fact that it tends to be dry and slightly scaly [1]. Different techniques have been developed to measure the skin properties that are influenced by the water content. Among the most widely used techniques are those involving the measurement of the skin impedance [2] – [5]. In this case the sensor chip must be brought into direct contact with the skin and therefore, a completely flat front surface of the sensor chip is necessary [6], [7]. One disadvantage of this type of sensor is the pollution of the chip caused by the skin.

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 [8] – [10]. This is an important parameter for evaluating the efficiency of the water barrier function. The more perfect the skin protective coat is, the higher the water content and the lower the TEWL. Disorders such as atopic dermatitis arise when the barrier function does not work properly. TEWL measurements allow the discovery of disturbances in the skin protective function in an early stage. By this way the onset of dermatological therapies can be accomplished in good time.

Different methods for TEWL measurement from local skin sites have been described: closed chamber methods and open chamber methods [9]. In this work we use a new type of sensor in a closed chamber arrangement. This arrangement offers the advantage of reduced influence of the environment resulting in more stable and reproducible measurements.

Measuring Principle and Sensor Technology

When the sensor device touches the skin a small hermetically closed measuring chamber is formed. A miniaturized humidity sensor is located on the top of this chamber in a distance of about 1.4 mm away from the skin surface (Fig. 1). The water vapor emitted from the skin fills the measuring chamber and causes an increasing relative humidity inside the chamber. A part of this humidity condenses on the comparable cold humidity sensor surface causing there a growing film of water. The growing rate of this film can be expressed by the change of the sensor impedance within a defined time interval.

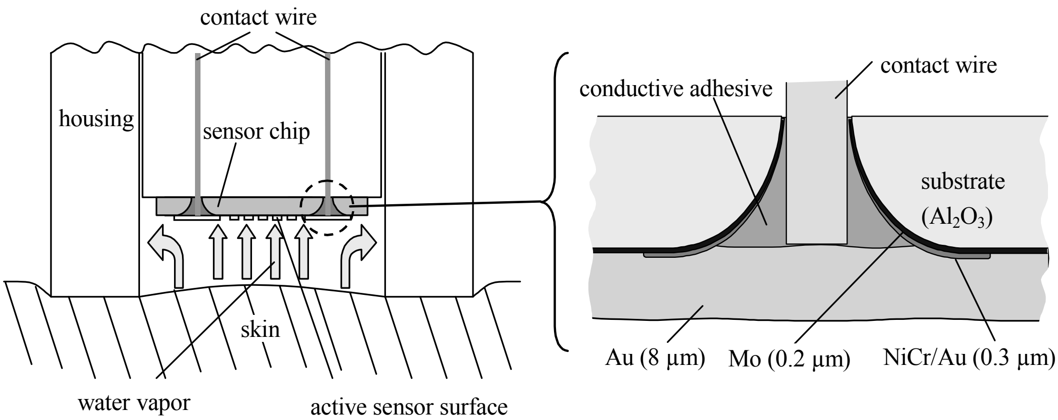
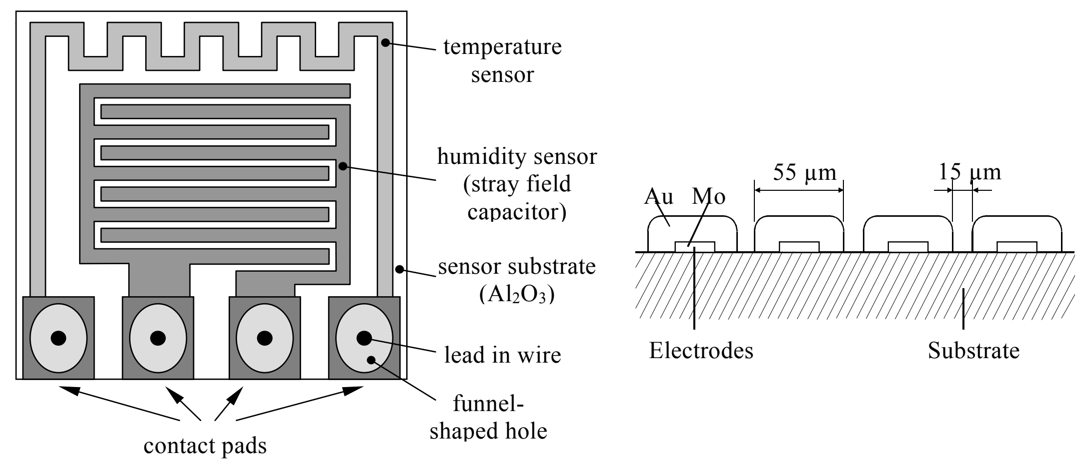


Fig. 1: Schematic cross sectional view of the TEWL-sensor with closed measuring chamber (increasing concentration of water vapor in the chamber after touching the skin). The funnel-shaped holes are produced by a special laser drilling process. The thick gold layer is deposited by electroplating.



(a) (b)

Fig. 2: (a) Schematic structure of the thin film microsensor. The chip dimensions are 5 mm x 5 mm x 0.6 mm. (b) Schematic cross sectional view of the electrode system.

The novel microsensor used in this work consists of a small ceramic substrate (5 mm x 5 mm x 0.6 mm) carrying a metallic interdigital electrode system (Fig. 2). We have used a double-layer system of molybdenum and gold for the sensor electrodes. The molybdenum film has been deposited by rf-sputtering; the rather thick gold film (8 µm) has been produced by electroplating. The width of the electrodes is about 55 µm; the gap between them is approximately 15 µm. The active moisture sensing area is 1.75 mm x 3.15 mm. The contacts of the electrodes are made of a sputtered layer system of molybdenum, nickelchrome and gold. The lead-in wires are guided through funnel-shaped holes to the rear substrate surface (Fig. 1). These holes were laser-drilled into the ceramic substrate using a CO_2-laser. The lead-in wires are bonded to the contacts by using an isotropically conductive adhesive. The result is a completely flat front surface of the sensor [6], [7]. This fact is important for the application as a TEWL-sensor. The sensitivity is significantly improved by covering the active area of the sensor chip with a hygroscopic inorganic salt film. All technological work has been carried out in the Institute of Sensor and Actuator Systems of the Vienna University of Technology.

Measurements and Results

The measurements have been carried out in the Shibaura Institute of Technology in Japan. We have used an LCR-meter HP 4285A connected to a computer. The measuring frequency was 500 kHz and the measuring voltage was 100 mV. We have used an equivalent circuit R parallel C and the capacitance C was chosen as the output quantity (Fig. 3). However, for further measurements carried out at the Vienna University of Technology we have used the conductance as the output quantity [10].

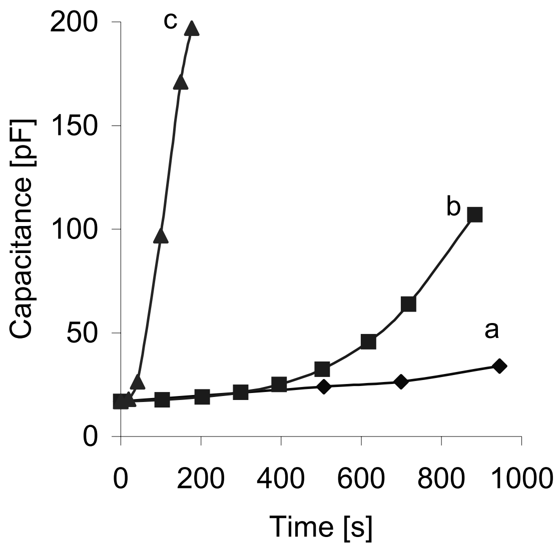


Fig. 3: Capacitance as a function of time. Curve a: normal skin of an elderly male person. Curve b: normal skin of a young male person. Curve c: atopic skin of a young male person. Measurements have been carried out at 500 kHz and 100 mV on the right forearm in a room with stable conditions (relative humidity 30%, temperature 23 °C).

Conclusion

The transepidermal water loss is an important factor for characterizing the health condition of human skin. TEWL measurements allow the discovery of dysfunctions of the skin even before they are visible. A measuring device with a novel moisture sensor in a closed chamber configuration has been introduced. The slope of the capacitance vs. time characteristic of the sensor can be used as a measure for the TEWL-value of the investigated skin.

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