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Novel dew point hygrometer fabricated with inkjet printing technology☆

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ABSTRACT

This paper reports a novel, first time made Dew Point Hygrometer (DPH) detector, which was fully fabricated with the inkjet printing technology. This type of the sensor operation was already known in DPH which is based on a silicon complex dew detector (Jachowicz and Senturia, 1981; Weremczuk et al., 2006) [1,2]. However, in our device the silicon substrate has been replaced by a thin, flexible Kapton foil. All components integrated in the detector: the interdigitated capacitive sensor electrodes, the thermoresistor and the heater were made by ink-jet printing technology. All individual elements of the printed dew point hygrometer detector have been characterized, and finally, their measurement features were described.

1. Introduction

Air humidity describes the amount of water vapour in air. Even the marginal small values of humidity can have significant influence on living organisms or inanimate objects. But the greatest impact it has on technological processes, therefore measuring and regulating of humidity is often of high importance for the process. Air humidity is most commonly described by either of two values – dew point temperature [3–5] or relative humidity [6,7]. In a hygrometers the dew point (DP) temperature is the temperature in which the condensation of water vapour begins on a surface of that temperature. Higher DP temperature means that the air is more humid. The DPH must consists of a detector to detect the instant when the water vapour condense on the surface at the dew point temperature, as well as a temperature sensor and a heater [8]. They are used to measure the surface temperature of the detector and to heat up the detector for condensed water evaporation just after DP temperature measurement.

The principle of operation of such a dew point hygrometer is based on gradually cooling the surface of the sensor, while the impedance comb detector must checks if the water condense on the surface. When this state occurs, the measured surface temperature is taken and treated as a gas humidity value. Finally, the condensed water is evaporated by heating up with the heater. In this way, applying continuous process of water condensation and evaporation, the DPH can follow humidity changes of the measured air. Each measurement cycle gives new humidity readout, independent of previous. This feature eliminates disadvantage of relative humidity sensors related to the time constant. Appropriate design of a dew point detector, and a control algorithm of a DPH, makes the time between successive readings can be just a few hundred millisecond [2]. Such good dynamic parameters allow the use of a dew point hygrometer for specific medical applications [9]. It is worth to point out, that the DP temperature is the absolute unit of gas humidity. Moreover, typically the DP hygrometers are much more accurate than RH meters.

2. Printed detector of the dew point hygrometer

2.1. Sensor design

The humidity sensor described in this paper was manufactured using Inkjet Printing technology. This technology uses printers similar to office inkjet printers, but they are more versatile, offers more precise printouts which are desirable in printed electronics [3,9–13]. This rapidly evolving technology allows production of sensors considerably cheaper than traditional silicon-based ones [1], and is expected to take over areas where big amounts of flexible, cheap and not too complex sensors are required. The use of maskless technology (photolithography is not needed) and the use

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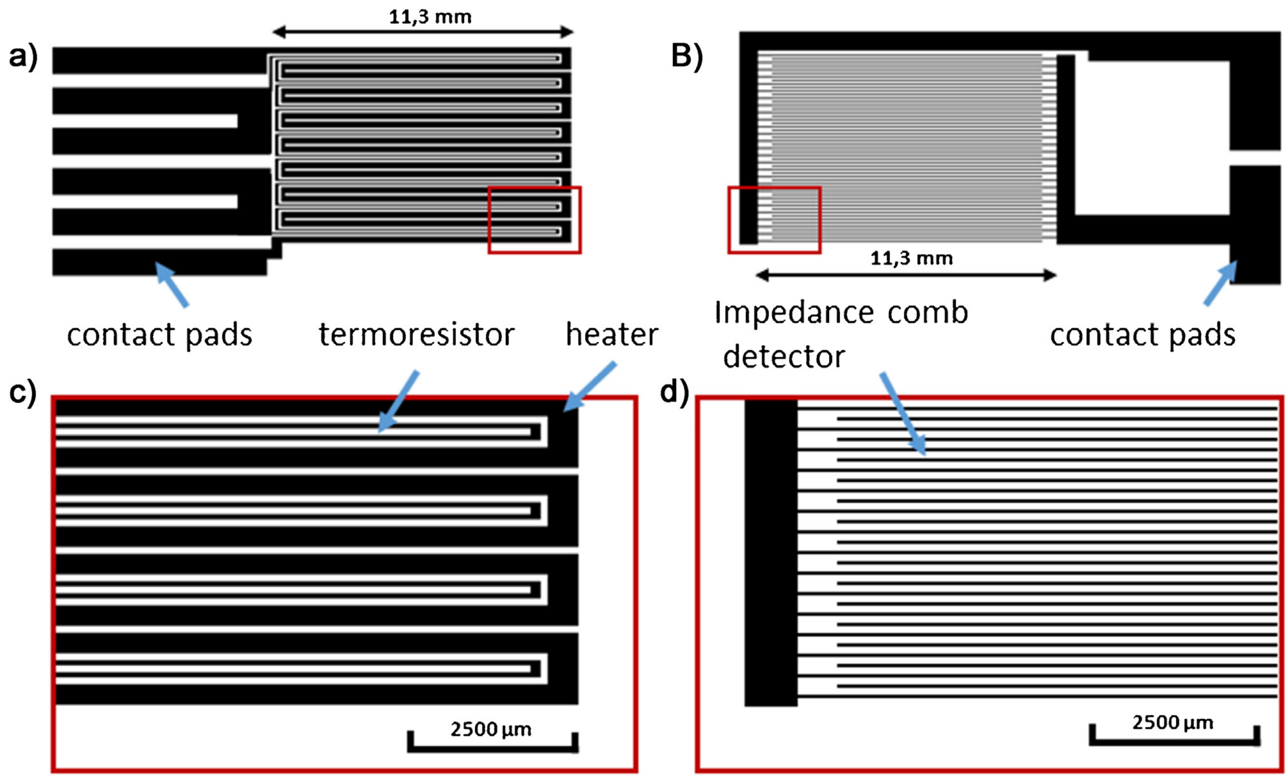

Fig. 1. The design of a) the bottom side: the heater and the thermoresitor, b) the top side: the impedance comb detector (contacts not to scale). Magnifications of designed structure: c) heater and thermoresitor (the bottom side), d) impedance comb detector (the top side).

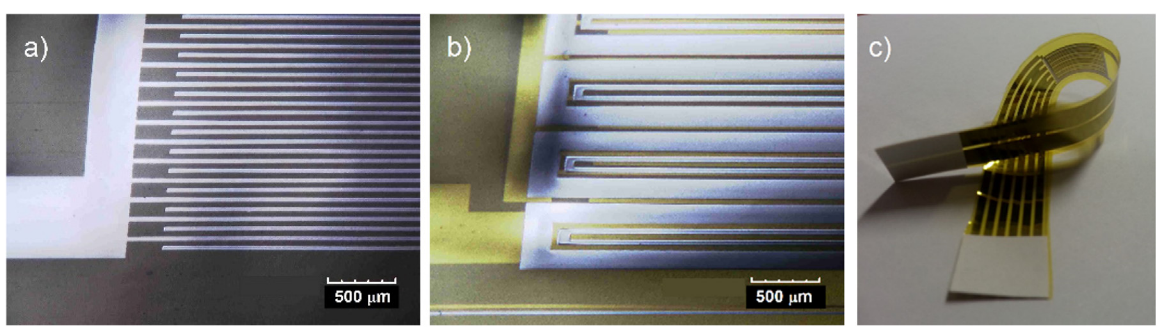

Fig. 2. Close-ups of: a) manufactured dew detector comb, b) meander-like shape of the thermoresistor (narrow lines) and of the heater (wide lines), c) printed DPH structure with long contact pads.

of additive methods of deposited layers (less waste of technological materials) are resulted of lower overall cost of fabrication technology.

The hygrometer structure presented it the paper was intended to be full fabricated with inkjet printing technology. However, using printing technology the major problem is to identify the interaction between the selected ink and the substrate. Therefore there must be chosen proper materials (both a substrate and an ink) to provide required contact angle in order to obtain a drop of ink with controlled and repeatable dimensions. The parameters limiting the use of inkjet printing are among other problems as a minimum diameter of ink drops on the substrate and as physical parameters of the substrate. Using conducting inks containing nanoparticles of metal, we must use a cartridge that will not be clogged during printing. Also, the substrate should withstand the temperature conditions that occurred during curing the inks (i.e. relatively high temperature).

As it has been described early, the dew point hygrometer, requires fabrication of three components in a single detector structure. The heater and the thermoresistor should measure and control the temperature of the detector in a uniform manner of the entire structure area. In addition, both expect opposite requirements for their resistance. The heater should have low resistance to provide adequate power at a relatively low supply voltage. While the thermoresistor should enable the measurement of temperature with resolution of at least 0.1 K. As a result of these opposite requirements the heater had very low resistance (some 150 Ω) and the theromoresitor relatively high resistance (some 740 Ω). These two elements have been integrated in a single layer (Fig. 1a and c, called bottom side) which has been back side of the substrate foil. On the top of the foil ("top side"), the interdigitated comb electrodes were formed as a dew detector. All components were printed on 12.5 μm flexible Kapton foil. The Kapton film provides adequate resistance against temperature (over 200 °C), and its small thickness allows the minimization of surface temperature measurement error with the bottom thermoresistor. The design close up of hygrometer structure are shown in Fig. 1. Active area of the detector has dimensions of 8 mm per 11.3 mm, where the comb electrodes have a