Microcondensation Sensors for Field Tests and for Simulation of Environments in Climate Chambers

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***Abstract* - Condensation associated with the risk of electrochemical and chemical migration plays an increasing significance in the field of reliability of electronic components. The trends towards challenging electronic assembly technologies such as minimization of conductive track widths and spacing, and higher density in electric elements are increasingly faced with the negative influences of micro-condensation. The condensation occurs as a result of the thermodynamic conditions in the environment of the electronic board. The condensed water is in equilibrium of condensation and evaporation, not in a static state. Due to this fact, there is a demand for sensors to record the real state permanently. Due to its miniaturized packaging, a new generation of micro-condensation sensors allows placement on different parts of electronic devices. Results of field tests in different automobiles and in climate chambers are presented.**

Keywords – condensation, humidity, migration, corrosion.

I. INTRODUCTION

In recent years, humidity sensors have found an extended range of application. Increasing demand for improvements of quality, reliability and energy control of technical and non-technical processes lead to new relative and absolute measurement humidity sensors [1]. The common type of sensors, the polymer sensors, is fabricated from a hygroscopic material. The electrical properties change as it absorbs water molecules. For measurement of absolute humidity dew point hygrometers are offered. The gas is cooling down until condensation appears on a small mirror. The temperature at which this happens is measured and is defined as the dew point temperature. The onset of condensation is sensed optically [2].

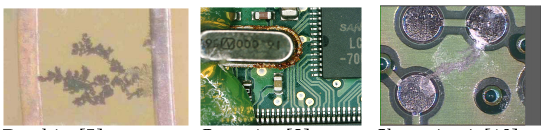
Failures of electronic components due to corrosion as a result of condensate ion can be studied only to a limited extent with the above mentioned instruments [3]. For monitoring by measurements of condensation processes in field tests or laboratory conditions, new measuring systems are required.

The presented microcondensation sensors measure the condensation directly. The basic principle consists of a stray field capacitor where the electric flux lines intersect the condensed water drops [4].

The miniaturization of the stray field interdigital capacitor in combination with a signal preprocessing close to this transducer, allows the measurement of water mass in the range up to 30 µg/mm^2. Depending on the comb pattern of specifically designed stray field capacity in combination with a water drops sensitive detection system, a change of the capacity with increasing water mass is fact. By varying the comb pattern, the sensitivity to the measured water mass can be adjusted (water drops in the range of 5 - 15 or 5 - 30 µg/mm²).

II. INFLUENCE OF CONDENSATION ON CORROSION

In the last years, an increasing number of papers were published dealing with any kind of corrosion of printed circuit electronic boards [5, 6]. Most of these are related to failures concerning the electronic reliability. Some authors reduce the failure to electrochemical or chemical corrosion [7, 8, 9]. Adding the growth of dendrites, the problem is becoming worse. Figure 1 presents a selection of typical failures.



Dendrite [5] Corrosion [9] Short-circuit [10]

Figure 1. Different kinds of failure

What do all these examples of corrosion have in common? An essential role for the initiation of corrosion plays the presence of moisture. The presence of moisture causes electrolysis processes. These cause uncontrolled currents (leakage). The corrosion occurs by dissolution of the metal due to anodic oxidation. Electrolysis processes are already initiated significantly at relative humidities below dewing. Very thin films of water are formed already at 40 % relative humidity. At relative humidity of 60 %, water films are formed with a thickness up to 4 molecular layers. This water film can already interact with hygroscopic impurities on the board. At relative humidity of 80 %, water films are formed with a thickness up to 10 molecular layers [10]. These act similar to "normal water". Solution processes of salts on the surface can start and ionic processes run subsequently. In combination with higher temperatures these corrosion and migration processes are accelerated.

Electronic boards are more exposed to changing climatic conditions. This is a growing risk of condensation of water

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vapor on the materials and components of electronic devices and consequently the risk of corrosion.

The processes could not only be described by the real climatic conditions. Rather, knowledge of the processes near the surface is required. Quantitative data of surface temperature, of humidity in the boundary layer, and, in particular, of the real condensation are necessary. Using microcondensation sensors, these data can be obtained.

III. MICROSYSTEM

Based on the increasing interest in direct condensation testing, different principles exist (e.g. optical [11], optoelectronical [12], and capacity [13] transducers).

We introduce an impedimetric principle and prefer such a solution for reasons of better miniaturization, better integration of condensation and temperature sensor, and to create smart systems with lower power consumption.

Because the customer is mainly interested in a calibrated sensor signal, the complete micro sensor system must be integrated. Starting with the detection system, transducer and signal pre-processing, the system has to be completed by the signal processing (linearization, error compensation, calibration, programming) and interface.

A. *Detection system*

The detection system consists of a PE CVD Si3N4 layer, typically approximately 500 nm in thickness. This system has to guarantee a high and long term stability and reproducibility (see Figure 2) of condensation. A second task of this layer is the protection of the metal layer underneath against corrosion.

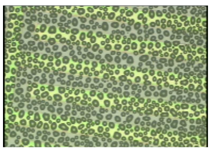

Figure 2. Condensation on sensor surface

B. *Transducer*

Two transducers are necessary, one for the measurement of temperature of the condensate and one for water mass measurement. The temperature transducer has been realized with a typical monolithic pn - junction. The water mass transducer has been designed as stray field capacity with interdigital structures (Figure 3). With a gap/line ratio of 25/33 (Figure 4), water mass measurements are possible between 5 and 25 µg/mm2.

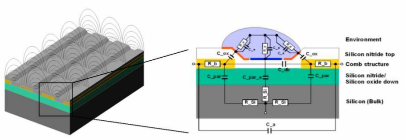

Figure 3. Model of stray field capacity

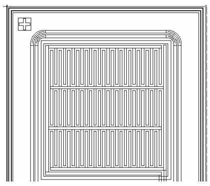

Figure 4. Design of interdigital electrodes

C. *Signal pre-processing*

With the demand regarding III, the signal pre-processing has been reduced to a capacity-frequency converter. This converter allows a distance from the sensor element to the signal processing of about 1 - 2 meter. The temperature sensor does not need signal pre-processing. The change of temperature related flow voltage (2 mV/K) can be prepared for the electronic via the same signal line.

The detection system, transducer, and signal pre-processing are hybrid integrated components (figure 5).

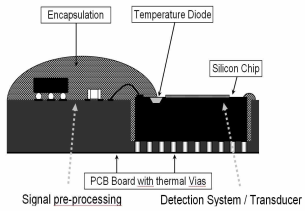

Figure 5. Draft of a cross section of a sensor element (detection system, transducer, signal pre-processing)

D. *Signal processing/Interface*

To obtain calibrated output signals for temperature and water mass, the primary signals from the sensor element have to be reworked. Therefore, the electronic part contains the appropriate parameters for linearization, temperature compensation, and programming. Tests for radio interference emission and immunity to electromagnetic fields were carried out and the results confirm that the sensor system (figure 6) meets the requirements of the automobile industry.

Figure 6. Complete sensor system

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IV. RESULTS

A. Calibrated output signal

The sensor system provides calibrated analog or digital output signals for temperature and water mass.

The calibration of the water mass is realized by taking pictures of the sensor surface at different stages of dewing and simultaneous measurement of the output signal of the sensor. By means of image processing, knowing the contact angle of water at the sensor surface, and mathematical models, a correlation between the determined water mass and the output signal was fixed. An external processor processes the signals to an analog (0-1V) or digital (I^2C) output signal (Figure 7).

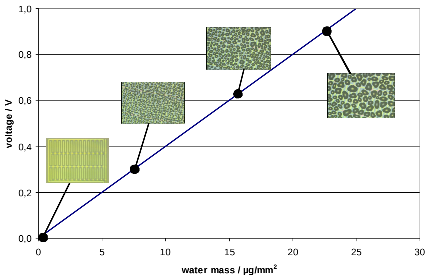

Figure 7. Calibration curve

The calibration of temperature is realised by comparison with resistance thermometer as reference in thermostat bath in dipping process.

B. Test results in automobiles

Different automobile suppliers have measured the condensation on different printed circuit boards at several places in an automobile and under different climatic conditions by means of the condensation sensor.

Figure 8. Sensor module on HIFI control unit (picture courtesy of BMW Group München)

One of the last tests was carried out at BMW, for example. Mounting places chosen were the battery in the right-side tray, the transmission tunnel on the airbag sensor, the fuse box on the passenger side, the vehicle battery, the data acquisition, and the HIFI control unit in the rear trunk. Sensor modules are used to measure condensation and temperature as well as relative humidity and temperature. Figure 8 shows the sensor modules placed on the HIFI control unit.

C. Tests in climate chambers

Based on the results in the automobile, comparable conditions were simulated in climate test chambers. With the standard ISO/DIS 16750-4 a temperature and humidity profile was defined to generate a dewing effect such as in an automobile environment (Figure 9) [14].

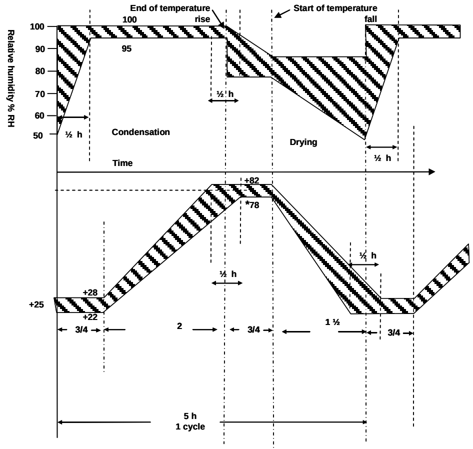

Figure 9. Dewing test cycle according to ISO/DIS 16750-4

With the condensation sensor mounted on the surface to be detected, statements can be taken about the real micro climate at the boundary layer during the test cycle (Figure 10).

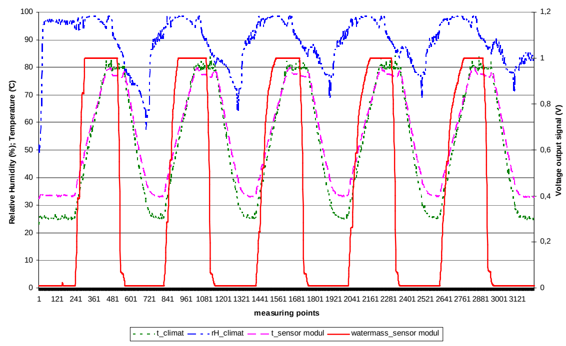

Figure 10. Measurement of condensation (watermass_sensor modul) and temperature (t_sensor modul) during the dewing test cycle in climate chamber (t_climate, rH_ climate)

The measured values in Figure 10 confirm that during the cycle time of 3 h the surface temperature has increased from 25 °C up to 80 °C and a condensate of 15 µg/mm2 has formed on the board.

V. Conclusion

In the paper a miniaturized sensor system has been described. The sensor system allows first time quantitative measurement of condensate mass and temperature with calibrated output signals. The system is suitable for field measurement. Tests in climate chambers and in automobiles are presented.

This sensor system is a tool for reliability tests and to support R&D and production of highly integrated printed circuit boards.

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