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Title: Design and Development of Capacitive Vapor Sensor with necessary signal conditioning

Abstract

Humidity has an important role in the quality of human life. Humidity measurement is very important task in many industrial processes for manufacturing of different products such as food, paper, textiles, semiconductors and petrochemical etc. Dynamic range of humidity measurement is very wide ranging from traces of humidity in PPM to very high percentage relative humidity (%RH). Monitoring of humidity is an important activity in numerous fields of industry because it may affect both the product, and the health and security of the workers. Therefore, the measurement of relative humidity has been rigorously studied and a verities of sensors like capacitive, resistive, thermal conductivity and optical have been developed during the last decades. But in absence of an accurate and desirable sensor to measure the trace moisture, it has become industry practice to rely on expensive workaround and over designed systems to eliminate moisture allowing huge safety margins. Thus, there is an increasing demand of suitable moisture sensor to detect the trace level moisture concentration in lower ppm in the gases such as nitrogen, argon, helium etc.

The main focus of this thesis is to design and development of a capacitive trace moisture sensor and the interfacing electronic circuit for the proper signal processing of resistive or capacitive humidity sensor. Several materials have been used for fabricating humidity sensors such as porous silicon, porous alumina, polymer etc. In this thesis a porous silicon based trace moisture sensor has been developed. Porous silicon (PS) is produced by chemical/electrochemical dissolution of crystalline silicon by anodic etching in a HF acid based electrolyte. The porous structure with pore diameter below 10 nm is fabricated by controlling the anodization parameters using precision Solatron

Electrochemical Cell (1280C. Pore size and morphology has been studied using field-emission scanning electron micrograph. The electrical properties were evaluated by impedance spectroscopy over wide excitation frequency for different contents of water vapor in N_2 gas with Agilent 4294A Impedance Analyzer. An equivalent circuit of the sensor for describing the response behavior is also discussed.

For real time humidity measurement, the sensor is interfaced with suitable interface electronics circuit to get the final output into voltage form or frequency or time period of the output signal. In this thesis two simple signal conditioning circuits based on relaxation oscillator for both resistive and capacitive humidity sensors have been developed. The circuit utilizes OPAMP based active bridge for incremental resistance change into frequency or duty cycle for resistive humidity sensor and capacitance change into frequency for capacitive humidity sensor with temperature compensation capability.

Finally, this thesis studied the non ideal behavior such as the effect of ambient temperature on different capacitive humidity sensors. The sensors studied are having sensing materials of different types such as polymer, aluminium oxide and polymer based micro humidity sensor fabricated using MEMS technology. Temperature behavior of the sensor has been modeled using the humidity and temperature characteristics of the sensors. A generalized method has been developed using soft computing ANN technique to compensate the temperature error of different capacitive humidity sensors. An artificial neural network based inverse model of the sensor has been used to minimize the effect of temperature and non linearity of different kind of humidity sensors Output of the ANN is the estimated humidity in %RH. The ANN is based on multi layer feed forward network (MLP) trained by back propagation algorithm. The simulation studies are carried out in MATLAB ANN toolbox environment with different activation functions and hidden nodes. The maximum error for nonlinearity using the ANN technique are 0.2 % and temperature error of 0.08 % for temperature range between 10 °C to 60 °C of sensor 3 and 0.01 % for temperature range between 25 °C to 85 °C of sensor 4 respectively.