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Title of the Thesis: “Study of Constant Phase Element for Sensor Development”

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ABSTRACT

The aim of this thesis is the utilization of the phase angle of the Constant Phase Element (CPE) as a sensing parameter for the measurement of humidity and liquid level. First, a constant phase sensor has been fabricated for the measurement of percentage relative humidity. The sensor consists of an interdigitated electrode sandwiched between two identical microporous thin film layers of γ-Al_2O_3. The solution for the oxide film is prepared by sol-gel method and the film is dip coated by an automatic dip coating system. Electrical characteristics of the sensor are determined with the help of the Agilent 4294A impedance analyzer in the frequency range of 100 Hz to 5 MHz when the humidity level is varied from 4% to 96% RH. It is observed that the phase angle of the sensor is fairly constant for the frequency range of 1 MHz to 5 MHz. Phase angle is close to −90° at 4% RH and decreases with the increase in humidity. Response time of the sensor is ~80 s and recovery time is ~53 s respectively.

It is reported in various literatures that the sensitivity of a capacitive humidity sensor is high at low signal frequency, but the effect of the signal frequency on other characteristics is rarely investigated. So, the role of signal frequency on the response characteristics of a nanostructure ceramic thin film capacitive humidity sensor fabricated by sol-gel method was investigated for the first time. Experimental results show that although the sensitivity is high at low frequency, the performance of the sensor is highly nonlinear and frequency dependent. At high frequency above 100

kHz, the sensitivity is reduced, but the other characteristics of the sensor are improved significantly. Improved characteristics are due to the reduced effect of double layer capacitance that plays a significant role for extreme sensitivity at low frequency. Improved response characteristics at higher frequencies will reduce the complexity of the signal conditioning, particularly the nonlinearity and the hysteresis errors, the compensation of which is essential for almost all types of the humidity sensors.

In the conventional contact type capacitive liquid level sensors, when a metal electrode having an insulator film is immersed in polar/ionic medium, it shows the constant phase behavior at metal-insulator interface with the polar/ionic medium due to the formation of the double layer. Therefore, modeling the double layer by pure capacitor may cause significant error for level measurement. Therefore, a constant phase sensor for conducting liquid level sensing has been designed and fabricated to minimize the error due to double layer effect and fluctuation of the input signal frequency. The constant phase sensor is fabricated by depositing thin porous insulating film of poly-methayl-metha acrylate (PMMA) on both sides of a copper cladded polyimide substrate. The sensor is then connected to the Agilent 4294A impedance analyzer to study the electrical characteristics with the variation of water level in the range of 0-4 cm. The sensor shows constant phase behavior from 100 kHz to 1 MHz and the significant change in phase angle with the variation of liquid level (2.1°/cm) is observed. Finally, the sensor is interfaced with a simple phase detection circuit to obtain voltage signal. The output of the circuit is calibrated in terms of liquid level. The important feature of the sensor is that the output response is sensitive to liquid level variation and independent of signal frequency. The fabrication of the sensor requires cheap material, bulk producible but it is applicable for conducting liquid. Proposed CPE sensor fabricated by thin polyimide strip is flexible and can be rolled and transported easily to the remote location.