Introduction

Temperature and % relative humidity (%RH) sensors on paper substrate are demonstrated. The fabrication of sensors involves inkjet printing technology and a new type of specialty paper substrate for electronics. Non-conventional processes offer several advantages such as: easy processing, reduced costs, and large-area fabrication. Inkjet printer’s unique ability to deliver fluid onto a substrate with high spatial accuracy is critical for making devices and structures. The sensors presented in the project are on paper substrates which will further reduce the cost of manufacturing and allow the possibility of new areas of application. The main objective of the work is to fabricate sensors with desired characteristics: high sensitivity, small hysteresis, good linearity, low temperature coefficient, and long-term stability.

Principles of Sensors

Temperature sensor:
Utilizes thermally sensitive resistor which the electrical resistance is a function of temperature, also known as a thermistor. The temperature coefficient (α) describes the behavior of a sensor.
\[
\alpha = \frac{R(T) - R(0)}{R(0) \Delta T}
\]

% RH sensor:
Interdigitated capacitor structure with a certain capacitance value, C
substrate
is coated with a polymer sensing layer, cellulose acetate butyrate (CAB). Polymer sensing layer absorbs analytes from the atmosphere which has its own capacitance C
sensing layer
. Thus, the total capacitance is
\[
C_{total} = C_{substrate} + C_{sensing layer}
\]

Humidity Sensor

- All three devices showed hysteresis, 8 μm CAB had largest hysteresis.
- \( \Delta C_{60\% \text{RH}} = 24.9 \text{ pF} \)
- Hysteresis gap increases with the CAB layer.

Temperature Sensor

- The gap, \( \Delta R \), becomes more pronounced with increase in %RH level and showed the largest gap at 70 % RH, \( \Delta R_{20\%C} = 67.2 \Omega \).
- Good linearity until 40 °C for high %RH levels.
- \( \alpha \) coefficients calculated on linear region from -20 ~ 40 °C of the graph.
- The average of \( \alpha \) coefficients.
  - \( \alpha = 6.8 \times 10^{-4} \text{ K}^{-1} \)
- Long-term test showed a significant drop (148.1 \( \Omega \)) from the beginning for more than 100 hours of testing.

Summary

- Temperature and humidity sensors on paper substrates were made using DOD inkjet printer.
- Humidity sensors showed increase in hysteresis gap \( \Delta C \) with thicker CAB layer. CAB layer is not thick enough to capture most of the electric field.
- The absorption of the vapors in the paper substrate and CAB sensing layer increases the permittivity, thus increasing the total capacitance.
- Temperature sensors features relatively low \( \alpha \) coefficients and good linearity at lower % RH levels.
- Long-term test illustrated the device will drift for prolonged usage.