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Design and Development of Solar Cell Integrated Moisture and Temperature Sensors for Photovoltaic Modules

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AIM AND OBJECTIVE

- Development of solar cell integrated humidity and temperature sensors for in-situ measurement of moisture ingress and cell temperature.
- The moisture sensor measures the capacitance, which is influenced by moisture diffusion inside EVA.
- The temperature sensor measures resistive properties which is subjective to the cell temperature.
- The sensors are screen-printed on solar wafers and can be integrated into PV modules alongside other solar cells.

DESIGN APPROACH

Moisture sensor

- Interdigitated capacitors with comb-shaped electrodes
- EVA used as dielectric of capacitor

Parameters

Number of fingers (N)	10
Length of the electrode (L)	5 mm
Gap between fingers (G)	200 µm
Width of the finger (W)	60 µm
Thickness of the finger (t)	20 µm

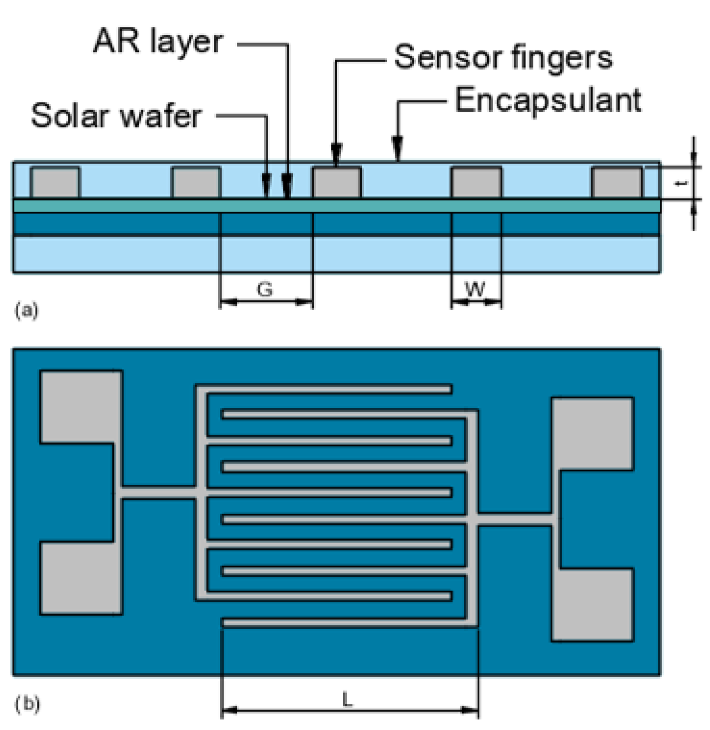


Figure 1: Schematic drawing of the moisture sensor with design parameters (a) Cross-sectional view (b) Top view.

Temperature sensor

- Design based on resistance temperature detectors with single square rod
- The resistivity of conductive materials used as a temperature detector

Parameters

Length of the electrode (L)	13.75 mm
Width of the finger (W)	60 µm
Thickness of the finger (t)	20 µm

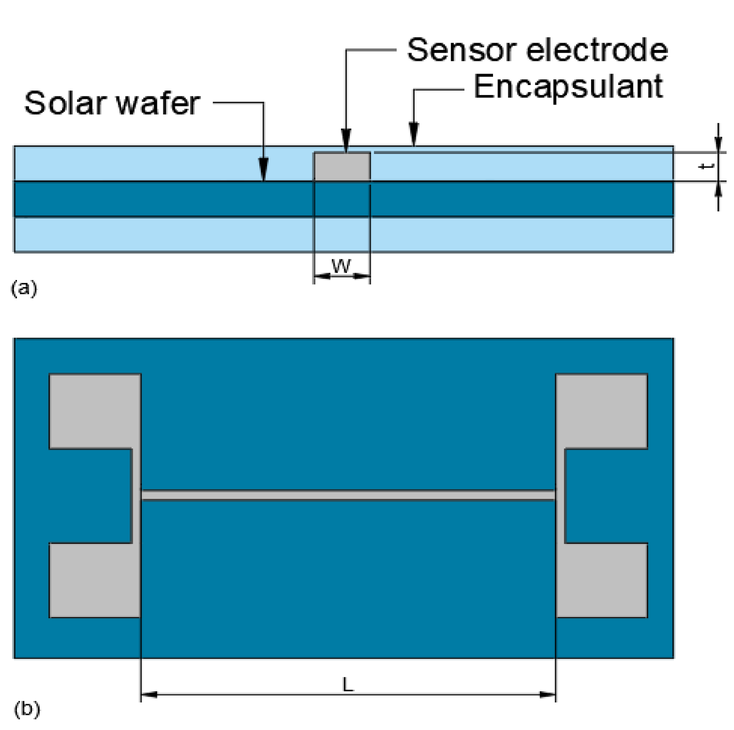
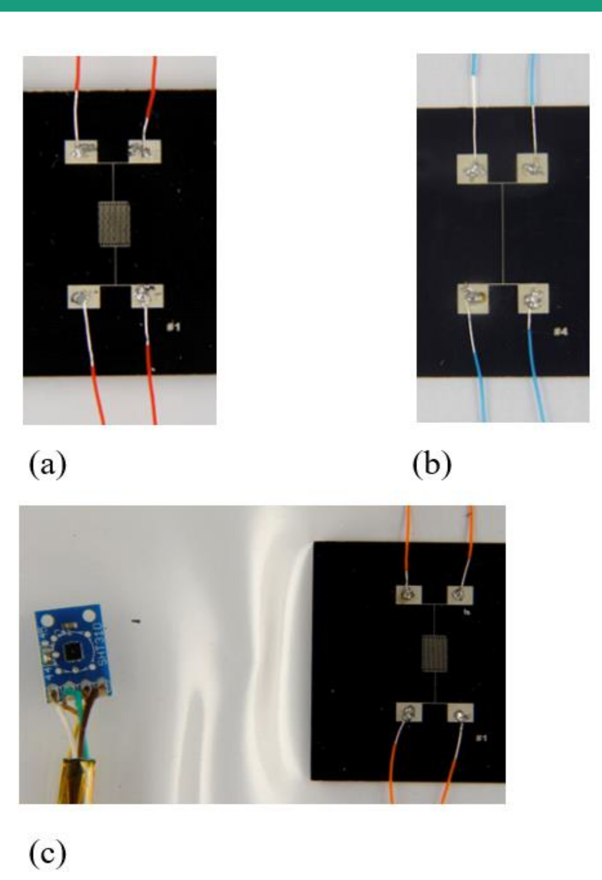


Figure 2: Schematic drawing of the temperature sensor with design parameters (a) Cross-sectional view (b) Top view.

SENSOR FABRICATION



- Screen printing of sensors on the front side of solar cells
- Laser cutting of sensors wafer into horizontal strips
- The Sensors Strip is laminated between two layers for EVA with a standard lamination process

Figure 3:
(a) laminated screen-printed humidity sensor
(b) laminated screen-printed temperature sensor
(c) commercial humidity sensor laminated between the EVA sheets with a sensor strip.

PROOF OF CONCEPT

Moisture sensor

- LCR meter Agilent 4327B used for capacitance measurement
- Relative humidity controlled in steps from 20 %RH to 85 %RH (at constant temperature 85 °C)
- The test was repeated 5 times ("five-cycle test")
- Exponential behavior, $C = m + Ae^{B\%RH}$

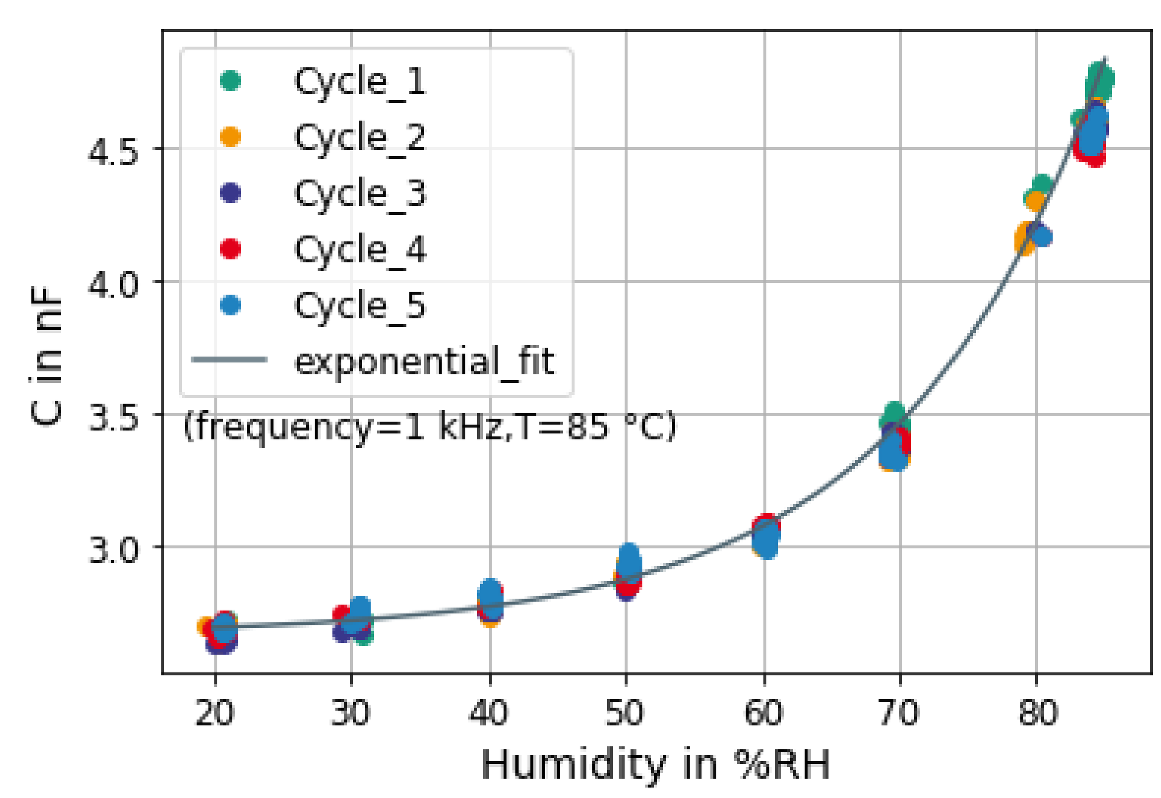


Figure 5: Measured capacitance of humidity sensor at 1 kHz with exponential curve fit of the five-cycle test at 85 °C

Temperature sensor

- Multimeter Agilent 34980A used for resistance measurement
- Temperature range: -40 °C to 85 °C
- Holding time at a constant temperature approximately 2 h
- Calibration of sensors values according to IEC 60751,

$$R = R_0(1 + At + Bt^2)$$

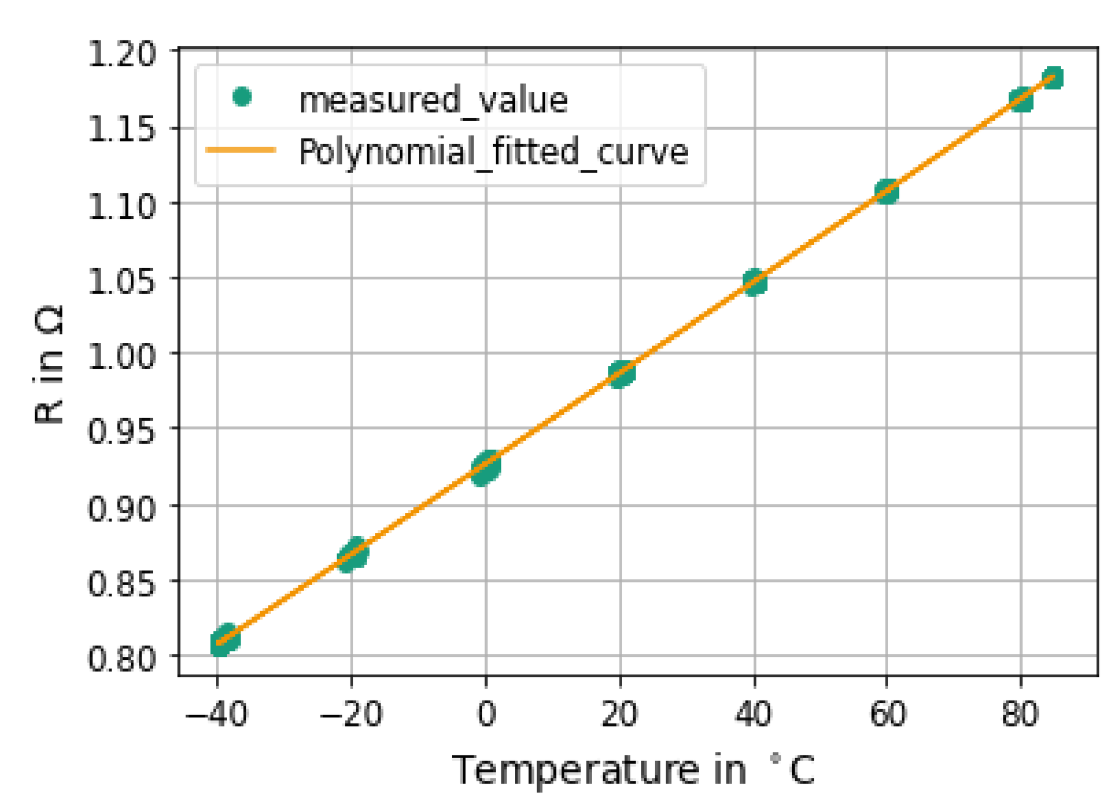


Figure 6: Temperature dependent resistance measurement of temperature sensor

SUMMARY AND OUTLOOK

- Moisture sensor provided a reproducible response in cycle test, and it gives an exponential response at constant temperature.
- Temperature sensor showed polynomial response with a high reproducibility.
- For a full calibration of the humidity sensor, investigations at various temperatures need to be performed.
- The next steps are measurements of relative humidity and temperature during operation.