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The effect of low humidity air flow on the SAW sensor module with ultra-thin CuPc layer

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Summary:
This contribution reports a stepwise airflow experiment in which the flow rate Q was changed between 25–1250 ml/min while moisture conditions were controlled by a fixed dew point of dp = −19.9°C, correspondingto RH ≈ 5.4%. To avoid scale domination by the carrier frequency, f and f0 were presented as deviations from their meanvalues, while Δf was analyzed directly in Hz. The Δf(t) plot with Q annotations shows distinct transient and quasi-steady responses for each air flow step. Mean Δf values extracted for each Q are summarized by a bar chart, showing an over all increase of Δf with increasing air flow rate. The presented figures provide a compact conference-ready representation of air flow influence on SAW response under controlled low level humidity.

Keywords: surface acoustic wave; airflow rate; frequency shift; dewpoint; relative humidity

Background, Motivation and Objective

Surface acoustic wave (SAW) devices are sensitive to changes in the near-surface environment[1]. Air flow can modify transport and boundary layer conditions above the sensingsurface, thereby affecting the measured frequencyresponse. The objective of this study is to present a clear data-processing and visualization work flow for SAW time-series measuredduring sequential air flow steps and to quantify how the frequency shift Δf depends on Q under a fixed low level dew point condition.

Sensor Module and Measurement Setup

The investigated device is based on two acoustic lines fabricated on an ST-cut, temperature-compensated quartz substrate, operating at approximately 205 MHz. Copper phthalocyanine (CuPc), an organic semiconductor, was deposited by physical vacuum evaporation method (PVD) as an ultrathin layer (~0.4 nm) on one of the acoustic paths to form the sensing layer (see Fig.1). The bonded module was placed in a measuring chamber with an electronic set-up with a swiching channels (see Fig.2 and Fig.3).

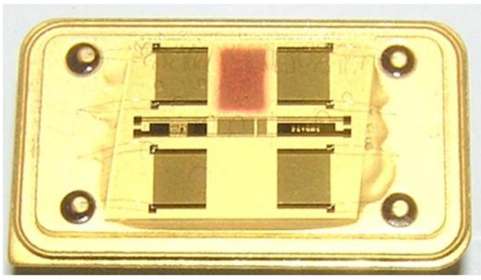

Fig. 1. SAW Components module (Dresden, Germany) with a created CuPc layer

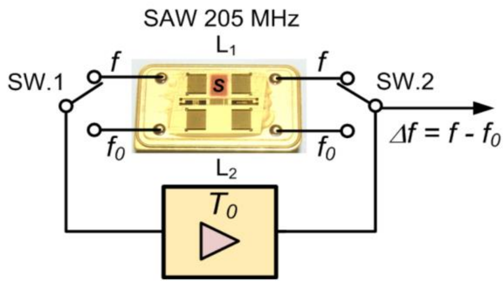

Fig. 2. SAW (205 MHz) measurement scheme

The measurement system comprises severalcomponents enabling signal excitation, precise frequency readout, and switching between the two acoustic paths of the sensor module. It includes: (1) SAW electronic set-up, (2) frequencymeter, (3) digital switches between SAW lines, (4) chamber with SAW sensor module.

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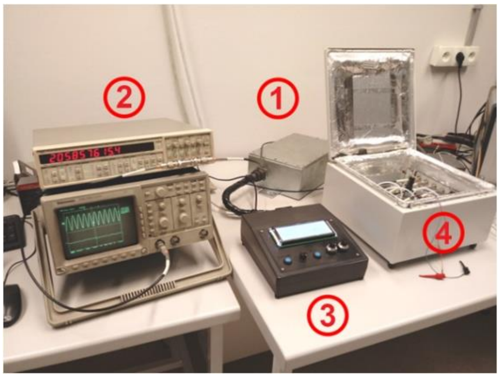

Fig. 3. Measurement system with a double temperature isolated chamber (4)

Description of the New Method or System

The reference frequency f0 corresponds to the acoustic path without the CuPc layer, while f is measured on the path coated with CuPc film. The frequency shift is defined as Δf=f-f0. Recorded columns were rescaled to obtain time, f, f0 and Δf in physical units. Scatter plotting was used to preserve transient details. The channels f and f0 were displayed as mean-deviation traces (kHz) for readability, and air flow stages were annotated by Q labels placed below thedata region to avoid overlap with measurement points. The dew point dp = −19.9°C was converted to RH using the measured temperature and reported as a concise figure annotation.

Results

The combined plotof f, f0 and Δf versus time (Fig. 4) reveals characteristic signatures correlated with air flow steps. The dedicated Δf(t) scatterplot (Fig. 5) highlights step-dependent transients and plateaus for Q = 25-1250 ml/min at RH ≈ 5.4%. A summary bar chart (Fig. 6) shows an overall increasing trend of Δf with increasing Q.The sensitivity, estimated from the slope of the $\Delta f(Q)$curve for Q=25-1250ml/min, was S≈ 0,00531 Hz/(ml/min) (≈ 5.31 Hz/(L/min)), with local variations due to nonlinear response [2].

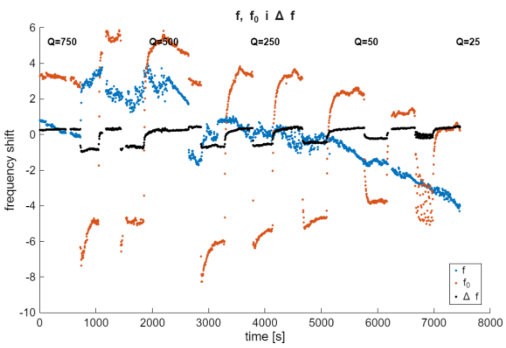

Fig. 4. Scatterplotof f, f0 and Δf (mean deviations) versus time with air flow stage labels Q.

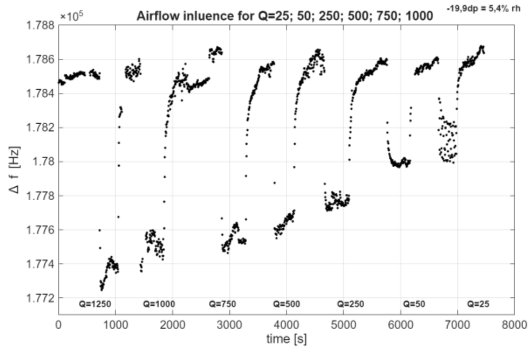

Fig. 5. Frequency shift Δf versus time with air flow labels Q and humidity condition (dp = −19.9°C, RH ≈ 5.4%).

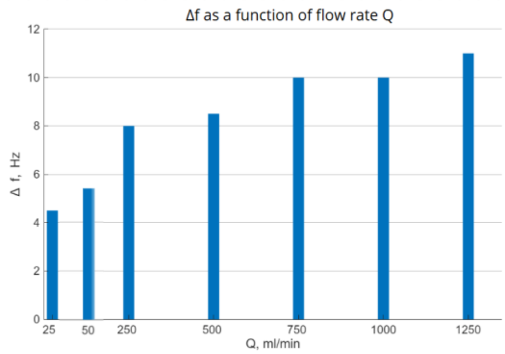

Fig. 6. Mean Δf as a function of air flow rate Q (ml/min) summarized as a bar chart.

Conclusion

A step wise dry-air flow experiment (Q = 25–1250 ml/min) performed at a fixed low dew point (dp = −19.9°C, RH ≈ 5.4%) demonstratedthat the SAW frequency shift Δf exhibits clear, repeat able responses to changes in flow rate. Scatter based visualization preserved transient behavior after each air flow step and revealed quasi steady plateaus that enable reliable extraction of mean Δf values. The summarized results indicate an overall increase of Δf with increasing Q, suggesting that enhanced convective transport and modified near-surface boundary-layer conditions measurably affect the SAW response even under low constant humidity.

References

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