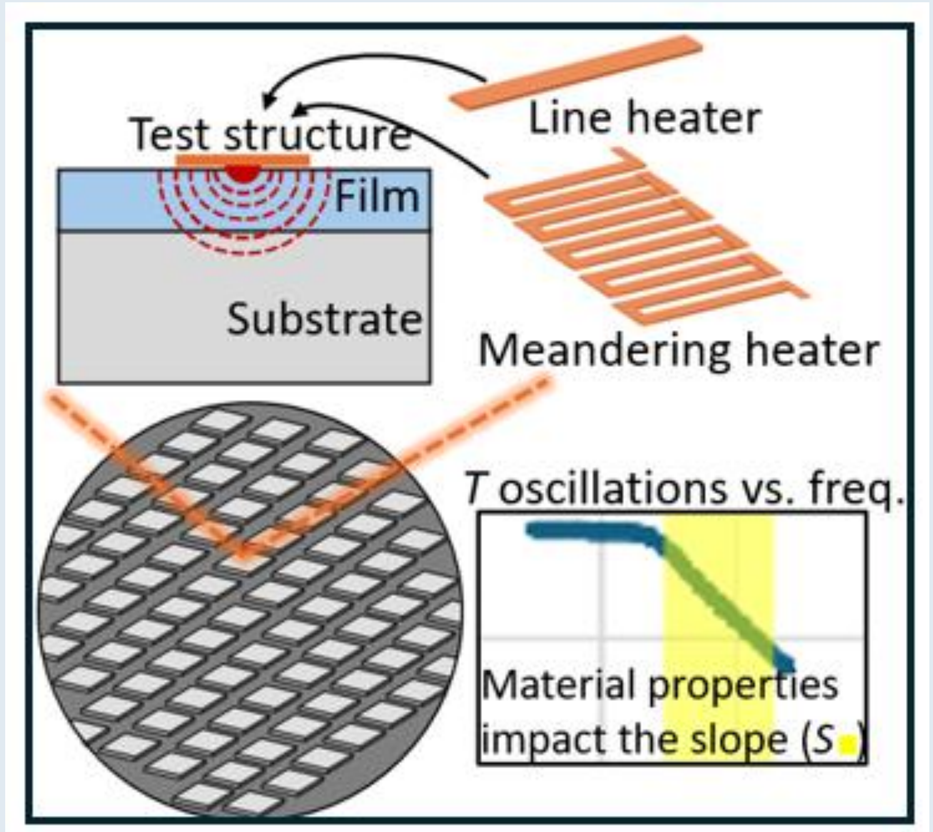
3ω-method in Production Flow for Thermal Flow Sensors



In the EFRO OOST Meteorite II research project we develop the test insertions, serving as process control monitors of wafers quality after front-end production. Specifically, we target the thermal properties of the sensor's material stack.

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Introduction

As a part of MEMS, the thermal flow sensors are produced on wafers, sawn into individual chips, assembled into modules and, at the end, the product is tested. Due to high customization of products, there are no common tests to be ‘inserted’ into the production flow at earlier stages. For some products, this results in low yield.

The performance of the flow meter, i.e., penetration and diffusion of the thermal wave, is governed by the material properties that are sensitive to variations in the fabrication process (conditions). We develop the test insertions, the test structures and the methodology, to assess the product quality by measuring thermal properties on a wafer.

Methodology

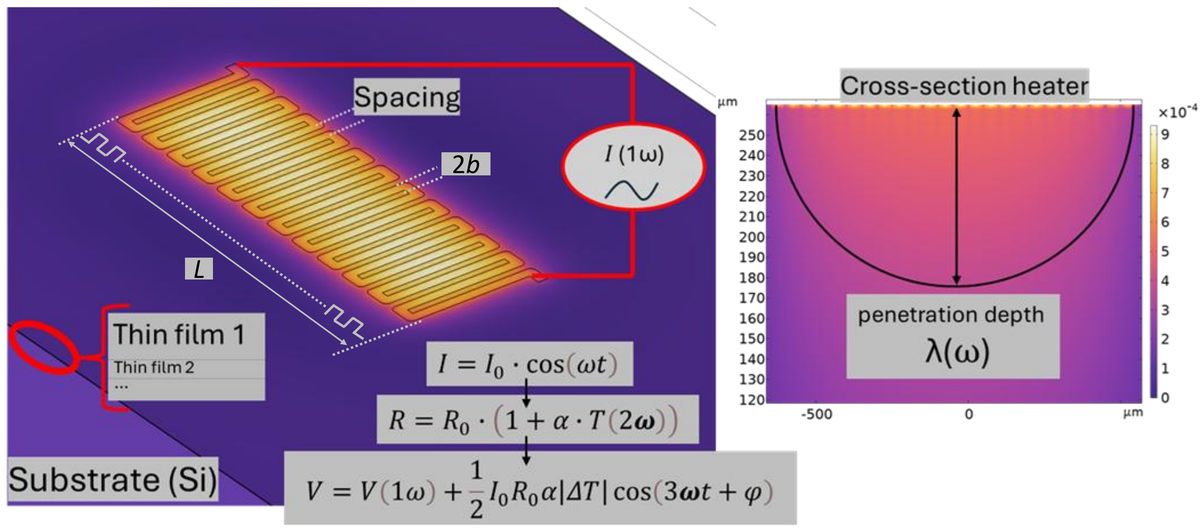

Figure 1. Cross-section of meander heater on top of the thin film and substrate.

For the test insertions, we use the 3-omega method, in which conductive structures with a positive Temperature Coefficient of Resistance (TCR) are deposited on a wafer.

The slope method [1] uses the real part of ΔT and the heater frequency, where the slope (S) relates to thermal conductivity.

$$k_{film} = \frac{P \cdot t_{film}}{2bL} \left[\Delta T_{s+f} + 2S\right]^{-1}_{Average}$$

In the differential method [2], the thermal conductivity is calculated using the average temperature rise difference between 2 material stacks; the initial one with the targeted thin film, and the reference one without it.

$$k_{film} = \frac{P \cdot t_{film}}{2bL} \left[\Delta T_{initial} - \Delta T_{reference}\right]^{-1}_{Average}$$

Results

The performed thermal analysis and FEM models proved that the geometry of the heater test structures are imperative in accurate determination of the thermal physical properties.

COMSOL® models have been developed for two types of heaters, line and meandering, and depending on the material stack, the optimal geometries have been determined based on the slope and differential 3-omega methods.

Wafers with the corresponding material stacks and heating structures have been fabricated, and the proposed test insertion methodology is being validated by 3-omega experiments.

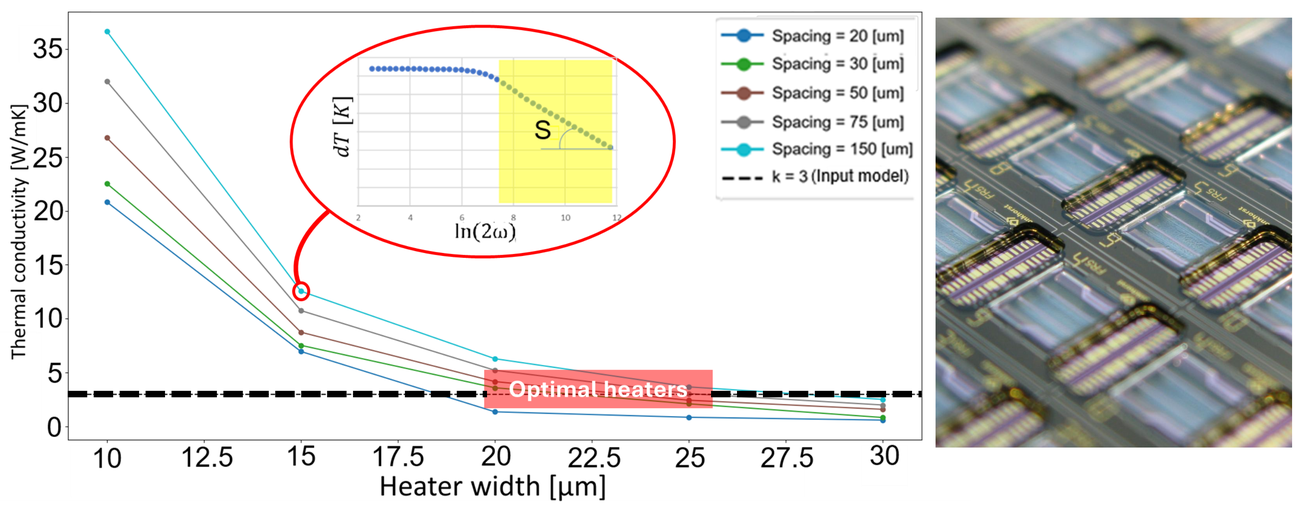

Figure 2. Calculated thermal conductivity of SiRN (1um) using the slope method for various meandering heaters. Each point is a result of a separate model, where the slope is determined as shown in the insert. On the right the fabricated chips with the chosen test structures are shown.

REFERENCES

[1] 3-omega Slope method: T. Borca-Tasciuc et al., Data reduction in 3ω method for thin-film thermal conductivity determination, Review of Scientific Instruments 72, 2139 (2001).
[2] 3-omega Differential method: J. Alvarez-Quintana, J Rodriguez-Viejo, Extension of the 3ω method to measure the thermal conductivity of thin films without a reference sample, Sensors and Actuators A 142 (2008) 232–236.

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