Prototype 7:
Device C2TOP

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Derived from Atomic Force Microscopy, Scanning Thermal Microscopy (SThM) has become a major tool for investigating heat transport of materials at very low scales. Depending on the probe used most of the SThM techniques are able to operate in two complementary modes, either in passive mode for surface temperature measurements [1], or in active mode for thermal parameters estimation (thermal conductivity or diffusivity typically) [2]. However calibration procedures and adapted tools still have to be developed before considering SThM as a quantitative method.

In passive mode, calibration samples must be able to provide a homogenous local controlled hot area with the reference temperature accessible, on which a probe can land. The goal is to compare the probe temperature to the actual surface temperature of the contact area, and eventually estimate the perturbation heat power generated by the probe.

SThM calibration measurements have previously been performed using standard micro-hotplates not specifically designed for that purpose [3]. These hotplates had a large heated area and their surface temperature was not directly accessible. Moreover, the perturbation heat power sensitivity was limited by the large amount of Joule power required for heating the device (70 mW required to reach 500°C).

Based on these previous results, the new designs developed in Quantiheat exhibit low-power consumption and uniform circular temperature distribution over the SThM contact area (see Figure 1). The minimization of the power consumption is crucial for increasing the thermal sensitivity (13 mW required to reach 500°C).

Device Specifications

The calibration chips are made of a platinum heater, with an area of 50x50 μm^2 sandwiched in a suspended silicon nitride membrane. Chips are equipped with a resistive temperature detector (RTD) and a SThM contact area of 10x10 μm^2, as shown in Figure 1.

The RTD sensor has a 4 terminal contact patterned locally and centered on top of the heating area. It provides the mean actual surface contact temperature after conversion using a calibrated Temperature of Coefficient Resistance (TCR) of 0.00185 K^{-1}.

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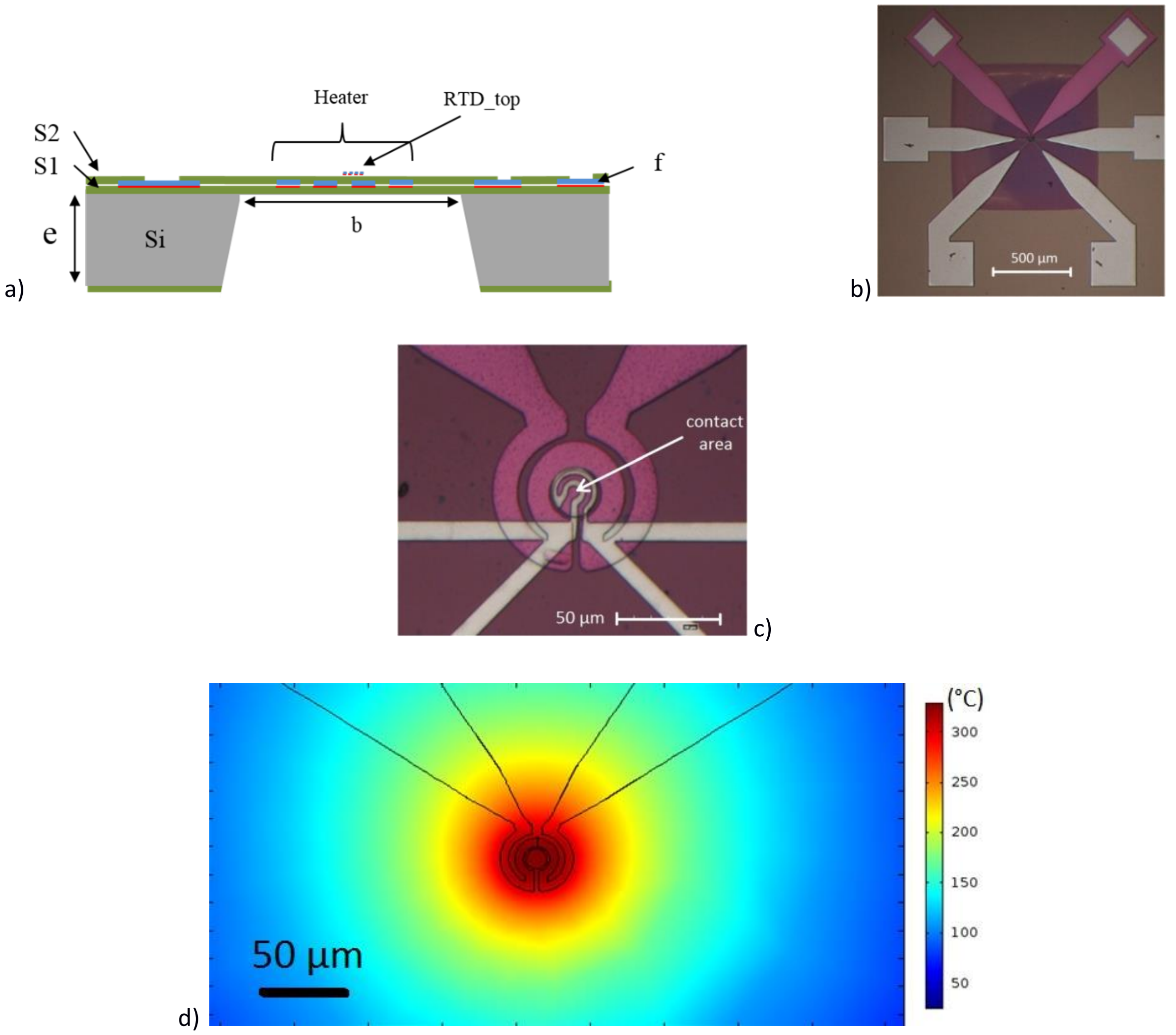

Figure 1: Design of calibration chips with heating area of 50x50 µm^2 and contact area of 10 x 10 µm^2: a) side-view of the design; b) top-view of the full chip; c) zoom on the RTD sensor; d) FEM simulation of the temperature distribution.

Table 1: Parameters of device C2.

	Materials	**Thickness**	**Main dimension**	**Resistor value**
Top metal RTD	Ta + Pt	d=10 nm + 140 nm	a = 10x10 µm^2	50-70 Ω
Membrane	SiN (layer S1) + SiN LP (layer S2)	S1 = 200 nm S2 = 400 nm	b = 1 mm Square bxb mm^2	
Heater	Ta + Pt	f=15 nm + 135 nm	c= 50 µm	90-250 Ω
Substrate	Si	e=390 µm	-	-

Applications

- SThM Probe calibration and evaluation.
- Surface temperature calibration tool without lateral gradient (thermally homogeneous testing area).
- Low power consumption and large temperature range (from ambient to 500°C).

Among the different tested designs, a combination of simulations and experiments allowed these calibration devices to be significantly improved [4, 5].

Results depicted in Figure 1 clearly show the effect of the probe thermal perturbation that can be quantified using a specific factor: $\boldsymbol{\tau} = \frac{\boldsymbol{T_p - T_a}}{\boldsymbol{T_s - T_a}}$

In this factor, T_s is the RTD surface temperature before contact; T_p is the temperature provided by the SThM probe and T_a is the ambient temperature. Such a factor is one of the most significant parameters that characterize temperature probe efficiency and can be used to correct measured temperature values. In the case of Figure 1, the resulting mean value of τ gives 0.6 [3-5]. It would be of great interest to test other SThM probes in the same configuration.

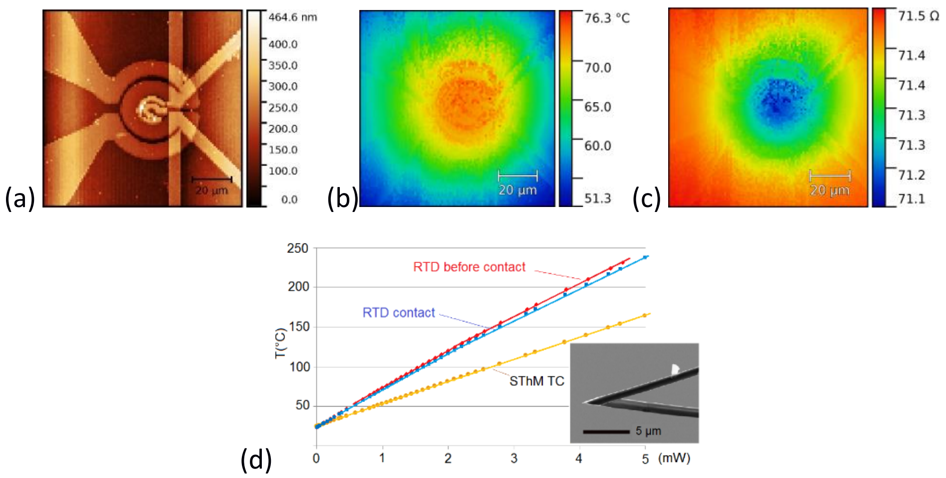

Figure 1 Measurement results obtained with a thermocouple SThM probe: a) topography; b) probe temperature; RTD values; comparison between probe temperature (T_p) and T_s (RTD) before and during contact versus input power.

In addition to this factor, a comparison between T_s before and during contact gives a direct indication to the thermal perturbation of the probe.

References

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