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A NOVEL STRUCTURE AND EXPERIMENTAL PROCEDURE FOR NANOCALORIMETRY

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Calorimetry is the process of quantifying internal energy changes as a result of temperature changes, in which enthalpy is a measure of the internal energy. Differential calorimetry has been around for about half a century and has been primarily adopted to eliminate the unknown sources of heat losses from the "test" structure by introducing a "reference" structure, e.g. [1]. Over the past decade, the need for small-scale measurements have led to the development of MEMS based differential calorimetry techniques, e.g. [2], which is an ideal platform to satisfy the requirements for fabrication of identical "reference" and "test" structures. However, one should be cautious that the "identical" geometry and dimension are only the required but not necessarily the sufficient condition, in this approach. Indeed, the necessary and sufficient condition to achieve the highest resolution and accuracy is for the "test" and "reference" structures to have identical thermal "footprint" and "behavior".

In this manuscript, we propose a single microfabricated suspended bridge and a procedure that eliminate the need for differential calorimetry. As a proof of concept, we have developed a model for melting process of a "tin" suspended structure that includes a patterned metal bridge heater and sensor, an insulation layer and a tin specimen (Fig. 1). The setup is primarily based on electrical resistance heating and thermometry and parametric estimation method by solving the heat conduction equation with phase transformation. When the temperature of the material exceeds the phase-transition temperature, additional energy is required to rearrange the bonds between the molecules of the material, which exhibits slope change of the temperature rise and can be captured by parameter fitting method. The calculated results include latent heat of the specimen and heat capacity of the sample bridge. With a priori knowledge of the specific heat of the heater and the insulator, this structure can be also used to obtain the specific heat of the specimen, thereby, eliminate the requirement for the "reference" structure.

For the structure illustrated in Fig. 1, and combined with the approximated latent heat of the specimen as illustrated in Fig. 2, the transient response of the bridge was numerically simulated using MathCad. The simulation results shown in Fig. 3 indicate that the proposed setup and procedure is capable of resolving ~0.1 K temperature rise, that yields nearly an order of

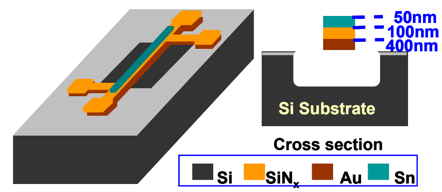

Figure 1: Schematic view of single structure

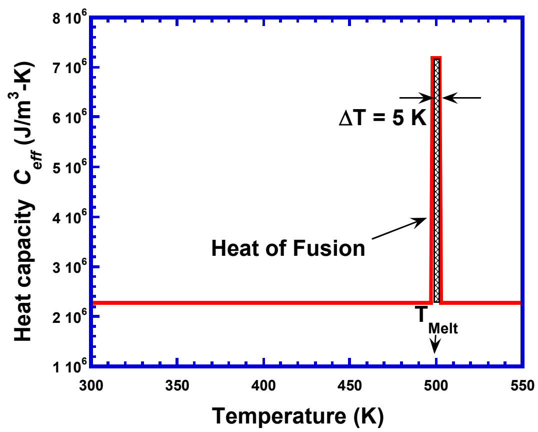

Figure 2: Heat Capacity of the specimen.

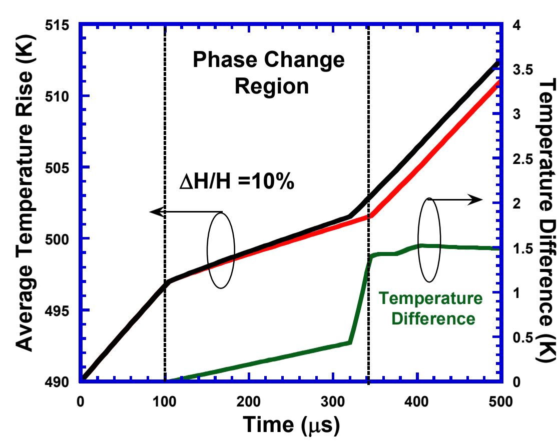

Figure 3: Sensitivity analysis for single structure.

magnitude improvement in sensitivity and accuracy in the estimation of latent heat compared to the “differential” calorimetry technique.

References

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