Development and optimization of a
novel miniaturized ceramic differential scanning calorimeter

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Differential scanning calorimetry (DSC) is widely-used to analyze thermodynamic material properties. However, materials that form aggressive or corrosive reaction products cannot be easily analyzed with conventional DSC devices, since they contaminate or damage these highly complex and cost-intensive apparatuses. Moreover, classical DSC devices are designed as stationary table top units and therefore are not suitable for mobile usage.
To allow for mobile DSC applications and for the detection of aggressive materials, the objective of our work is to develop a low-cost miniaturized ceramic differential scanning calorimeter device that consists of only one single chip that includes all functional elements, i.e. crucible, sample and reference temperature sensors, heater, and reference. In this article, the development process of this miniaturized DSC chip is presented: Utilizing finite element method (FEM), the DSC chip was stepwise developed and optimized, leading to a well-functioning device of a size of only 11 mm x 39 mm x 1.2 mm (Fig. 1 a). In the sensor head, crucible, sample and reference temperature sensors, heater, and reference are vertically integrated (Fig. 1 b). Due to its small size, the power consumption is below 2.5 W, enabling the user to run the sensor system via USB connection directly from a laptop (Fig. 1 c). The DSC chip is fully manufactured in Low Temperature Co-firing Ceramics (LTCC) Technology. The use of ceramics as substrate material ensures high temperature stability allowing for DSC analysis up to 650 °C with high heating rates up to 300 K/min. A calorimetric sensitivity of 0.24 W/K was found. Furthermore, resolution tests with Dotriacontane as test substance revealed a temperature resolution which is comparable to conventional devices.

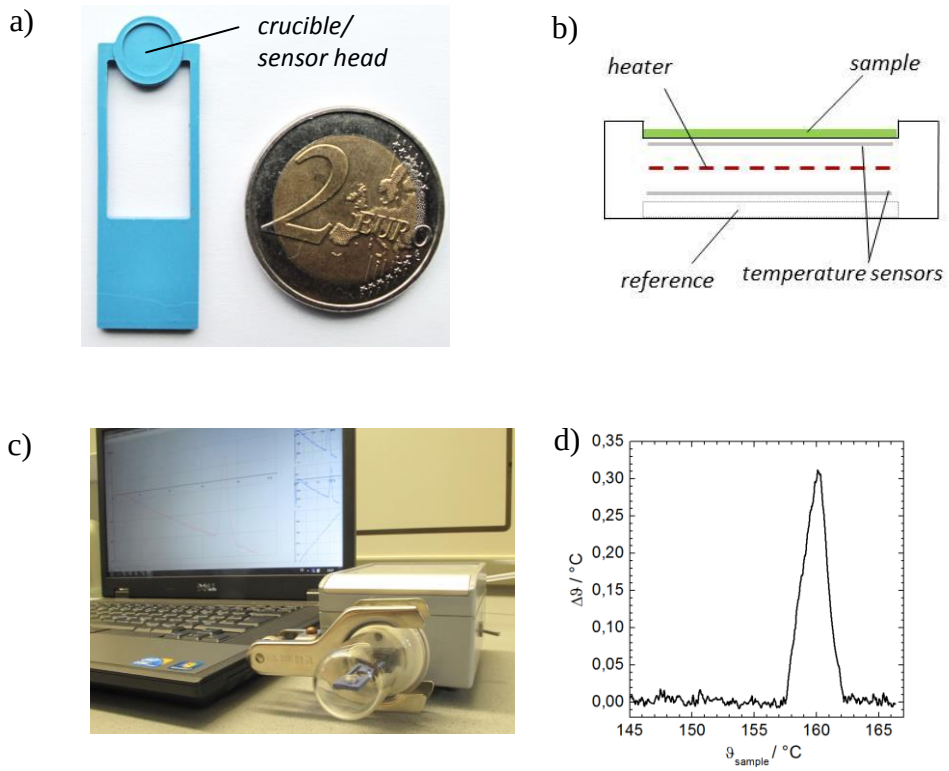

Fig. 1: a) latest version of the miniaturized DSC device, b) vertical arrangement of functional elements in the sensor head, c) DSC device connected to USB port of a laptop, d) measurement of Indium (35,23 mg).

References:

[1] W. Missal, J. Kita, E. Wappler, F. Bechtold, R. Moos, “Calorimetric sensitivity and thermal resolution of a novel miniaturized ceramic DSC chip in LTCC technology”, Thermochimica Acta 543 (2012) 142-149, doi: 10.1016/j.tca.2012.05.019

[2] W. Missal, J.Kita, E. Wappler, F. Gora, A. Kipka, T. Bartnitzek, F. Bechtold, D. Schabbel, B. Pawlowski, R. Moos, “Miniaturized ceramic differential scanning calorimeter with integrated oven and crucible in LTCC technology”, Sensors and Actuators A: Physical 172 (2011) 21-26, doi: 10.1016/j.sna.2011.01.025

[3] J. Kita, W. Missal, E. Wappler, F. Bechtold, R. Moos, “Development of a Miniaturized Ceramic Differential Calorimeter Device in LTCC Technology”, Journal of Ceramic Science and Technology 4 (2014) 137-144, doi: 10.4416/JCST2013-00008