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Abstract

Microcalorimetric measurement on a microfluidic chip in a thermally fluctuating environment

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Abstract: We show the suppression of fluctuating background temperatures on a microfluidic chip with an integrated differential heat flux sensing system for the measurement of bacterial growth through metabolic heat. In contrast to previous systems involving more controlled thermal environments and larger sensors and microfluidic channels, we expose a smaller chip with a smaller sensor to a thermally fluctuating environment without additional isolation. We demonstrate that, leveraging the differential sensing strategy, our system can detect bacterial growth in the exponential growth phase, despite the large environmental temperature fluctuations.

Keywords: Heat flux Measurement, Microfluidics; Microbiology

1. Introduction

Measuring the heat flux on a microfluidic platform allows monitoring exothermic reactions for investigations into cellular metabolic activity and changes. Previously, the exponential growth curve of a bacterial population has been measured in a thermally stable laboratory environment with temperature stabilization by a PMMA box and copper as thermal mass [1]. In this work, we explore the limits of the microcalorimetric measurements of a microfluidic chip in a thermally fluctuating environment without further thermal isolation.

2. Materials and Methods

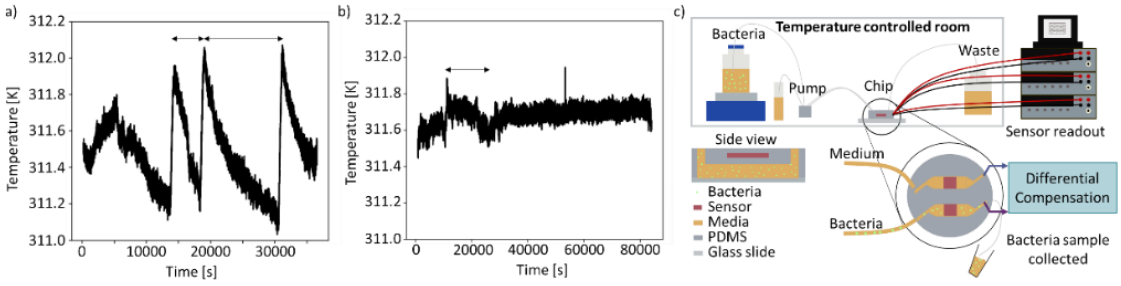

Figure 1. Temperature measurements in both the thermally less stable (a – **System 1**) and the thermally stable environment (b – **System 2**). The fluctuations in **System 1** are in the range of 1 K from 1.0 h to 3.3 h, whereas in **System 2** the range of temperature is 0.3 K over 4.2 h. The data shown is for the duration of the whole experiment. A schematic of the measurement setup is shown in c).

Two different experimental systems are analyzed in this work: **System 1** with higher thermal fluctuations as shown in Figure 1 a) is in a temperature-controlled room, whereas **System 2** is in an incubator with an additional PMMA box protecting the microfluidic chip. The latter shows less thermal fluctuations (see Figure 1 b). The microfluidic chip used in both experiments were fabricated by the same steps as discussed previously in [1], but with different dimensions as indicated in Table 1.

The temperature sensors (PT1000) in both experimental setups were placed in close proximity to the chip. The experimental setup with the integrated heat flux sensors in PDMS applies a differential compensation scheme using the data from the two microfluidic channels (control and bacterial).

3. Discussion

Figure 2 shows the differentially compensated heat flux measurements applying the data analysis approach as presented in literature [1]. Figure 2 a), b) and c) show the heat flux originating from bacteria metabolism (green) in comparison with Optical Density measurements (black). Figure 2 a) shows a small increase of the heat flux at the middle of the exponential growth of the bacteria (indicated by arrow), under the influence of a fluctuating environmental temperature in **System 1**. The larger spread in the heat flux values reflect the two different models of heat flux sensors used (gSKIN XM vs. gSKIN XP). Figure 2 b), shows the heat flux during exponential growth of the bacteria in the temperature-controlled environment, **System 2**. Figure 2 c) shows the clear exponential growth of the bacteria when comparing heat flux signal and the Optical Density.

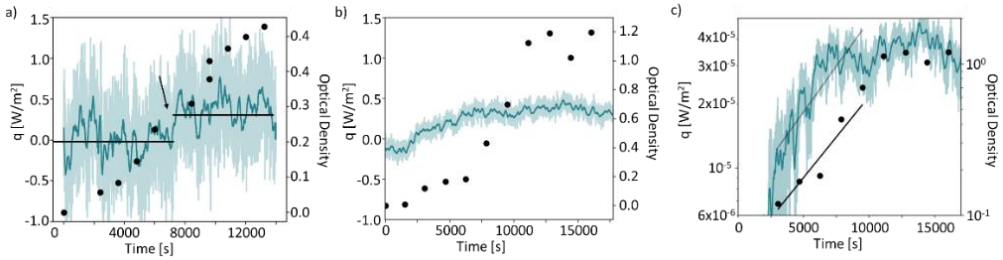

Figure 2. Differentially compensated heat flux measurements in the two differing systems. a) shows the data in **System 1**. A change in the heat flux is visible in the exponential growth phase (as indicated by the arrow). b) and c), **System 2**, show previously published data [1]. The data shown is the point at which the bacteria was added to the system (t = 0 s is the addition of bacteria). In all figures, the opaque data is the raw heat flux signal and the dark line shows a 200-point moving average.

Table 1 summarizes the achieved properties when comparing the performance of the two systems. We show that the differential set-up measures metabolic heat flux and suppresses the influence of large thermal fluctuations, and that the spread in heat flux values are mainly related to the sensor limitations.

Table 1. Table overview over system properties.

Property	System 1	System 2
Growth detection	Yes	Yes
Channel size (underneath sensor)	6 mm x 6 mm x 170 μm	12 mm x 12 mm x 320 μm
Sensor	gSKIN XM	gSKIN XP
Temperature fluctuation	1 K	0.3 K
Standard deviation heat flux	0.32 W/m²	0.05 W/m²

Conflicts of Interest: The authors declare no conflict of interest.

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