

## **A Disposable, Self-Contained PCR Chip**

Jitae Kim<sup>a</sup>, Doyoung Byun<sup>b</sup>, Michael G. Mauk<sup>a</sup>, and Haim H. Bau<sup>a, 1</sup>

<sup>a</sup> *Department of Mechanical Engineering and Applied Mechanics*

*University of Pennsylvania, Philadelphia, PA 19104-6315, USA*

<sup>b</sup> *Department of Aerospace and Information Engineering*

*Konkuk University, Seoul, 143-701, Rep. Korea*

### **Supplementary Materials**

#### **1. Videos: paraffin migration in a mock-up of the reactor (Hele-Shaw cell)**

- Video I: Paraffin layer initially deposited along the chamber's ceiling
- Video II: Paraffin layer initially deposited along the chamber's floor

#### **2. The chip fabrication and the reagent encapsulation processes**

The PCR chip (Fig. 1) was made with three layers of polycarbonate (PC) sheets. The 750 $\mu$ m-thick middle layer (II) was milled with a CNC machine (Haas Automation, Inc., Oxnard, CA) to create two reaction chambers, connecting conduits, and thermal-isolation grooves. Sheets I and III formed, respectively, the bottom and cap of the chip. Layer III contained the entry and exit ports for the introduction and removal of the sample.

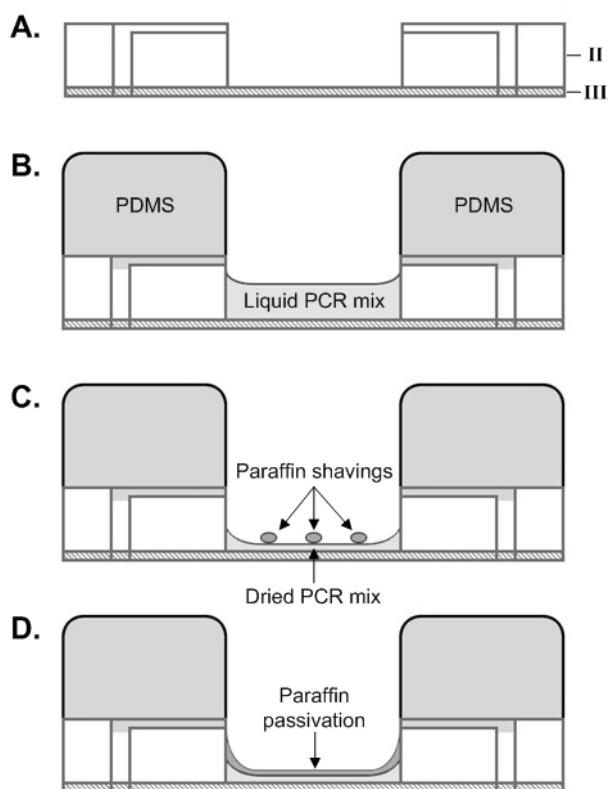
Sheets II and III were solvent-bonded at room temperature. To this end, the top sheet (III) was treated with oxygen plasma (Diener electronic, PA) for 3 min at 100W to enhance the solvent's wettability and improve surface coverage and bond quality. A thin layer of acetonitrile (Fisher Scientific) was applied to the middle layer (II). Then the top layer (III) was placed above

---

<sup>1</sup> Corresponding author: bau@seas.upenn.edu

the middle layer. Subsequently, an acrylic brayer was run over the two stacked layers to ensure a good seal between them.

Next, the PCR reagents were placed in the PCR chamber. The reagents' loading process is depicted schematically in Fig. S1. The as yet bottomless chip, consisting of layers II and III, was placed upside down (Fig. S1A), and a PDMS mold was placed on top of layer II (Fig. S1B). The mold is a negative replica of the conduits and, when in place, fits snugly into the conduits. The purpose of the PDMS mold is to prevent any wet reagents or paraffin from accidentally entering into the conduits or spreading along the surface of layer II during the loading process. The wet PCR reagents (see section 4 of the manuscript for details of the reagents' composition) were placed in one chamber and left to dry, resulting in the formation of a solid powder.



**Fig. S1:** *In situ* preparation of paraffin-encapsulated, dry reagents. (A) An uncapped chip turned upside down (B) Wet PCR reagents loaded and left to dry (C) Paraffin shavings placed on the dried reagents (D) Paraffin melting and subsequently coating the reagents.

Approximately 4mg of paraffin shavings (Ampliwax<sup>®</sup> PCR Gem 50, Roche, Switzerland) were placed on the dried reagent layer (Fig. S1C). The chip was then placed on a hot plate at 70 °C until the wax melted and coated the dry PCR reagents. When the chip was removed from the hot plate, the wax solidified, forming a protective layer (Fig. S1D). Finally, the bottom PC sheet (I) was connected to the chip, using room temperature solvent bonding similar to the bonding of layers II and III (Fig. S1A). Above, we described just one technique of encapsulating the reagents with paraffin. It is also possible to do the encapsulation outside the PCR chamber and introduce the encapsulated PCR pellet into the chamber.

### **3. The effect of thermal guards**

Thermal isolation, consisting of air gap chambers, is considered to be a simple and efficient means to diminish thermal crosstalk among the reaction chamber, the ambient, and the system's other components and to reduce the heating time of the PCR reactor.

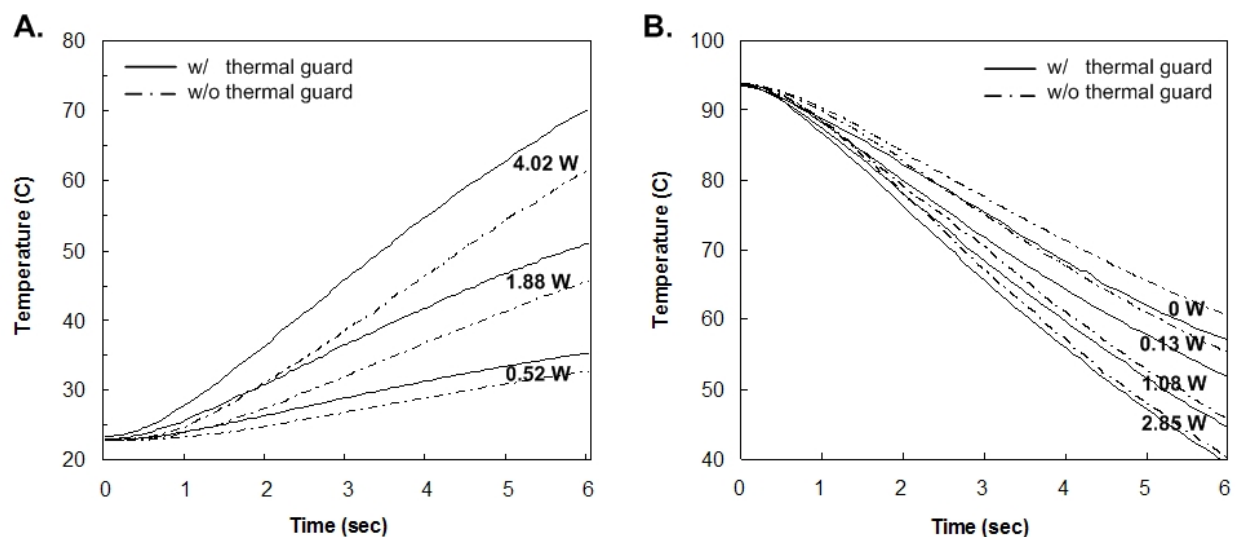
To evaluate the effect of the thermal guard, we fabricated two nearly identical PCR chips. One chip contained thermal guards surrounding the PCR reactor (see Fig. 1 in the manuscript), while the other did not (not shown). The thermal guard was 1 mm in width and 0.75 mm in depth and defined a discontinuous, rectangular frame with a footprint area of 12 mm × 13 mm, which matched the TEs' surface area.

Figs. S2A and S2B depict, respectively, the heating and cooling profiles of the PCR reactors with (solid lines) and without (dashed lines) thermal guards. The temperature was measured as a function of time with a thermocouple inserted inside the PCR chamber and positioned at the center of the chamber's floor. The various lines correspond to different power inputs to each TE

unit. Fig. S2A depicts the temperature as a function of time when the chamber is heated from room temperature using two TE units. Not surprisingly, the thermal guard reduces heat losses to the ambient and, therefore, the PCR reactor with the thermal guard (solid line) exhibits a faster temperature increase (by approximately 20%) than the reactor without the thermal guard.

Fig. S2B depicts the reactor's temperature as a function of time when the reactor is initially at 94 °C and the TEs operate in a cooling mode. When no power is applied, the PCR reactor with the thermal guard cools faster than the one without the heat guard, possibly by preventing heat flow from the heated part of the chip into the PCR chamber. When the power input to the TE units is increased (cooling mode), the thermal guards play little role since the heat removal through the TEs' surfaces dominates. At higher TE cooling powers, there is very little difference between the temperatures of the chips with and without the thermal guards.

The thermal guard is also beneficial for the operation of the control system as it reduces the effect of environmental temperature fluctuations on the PCR chamber.



**Fig. S2:** The effect of the thermal guards on the thermal response at various power inputs to the TE module. (A) The heating and (B) cooling profiles of the PCR chamber with (solid lines) and without (dashed lines) thermal guards