Temperature Sensor Characterization

The temperature sensor was first calibrated using an environmental test chamber (9023, Delta Design Inc., CA) maintained at a series of temperatures which are measured with high accuracy temperature reference probes (5628, Fluke Calibration, UT). The measured resistance (R) of the thin-film gold temperature sensor was observed to vary linearly with temperature (T). The dependence could be represented by the relationship $R=R_0[1+\alpha(T-T_0)]$, where R_0 is the sensor resistance at a reference temperature T_0, and α is the temperature coefficient of resistance (TCR) of the sensor. Fitting this relationship to the measurement data allowed determination of the parameter values, which were used to determine the chamber temperature from the measured sensor resistance during cell capture and release experiments. The temperature sensor typically had a measured resistance of 209.60 Ω at a reference temperature of 21.9 °C with a TCR of 2.58×10^{-3} 1/°C, as shown in Figure S1A. We then characterized the temperature control of the chamber through which D-PBS buffer was continuously infused to simulate the cell capture or release process. The chamber temperature, controlled in closed loop by the integrated heaters via feedback from the temperature sensor, was seen to increase from room temperature (~24 °C) to 48 °C rapidly (with an approximate closed loop time constant of 2.7 s based on an exponential fit) while exhibiting a minimal overshoot (~ 0.2 °C) (Figure S1B). The temperature remained within approximately 0.1 °C of the desired temperature setpoint for the duration of each experiment, as shown in the inset of Figure S1B.

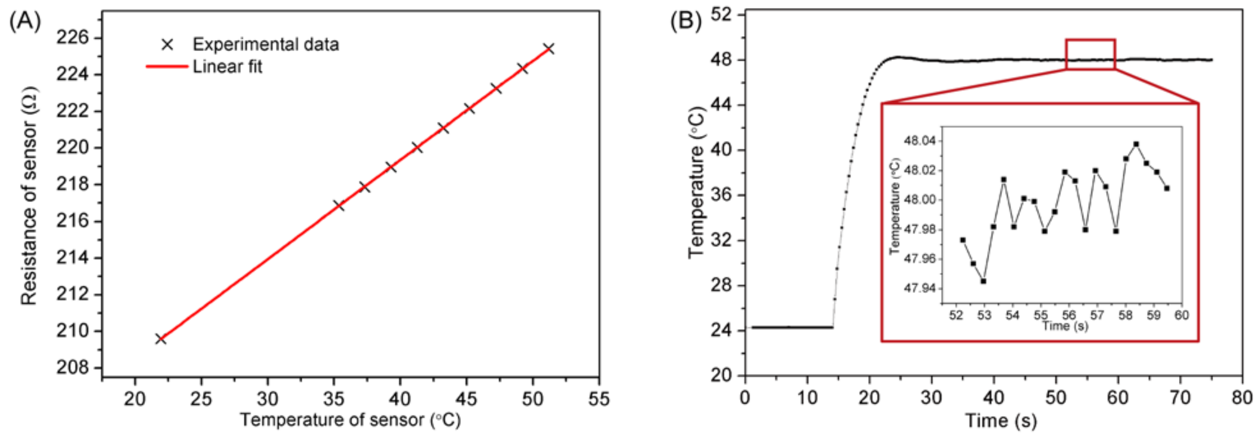

Figure S1. (A) Resistance of temperature sensor (*R*) showing highly linear dependence on temperature (*T*). The solid line represents a linear fit to the experimental data with a regression equation: $R = 209.6\,[1 + 2.58\times10^{-3}\,(T\text{-}21.9)]$ (coefficient of determination R^2=0.999). (B) Time-resolved tracking of the temperature inside the D-PBS filled chamber, with the inset showing noise that was present during temperature measurements.

Simulation of Temperature Distribution

To evaluate the uniformity of the temperature distribution in the chamber, we present results from numerical simulation using a three-dimensional steady-state heat transfer model.[1] The model considers heat conduction in the solid materials as well as forced convection due to the buffer flow (flow rate: 5 μL/min), with natural convection neglected. Properties at room temperature are used for the solid materials, and the property of the aqueous buffer is evaluated at the average temperature (36 °C) over the range (24 °C to 48 °C) used in the experiments. The model includes the Pyrex glass substrate (thermal conductivity: 1.3 W/m·K), gold heaters (thermal conductivity: 317 W/m·K), a PDMS membrane (thermal conductivity: 0.16 W/m·K) above the SiO_2 electrical passivation layer, liquid buffer in the chamber (thermal conductivity 0.62 W/m·K), and PDMS sheet (thermal conductivity: 0.16 W/m·K), with the SiO_2 passivation layer neglected due to its small thickness (< 1 μm). The model is solved using the COMSOL Multiphysics software package (COMSOL, Inc., CA).

The temperature distribution in the chamber at a flow rate of 5 μL/min is shown in Figure S2. It can be seen that the temperature throughout the chamber was quite uniform, thanks to the heater design, which has a relatively large size with respect to that of the chamber. The temperature variation is less than 0.03 °C on the lower chamber surface, to which aptamer molecules are immobilized (Figure S2A), as well as *xz*-plane of symmetry inside the chamber (Figure S2B). There is approximately a 0.2 °C difference between the temperatures on the lower chamber surface and on the substrate surface where the temperature sensor is located. This temperature difference is insignificant compared to the magnitude of temperature changes used in thermally activated cell release, and if desired, could be used as a correction value because of the more uniform in-plane temperature distributions. Based on this numerical analysis, it is concluded that the temperature distribution generated by the on-chip heaters is sufficiently uniform in the chamber for the cell capture and release experiments.

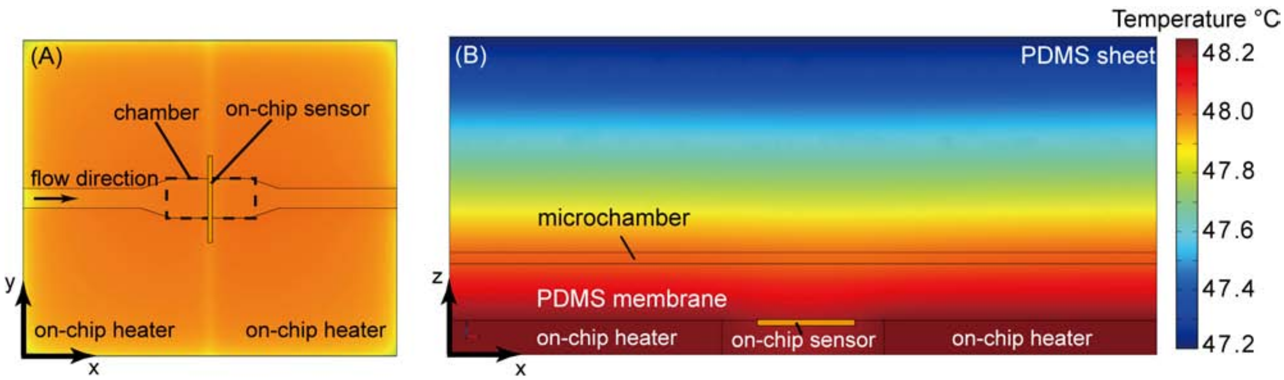

Figure S2. Numerically determined temperature distribution in the chamber within (A) *xy*-plane on the lower surface of the chamber and (b) xz-plane of symmetry.

1. Q. Lin, F. K. Jiang, X. Q. Wang, Y. Xu, Z. G. Han, Y. C. Tai, J. Lew and C. M. Ho, *Journal of Micromechanics and Microengineering*, 2004, **14**, 1640-1649.