# Thermoelectric microfluidic valves for enabling portable liquid handling

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Spectrum

## Need

Over the past few years, the life science industry has grown more focused on building increasingly automated and portable technologies. These two goals are often mutually exclusive, as fully automated devices have large footprints and high logistical constraints while highly portable devices are limited to simple reactions. This tradeoff exists because of limitations in the ability to dispense, route, and manipulate specific volumes of liquids at desired time intervals. This is especially evident for next generation sequencing (NGS) technologies. Most sequencers are quite large, and the portability of recently developed smaller devices is substantially hindered by the need for manual, lab-based sample and library preparation.

## Our approach

We have developed a next-generation microfluidic valve that can provide highly complex liquid-handling in a portable, low-cost, and programmable electrofluidic device. Unlike currently available technologies, our approach uses electricity to control on-chip microfluidic valves, and thereby the movement of liquids, allowing the construction of programmable fluidic circuits that can autonomously execute complex liquid handling steps. This allows us to miniaturize and automate labor-intensive molecular assays without the logistics and environmental constraints traditionally associated with liquid-handling technologies. Starting with sample preparation, we are working on condensing and consolidating the manual and infrastructure-intensive aspects of the NGS workflow into an automated handheld device.

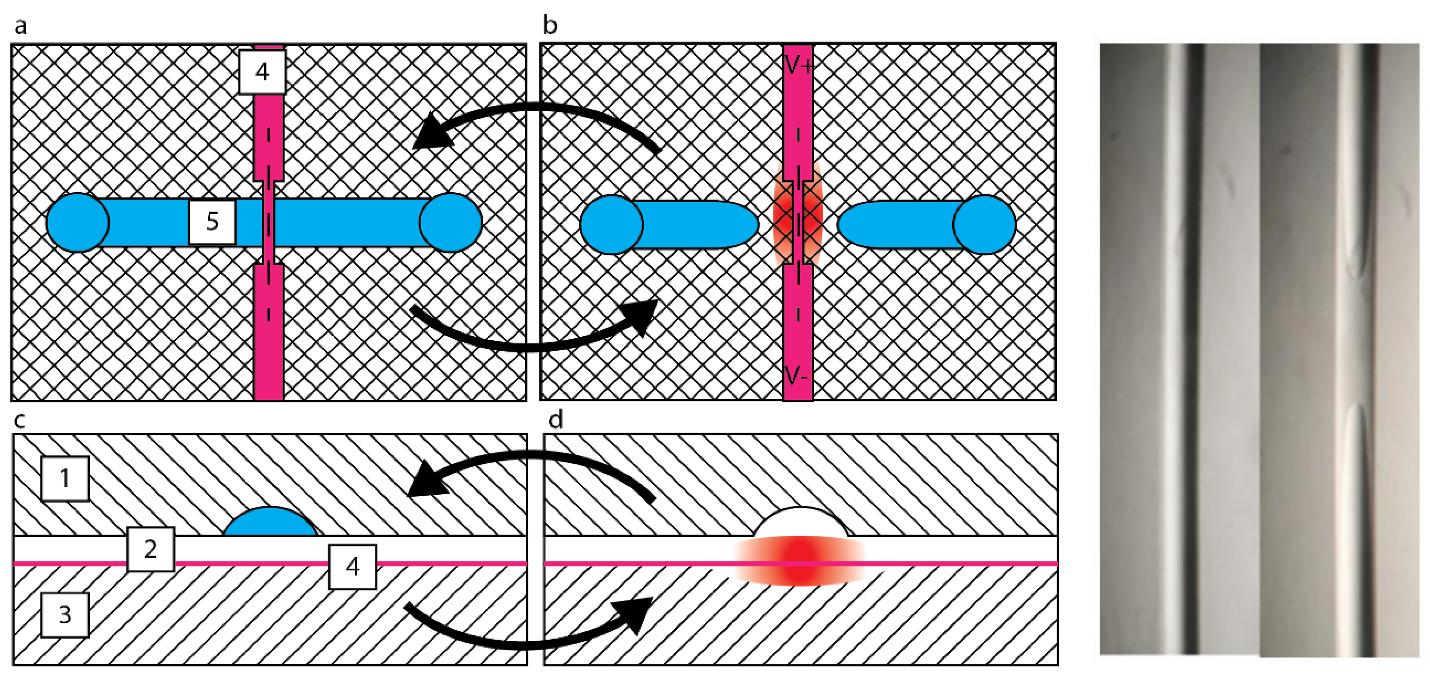


**FIGURE 1:** A thermoelectric microfluidic valve. Thermally actuated microfluidic valve. Numbered sections correspond to: 1) upper layer, more rigid than the middle layer 2) middle layer of thermally expansive elastomer 3) lower layer more rigid than the middle layer 4) thin coating of electrically conductive material 5) The microfluidic channel. Blue circles indicate ports through which the channel makes off-chip connections. a&b) Top down view of a valve. c&d) Cross sectional view of a valve along the dashed lines in a) and b) respectively. Valve is open in a,c, and the leftmost photo. Valve is closed in b,d, and the rightmost photo.

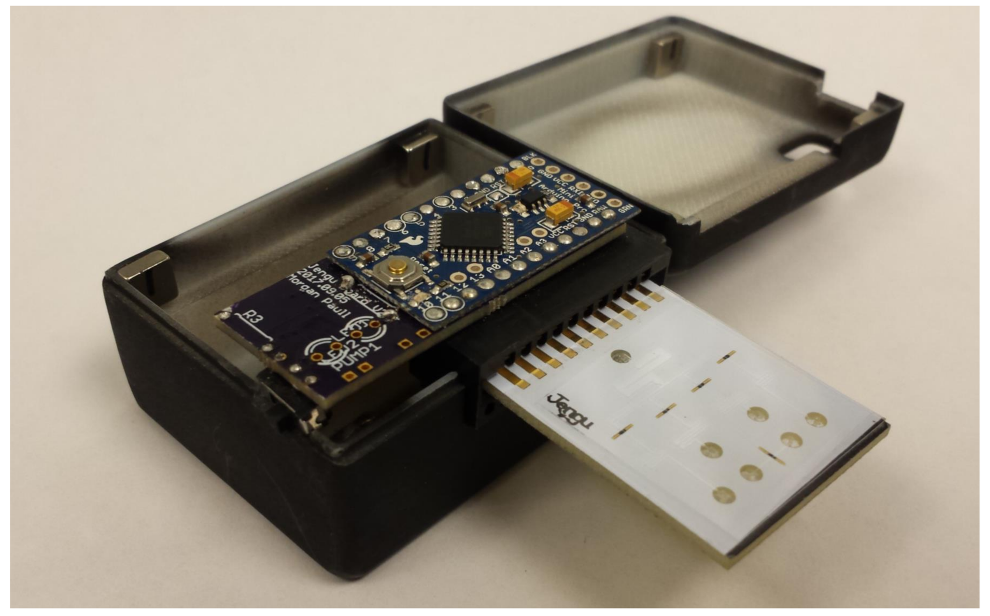

**FIGURE 4:** A portable chip controller. We used cheap and commercially available common electronics components to develop a portable controller that runs the microfluidic chips. Robust electrical contact is established with chips using a card edge connector. Open and closed states of each valve over time are determined by a program uploaded to an Arduino microcontroller. LEDs provide feedback on chip state. A simple lens and illumination system allows the user to visualize on-chip operations. The entire unit is powered by a 9 V battery.

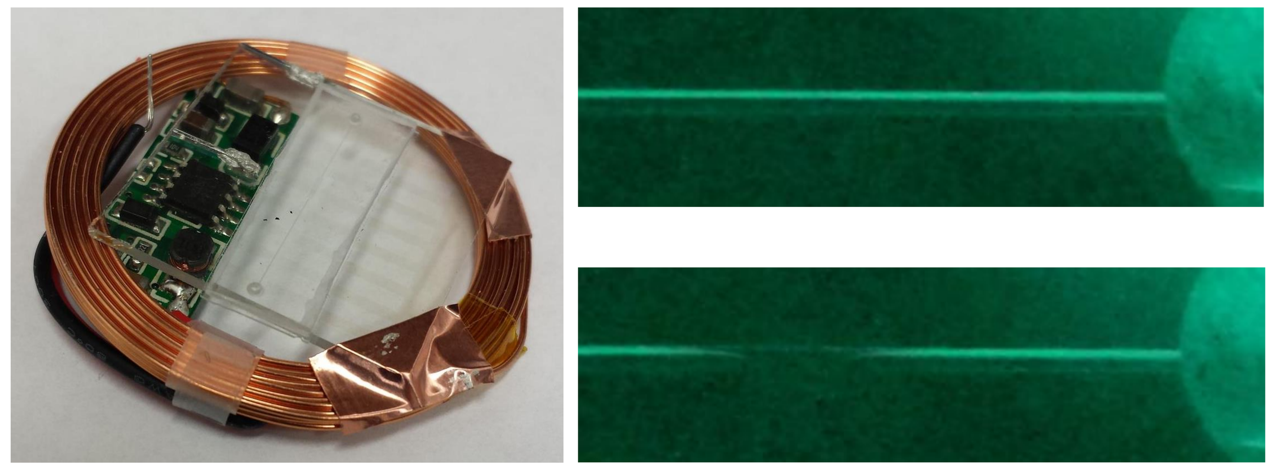

**FIGURE 5:** Alternative routes of actuation. Thermoelectric energy can be applied by means of Joule heating through wireless inductive coupling (left). Wireless valve control and powering allows for fluidic control with long term miniature devices in inaccessible locations, such as pumps internal to the body for medication delivery. Light can also be used to open and close valves. By spiking carbon black into the elastomer, we were able to apply local optothermal heating to actuate valves in arbitrary locations (right).

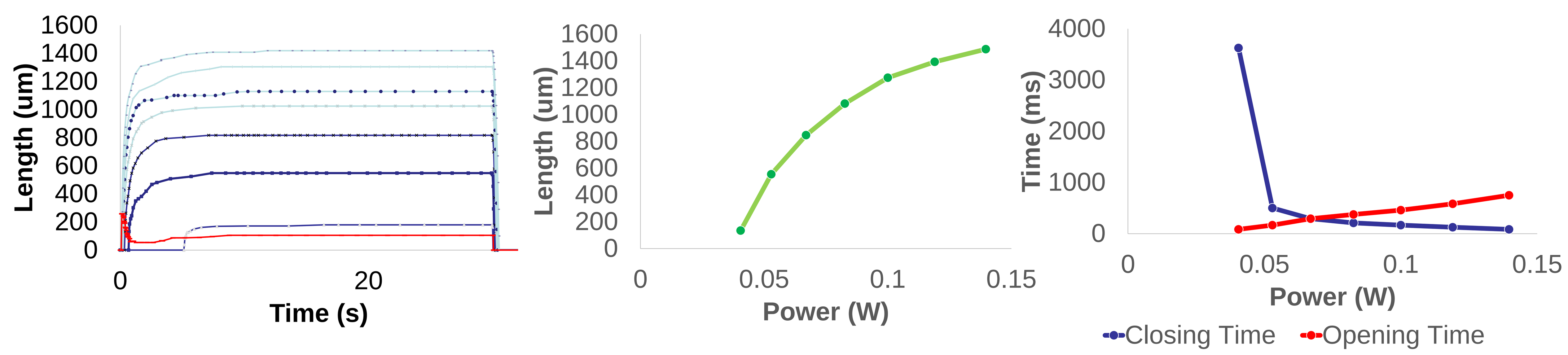


**FIGURE 2:** Valve performance. This data reflects a sample of the performance data we've collected now on over 100 different types of valves. In the leftmost plot the length of the closed section of valve is plotted over time. Power is applied to the valve from time 0 to 30 s, and seven different powers are shown in blue. This results in equilibrium closing lengths which increase with power. The closing times is the amount of time required to close the valve after power is applied, and decreases with power, while the opening time is the time required to open after power has been removed, and increases with power. Of course, modern electronics make combinations of these parameters possible, for example the red line shows a valve which opens and closes rapidly, and can be maintained shut with minimal power at minimal length, by applying a short higher power pulse, then maintaining closure at a lower energy.

**FIGURE 3:** Areas of impact


*Food safety, Aquaculture, Agriculture, Veterinary Medicine*

*Clinical medicine, Bioterror Surveillance, Public Health*

*At-home Diagnostics, Wearable Diagnostics, Implantable Diagnostics and Therapeutics*

## Translational Outlook

We've worked with the Stanford Office of Technology and Licensing to file a provisional patent, and will be following up with a full patent application in the following months. We've submitted a manuscript describing the technology and proof of concept applications.
Guided by Spectrum mentors, we've spent a year and a half thinking through all the aspects required for commercialization. We've spoken to numerous potential users, assessed the market landscape of multiple application areas, developed business models, and worked with manufacturers to scale up production. We graduated from the StartX Accelerator program in Fall of 2016. We are locking down technology partnerships with key industry players and are getting ready to raise a seed round.

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