LOW COST SMARTPHONE CONTROLLED DIGITAL MICROFLUIDIC CHIP IN A 3D-PRINTED MODULAR ASSEMBLY WITH REPLACABLE GLASS AND SCREEN PRINTED PAPER CHIPS

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ABSTRACT

This paper reports the development of an ultraportable, low-cost and modular digital microfluidic (DMF) system and its integration with a smartphone used as high-level controller and user interface. The smartphone in turn commands a microcontroller that generates the voltage signals required for droplet actuation in the DMF chip. Moreover, the smartphone camera is used for capturing the droplet motion, post processing and analyzing the droplet color changes to measure the droplet pH value. The holder assembly is fabricated using 3D printing technology to facilitate rapid prototyping where replaceable glass or paper chips can be inserted easily to the fabricated device.

KEYWORDS: Digital microfluidics, Rapid prototyping, Smartphone applications, 3D printing.

INTRODUCTION

One of the main challenges in developing portable and cost effective DMF systems is regarding the portability of the control modules, electrical connections and imaging systems. Recent advances in the hardware and software capabilities of smartphones creates an opportunity for development of these portable DMF systems [1]. On the other hand, to avoid cross contamination, and also to be used for different applications, the DMF chips must be easily replaced. To address these issues, 3D printing can be used to integrate the smart phones with replaceable and modular DMF systems. The low power rating of DMF systems allow for replacing the high power bench top equipment with high voltage, low cost and battery powered electronic circuitry. Although smartphones and 3D printing technology have been used for numerous continuous microfluidic applications [2], their use have not been explored for DMF applications. The modular 3D printed system reported here enhances the previous designs [3], [4] as it can be monitored and controlled by smartphones, and it is more compact, cost effective, rapidly prototyped and can perform image analysis where it does not require external microscope. Moreover, replaceable glass and low cost paper chips can be used in this device.

EXPERIMENTAL

Figure 1 shows the fabricated 3D printed and modular DMF platform assembly. The DMF chip frames are designed to be easily mounted and dis-mounted from the chip-to-board connection holder.

Figure 1: The proposed device design and implementation.

The main components of this system include holder assembly, battery powered high voltage electronic circuitry and a smart phone controlling the digital microfluidic operations via Bluetooth connection. The holder assembly is fabricated using a 3D printer. It has the necessary components including chip frame and spacer, electrical connection holders, batteries and phone holders. The main components of the electronic parts include portable power supply (battery), low power high voltage

amplifier, small and compact microcontroller, Bluetooth module for phone-to-microcontroller communication, high voltage switches and DMF chip-to-board connections. The measured total weight of this portable device is just 235 grams with total cost of 62 US $.

RESULTS AND DISCUSSION

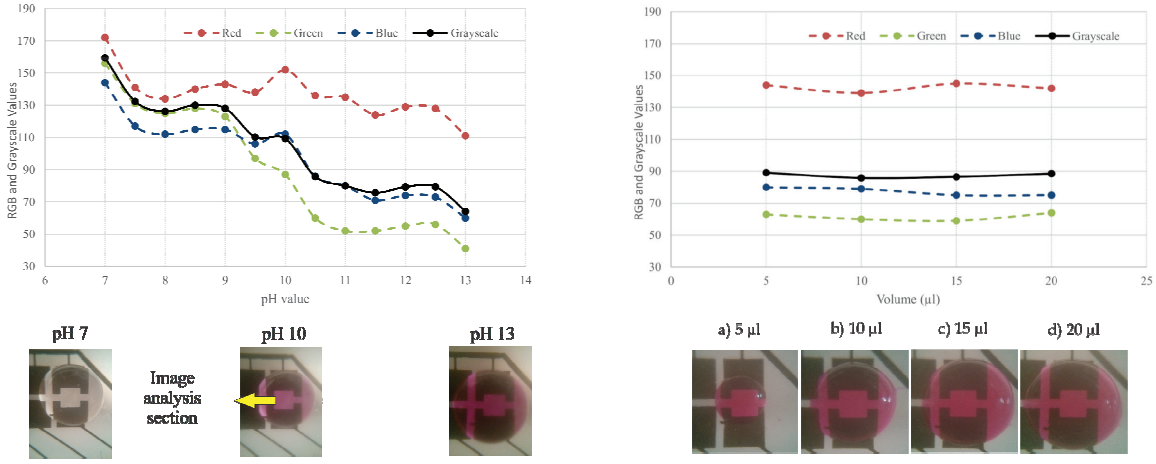

Figure 2: The change in the pH value measured by the smartphone camera.

The smartphone which is within the same size as the platform is used to monitor the system, take images and control the routing algorithm for droplet motion. Figure 2 demonstrates the capability of the device for measuring the pH value for a phenolphthalein solution. The volume of the droplet was changed from 5 to 20 µl. We found that the readings are independent of the droplet volume. Figure 3 shows the replaceable paper chips that can be used which are made from screen printed carbon and silver inks.

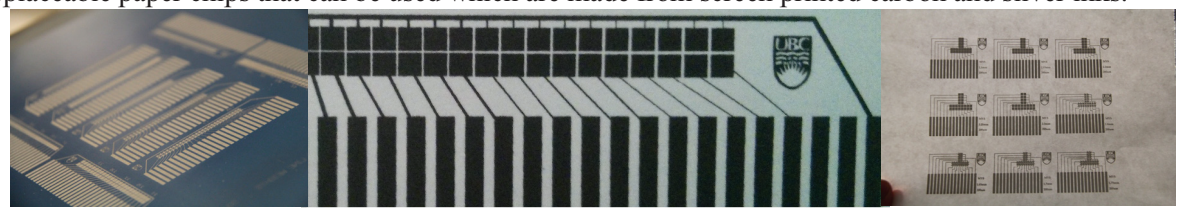

Figure 3: left to right: The screen printing mesh, screen printed DMF chip with carbon ink and silver ink.

CONCLUSION

The designed high voltage circuit generated the output voltage required for DMF operations. The device was able to measure the change in the pH value of the solution. Overall, the modular design, integration with smart phones, low (3D printing) fabrication cost and cost effective battery-powered electrical components extends the implementation of DMF technology to a wider range of applications.

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REFERENCES

[1] T. S. Park, W. Li, K. McCracken, and J. Yoon, “Smartphone quantifies Salmonella from paper microfluidics,” Lab Chip, vol. 13, no. 24, pp. 4832–4840., 2013.

[2] J. L. Erkal, A. Selimovic, B. C. Gross, S. Y. Lockwood, E. L. Walton, S. McNamara, R. S. Martin, and D. M. Spence, “3D printed microfluidic devices with integrated versatile and reusable electrodes.,” Lab Chip, vol. 14, no. 12, pp. 2023–32, Jun. 2014.

[3] J. Gong, S. Fan, and C. J. Kim, “Portable digital microfluidics platform with active but disposable lab-on-chip,” 17th IEEE Int. Conf. Micro Electro Mech. Syst., vol. 3, pp. 355–358, 2004.

[4] H. Kim, M. S. Bartsch, R. F. Renzi, J. He, J. L. Van de Vreugde, M. R. Claudnic, and K. D. Patel, “Automated digital microfluidic sample preparation for next-generation DNA sequencing.,” J. Lab. Autom., vol. 16, no. 6, pp. 405–14, Dec. 2011.

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