Indian Journal of Science and Technology, *Vol 11(36), DOI: 10.17485/ijst/2018/v11i36/96827, September 2018*
ISSN (Print): 0974-6846
ISSN (Online): 0974-5645

Design and Development of PDMS based Channel for Fluid Analysis

Prakash Rewatkar*, Suresh Balpande and Jayu Kalambe

Shri Ramdeobaba College of Engineering and Management, Nagpur – 440013, Maharashtra, India;
Frewatkarpp10@gmail.com, ssbalpande@gmail.com, jayukalambe@gmail.com

Abstract

Objectives: Design, fabrication and characterization of different shapes of PDMS based fluidic channels without clean room process to give the consumer an opportunity for detection of few common adulterants in milk. **Methods/Statistical Analysis:** The detail fabrication process of PDMS based microchannel and experimental analysis carried out for determination of adulteration in milk using colorimetric detection method is carried out. **Findings:** Recently there has been great deal of interest of polymer for fabrication of Microfludics devices. One of its great advantage is it does not required clean room process for prototyping of Microfludics chips. In this work we have fabricated and characterize different shapes of channels without clean room process. Experiments to detect Starch in the milk were carried out using the fabricated micro channel. Complete system including micro channel, ardruino microcontroller and TCS3200 colour sensor has been developed to detect the adulteration in milk. **Application/Improvements:** This system can provide a great platform for fluid analysis and biosensor applications.

Keywords: Adulterants, Ardruino Platform, Colorimetry, Microfludics, Molding, PDMS Polymer, MEMS

1. Introduction

Food is the primary need of human being which plays major sustaining role. The quality food is the need of an hour to stay healthy, live longer and sustain in worst environmental conditions. The lure of riches and general apathy towards mankind has led to adulterants being added to food from stones, brick powder, artificial colours, preservatives and harmful chemicals to enhance taste and look. Adulterated food lowers the quality which is injurious to health. Adulteration of food commonly defined as the addition or substation of any substances to or from food, so that the natural composition and the quality of food substance get affected, various adulterant present in the food, review regarding this is reported in the literature[1,2]. Recently there has been great deal of interest of polymer for fabrication of MEMS device. They are extensively used in the MEMS and Microfludics application. Polydimethylsiloxane called PDMS or dimethicone is a polymer widely used for the fabrication and prototyping of Microfludics chips. Apart from Microfludics, it is used as a food additive, in shampoos, and as an anti-foaming agent in beverages or in lubricating oils. One of its great advantage is it does not required clean room process for prototyping of Microfludics chips. In this work we have fabricated and characterize different shapes of channels without clean room process. In this paper detail fabrication process of PDMS and experimental analysis carried out for determination of adulteration in milk is presented.

For detection of this adulteration from food we have been designed PDMS material based channel. It is emerging materials in MEMS for manufacture it has most familiar material for the fast response and reasonable prototyping of microfluidics system[3,4]. It offers an appealing alternative platform to silicon and glass. Many polymers are available in marketplace such as Polystyrene (PS), Polycarbonate (PC), Polyvinyl Chloride (PVC), Cyclic Olefin Copolymer (COC), Polymethylmethacrylate

*Author for correspondence

(PMMA) and Polydimethylsiloxane (PDMS) for project the chips. So that Polydimethylsiloxane (PDMS) have most popular polymer today for reasons of easy fabrication, optical transparency, biocompatibility, robustness, insulating properties and lower Young's modulus. This incorporation of electronics with microfluidics devices forms a microfluidics system that provides the convenience feature and enables the use of portable application in Biochemical analysis, forensics, and drug delivery applications[5,6]. Along with this application there is also new application of this microfluidics device i.e. adulteration in food. This device developed quick test in adulteration in food to protect the household/small industries and common man in country against in food adulteration. The objective of this device to detect the common adulteration in food i.e. milk. Nowadays common adulteration in milk is starch, it has been added in milk to increase the SNR valve. For detection of starch from milk it required iodine solution by inserting milk and iodine solution from inlet of channel presence of starch can be detected. To detect adulteration in food we have designed different shapes of channels with PDMS material without clean room facilities. We have developed prototype of Microfludics system. Complete Automation system of Ardruino microcontroller and TCS3200 color sensor is also presented. The paper is organized is as follows, in section 2 Microfludics mechanics is discussed, material used for device fabrication and methodology is discussed in section 3 followed by experimental analysis which is discussed in section 4. The device can be automated using color sensors and Arduino board which is discussed in section 5 followed by conclusion.

2. Microfluidic Mechanics and Materials used for Device Fabrication

Microfludics refers to the behavior and of liquids constrained to volumes near the up range. It is multidisciplinary field with a wide variety of application the length scale of microfluidic device is smaller in magnitude than macroscopic flows. Typically, microfluidic systems are smaller, operate faster, and ultimately it decrease sample size as well as minimizing analysis time and increase automation these are the significant benefits while handling of fluids at the micro scale. Method to fabricate PDMS channel is discussed in the literature[7]. Such devices allow applications in many areas such as medicine, biology, chemistry and physics.

The Reynolds number is a necessary parameter considered in microfluidics:

Reynolds number: In fluid mechanics Reynolds number is used to check whether the flow is laminar or turbulent. It is a dimensionless quantity that is used to predict the flow of the fluid through a micro channel it is denoted by Re and is defined mathematically as[4]:

$$\mathrm{Re} = \frac{VavgL\rho}{\mu} \quad (1)$$

where,

V is the average velocity of the fluid (m/s),

ρ is the density of fluid(kg/m^3),

μ is the viscosity of fluid(kg/m·s),

L is the length or diameter of the fluid(m).

Re depends on material properties (density, viscosity), boundary conditions, the following materials used for fabrication of microfluidics channels are discussed in this section.

1. PET

PET polymer (Polyethylene Terephthalate) is best known as the clear plastic used for beverage containers. As a raw material, PET is globally recognized as a safe, non-toxic, strong, lightweight, flexible material and 100% recyclable. Two monomers modified ethylene glycol and purified terephthalic acids are combined to form the polymer called polyethylene terephthalate. This material was used to make mold of different shapes i.e. Y shape, serpentine

2. PDMS (C_2H_6OSi)n

It is a polymer widely used for the fabrication and prototyping of chips[8]. Depending on the size of monomers chain, the non-cross-linked PDMS may be in liquid or semi-solid form. The siloxane bonds enable to obtain a flexible polymer chain with a high level of viscoelasticity. It is a non-toxic and non-flammable material. It is also called dimethicone which is present in shampoos (as dimethicone makes hair shiny and slippery), food (antifoaming agent), lubricants, kinetic sand, and heat-resistant tiles. The most importantly, no clean room facilities are required to use PDMS materials.

3. Ferrous Sulphate ($FeCl_3$)

It is also called ferric chloride, is an industrial scale commodity chemical compound, with the formula $FeCl_3$ and with iron in the +3 oxidation state. When $FeCl_3$ dissolved in water, iron (III) chloride undergoes hydrolysis and gives off heat in an exothermic reaction[9].

$$FeCl_3 + Cu \; FeCl_2 + CuCl$$

$$FeCl_3 + CuCl \; FeCl_2 + CuCl_2$$

4. Methodology used for Fabrication of Channels

The methodology used for fabrication of mold of different shapes was carried out by different ways.

Method 1: In first method, we have designed and transferred different patterns of channel shapes to Printed Circuit Boards (PCB) and etch out.

Method 2: A novel technique has been used for designing mold using PET material.

The fabrication of microfluids channels includes two stages i.e. mold preparation and channel fabrication using mold.

Stage 1: Mold Preparation

It includes the designing of channel pattern and transfers to PCB and etches out desired channel pattern to make a mold. The following steps were used to prepare mold as shown as Figures 1 and 2.

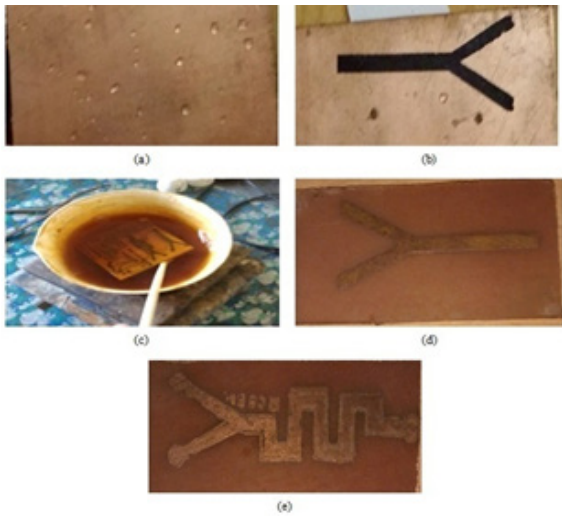

Figure 1. Mold preparation using PCB [a] Clean PCB, [b] channel patterning, [c] PCB Etching, [d] Remove the resist, [e] Desired channel mold.

- Cleaned PCB using acetone and IPA solution to remove all the dirt and grease Figure 1a
- Transferred different desired channel pattern on the PCB Figure 1b
- Etched for 10–15 minute in etching solution Figure 1c
- Removed the resist and left over is used as channel mold Figure 1d
- Channel design with two inlets and one outlet Figure 1e

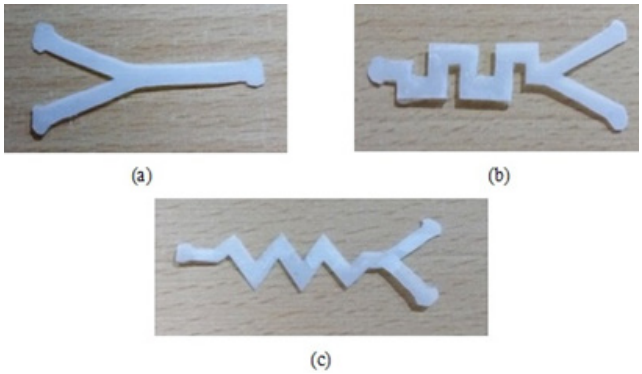

Figure 2. Mold preparation with PET [a] Y Shape, [b] Serpentine shape [c] Zig-Zag Shape.

Stage 2: Fabrication of Channels using PDMS Polymer

For fabrication of PDMS channel the following steps were used to fabricate micro channel

- PDMS and curing agent (ratio 10 : 1) were mixed up Figure 3a
- Desiccators used to remove air bubbles Figure 3b
- Adhered mold to petridish Figure 3c
- Poured PDMS in a petridish and again degassed to remove bubbles Figure 3d
- Heated for hardening the material for 15 minute at 70°C Figure 3e
- Pilled out the channel from petridish. Inlets provided for passing fluid and outlet for observation Figure 3f, g
- Bonded channels to glass strip For bonding purpose, 1–2 drops of PDMS solution coated on a glass strip using spin coater at 4500 rpm for 300[10] Figure 3h
- Heated devices for 15 minute at 70°C Figure 3I
- Fabricated different Shapes of channel i.e. Y, cerpentie and zig zag shape Figure 3 J, k, l

Figure 3. Fabrication process of different Shape channel with PDMS
[a] PDMS and curring agent [b] Desiccator [c] PDMS [d] Petidish in Desiccator [e] Hot plate [f] Pilled out the channel [g] Inlet and Outlet [h] Spin coater [i] Hot plate [j] Chanel [k][l] different shapes of channels.

3. Experimental Analysis

Food is essential for nourishment and sustenance of human life. Adulteration of food cheats the consumer which can pose serious risk to health. A common consumer may not have sufficient knowledge about purity and quality of food articles. With the help of microfluidics channels, one can detect adulteration quickly without using costly and sophisticated equipments or lab facility. Rice floor, arrowroot, wheat powder and starch are added to milk to increased SNF value. Use of starch is more hazardous to human health and hence an attempt has been made to detect it. For detection of starch from milk, we have used iodine solution prepared by following way 11, 12.

10 gm DI water + 1 gm iodine + 0.5 gm of potassium iodide

Our fabricated device has two inlets for passing the fluids and one outlet to analyze the results. One of the inlets used to pass few drops of milk solution and few drops of iodine solution passed from another inlet. The solutions got mixed at junction point, reaction took place and as an outcome solution became blue in color which indicates the presence of starch. The color shades reveals estimated % of adulterants mixed in milk.

The first experiment was carried out with pure milk and results are shown in Figure 4. It was found that colour of mixture was red which indicates purity of milk/ Adulterant free milk.

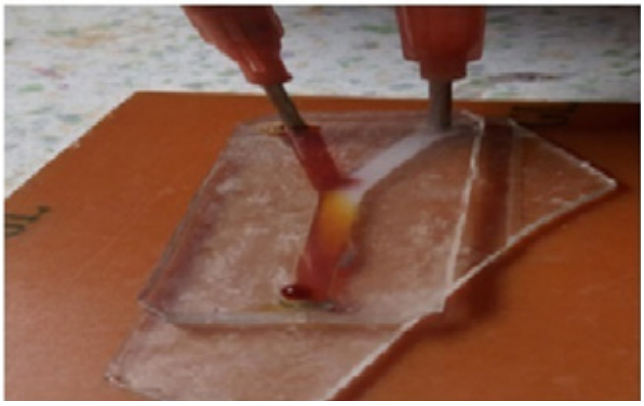

Figure 4. Experimental analysis of milk which is not adulterated.

In Figure 5, In this experiment, starch was mixed in pure milk and it is found that the color milk turned to violet blue which indicates the presence of starch i.e. milk is adulterated with starch.

The test setup includes fabricated channels, color sensor and controller is discussed in next section.

Figure 5. Experimental Analysis of milk which is adulterated with starch.

4. Test Setup

The experimentation on Y shape channel has been carried out. Syringes were used to pump milk solution and iodine solution from inlet ports and color observed at outlet port. For detection of color, we used TCS3200 RGB color sensor and interfaced with ardruino board. This arrangement was used to detect color and display results on serial monitor. The block schematic of tester is as shown in Figures 6, 7.

Figure 6. Block diagram of test Setup.

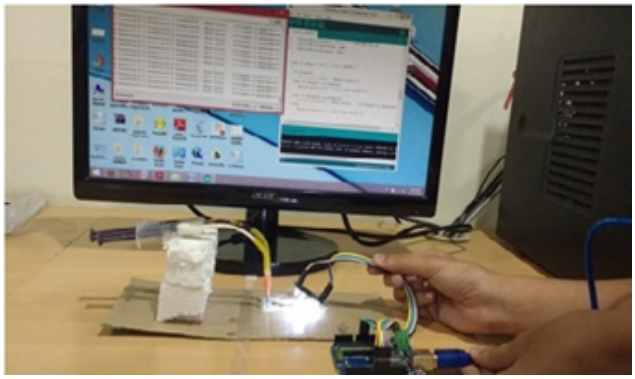

Figure 7. Test setup.

The color sensor scan color of the solution i.e. brown color for unadulterated milk and results are displayed on serial monitor in text form i.e. -Dark Red Colour ****"milk is unadulterated" as shown in Figure 8.

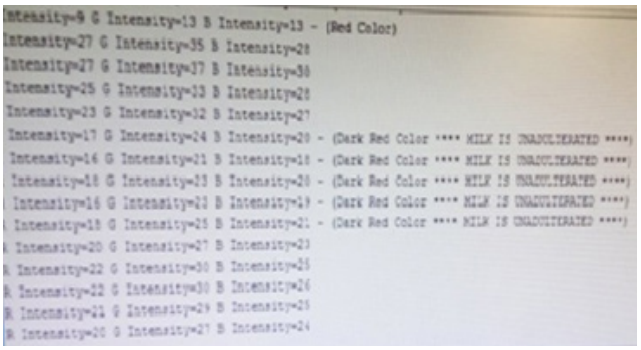

Figure 8. Serial monitor results (adulterant free milk).

If milk is adulterated, then color of the solution i.e. milk and iodine mixture turn to violet blue and message "Blue color*** milk is unadulterated" is displayed as shown in Figure 8.

5. Conclusion

In this work we have developed cost effective system for detection of adulteration in milk. We have designed different shapes of molds using PET sheet, PCB and fabricated channels. Fabrication of PDMS channels and system development for testing of adulterated milk is presented in this work. When milk and iodine solution mixed at equal proportion, formation of blue color indicates the presence of starch. Colorimetric detection method was used for adulteration detection. The shades of blue colour indicate presence of adulterant mixed in milk. The complete test setup was developed using fabricated PDMS channel, TCS3200 RGB color sensor and Ardruino microcontroller. This system can also be used for detecting different adulterant added in milk, fuel etc. This system can be extended with some modification for biosensor applications.

6. References

1. Abhirami S, Radha R. Detection of food adulteration in selected food items procured by homemaker. International Journal of Recent Scientific Research. 2015; 6(8):5938–43.
2. Gupta N, Panchal P. Extent of awareness and food adulteration detection in selected food items Purchased by Home Makers. Journal of Nutrition. 2009; 8:660–7.
3. Becker H, Locascio LE. Polymer microfluidic devices. Talanta. 2002; 56(2):267–87. https://doi.org/10.1016/S0039-9140(01)00594-X.
4. Anderson J, Danial T. Fabrication of topologically complex three-dimensional microfluidic systems in PDMS by Rapid Prototyping. Analytical Chemistry. 2000; 72(14):3158–64. https://doi.org/10.1021/ac9912294. PMid:10939381
5. Sia SK, Whitesides GM. Microfluidic devices fabricated in poly (dimethylsiloxane) for biological studies. Electrophoresis. 2003; 24(21):3563–76. https://doi.org/10.1002/elps.200305584. PMid:14613181
6. Kalambe PJ, Patrikar MR. Design of Microcantilever-Based Biosensor with Digital Feedback Control Circuit. Journal of Sensors. 2012; 2012:1–9.
7. Duffy DC, McDonald JC. Rapid prototyping of microfluidic systems in PDMS. Analytical Chemistry. 1998; 70(23):4974–84. https://doi.org/10.1021/ac980656z. PMid:21644679
8. Bourbabaa H, Achaibaa CB, Mohameda B. Mechanical behavior of polymeric membrane: Comparison between PDMS and PMMA for micro fluidic application. Energy Procedia. 2013; 36:231–7. https://doi.org/10.1016/j.egypro.2013.07.026.
9. Iron (III) chloride [Internet]. [cited 2017 Jun 22]. Available from: https://en.wikipedia.org/wiki/Iron (III) _chloride.
10. Pang X, Lucy JC, Lewis AC. Microfluidic derivatisation technique for determination of gaseous molecular iodine with GC–MS. Talanta. 2015; 137:214–9. https://doi.org/10.1016/j.talanta.2015.01.041. PMid:25770627
11. Balpande SS, Pande SR, Patrikar MR. Design and low cost fabrication of green vibration energy harvester. Sensors and Actuators A: Physical. 2016; 251:134–41. https://doi.org/10.1016/j.sna.2016.10.012.
12. Balpande SS, Bhaiyya ML, Pande RS. Low-cost fabrication of polymer substrate-based piezoelectric microgenerator with PPE, IDE and ME. Electronics Letters. 2017; 53(5):341–3. https://doi.org/10.1049/el.2016.4099.