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Original Article

High-Efficiency Drug Characterization through Microchannel-Integrated Microfluidic Systems

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ABSTRACT

Aim/Background: Micro-channels, characterized by their minuscule size ranging from 10 µm to 200 µm, find diverse applications across various fields such as biomedical, electronics, and chemical reactors, etc. Here, it was showed that easy, simples and low-cost methods for the fabrication of complex structured micro-fluidic channels. **Materials and Methods:** In addition, a new application was showed by using them. Importantly, in fabrication, initially, Acrylonitrile Butadiene Styrene (ABS) filaments were used to mould desired shape, later they are place in mould carefully. After this, Polydimethylsiloxane (PDMS) was poured into the mould followed by annealing which help to solidify the liquid PDMS. The remained ABS was removed by Acetone solvent. In this way, the various shapes of micro-fluidic channels were (80 µm) prepared. In a specific application scenario, these micro-fluidic channels were employed for characterization of drug, where substances like *Tridax procumbens* leaves extract was subjected to comprehensive testing for anti-fungal, anti-bacterial, and anti-viral properties. **Results:** The fabrication technique is successfully produced complex microchannel structures with high precision. The microfluidic platform enabled effective drug characterization, showcasing its potential for rapid and efficient biological testing. Qualitative analysis revealed that the microchannel design positively influenced both analysis efficiency and response time. **Conclusion:** This innovative approach not only facilitates the creation of intricate micro structures but also enhances the speed and accuracy of analytical processes. The integration of ABS filaments and PDMS in micro channel fabrication showcases a promising avenue for advancing point-of-care diagnostics with potential implications across various industries and research domains.

Keywords: Micro-fluidic channel, Polydimethylsiloxane, *Tridax procumbens*, Drug analysis.

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INTRODUCTION

Microchannels are tiny channels, in which usually dimensions starting from 10 µm to 200 µm, that have come to be important in science, engineering, and remedy (Sia *et al.*, 2003). Despite their small length, they play a massive role in guiding fluid drift, supporting with warmness transfer, and making chemical reactions occur exactly. These channels are specifically critical in microfluidic devices, where they control how fluids flow for responsibilities like analysing organic samples or turning in pills (Whitesides, 2006). They're also critical in cooling electronics, making sure gadgets work efficiently without overheating. Although making micro-channels offers its demanding situations, the latest advances have improved their fabrication (Bhatia *et al.*, 2014).

Microfluidics channels come in various types, each tailored to specific applications and requirements. Here are some common types, like Straight Channels, Serpentine Channels, Tapered Channels, Y-Shaped Channels, Cross-Junction Channels, Curved channels, Droplet-based channels, Coiled Channels, Pore Channels (Huh *et al.*, Dungchai *et al.*, Martinez *et al.*, Ligon *et al.*, 2010; Teh *et al.*, 2011; Jensen, 2012; Sackmann *et al.*, 2014), etc.

Apart from the various types of micro-channels they are different methods to fabricate them. For example, they are soft lithography, micromachining, 3D printing, Inkjet moulding, Electrochemical Machining (ECM) and Electroforming (Walker *et al.*, 2002; Sia *et al.*, Lee *et al.*, 2003; Qin *et al.*, 2010; Zhang *et al.*, 2017;) etc.

There are various applications of microchannels in different fields, such as biomedicine, health care, microfluidics cell culture, drug delivery, organ-on-chip (McDonald *et al.*, 2000), etc. Although microfluidics devices offer tremendous potential for chemical analysis, many existing synthetic methods are complex and require specialized equipment and knowledge. In addition, despite the growing interest in micro fluidics devices for pharmaceutical analysis, cost remains a major barrier to

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widespread adoption, especially in resource-limited settings. Focused research on to improve production efficiency and reduce costs without compromising productivity and reliability. The search for low-cost materials, scalable manufacturing processes, and new manufacturing techniques can help fill this gap and help make microfluidics technology more versatile.

Here, it was showed that fabrication of micro-fluidic channel by simple, low-cost, and easy methods and after fabrication, they are used for drug characterization analysis for qualitative and quantitative study.

MATERIALS AND METHODS

In addressing the challenge of removing aluminium coils from complex microfluidics channel structures without disrupting the channels themselves, we explored alternative materials and methods. Upon delving into existing literature, we discovered a potential solution involving the use of Acrylonitrile Butadiene Styrene (ABS), commonly utilized in 3D printing applications. ABS exhibits a unique property whereby it disintegrates upon interaction with acetone. This characteristic makes ABS an ideal candidate for our purposes. By immersing a small piece of ABS in acetone, it undergoes rapid disintegration, facilitating its removal from the microfluidics channels. The process involves introducing acetone into the channels, causing the ABS to dissolve gradually. This method offers a non-invasive and efficient means of removing the ABS material from within the channels, thereby circumventing the challenges associated with traditional aluminium coil removal. By leveraging the dissolving properties of ABS in ace- tone, we can ensure the seamless extraction of the material from intricate microfluidics channel structures. This innovative approach enhances the versatility and applicability of microfluidics channel fabrication, enabling the creation of complex geometries with greater ease and precision.

We refined our fabrication process by using straight ABS filaments, which we cut into the required sizes for constructing microfluidic channels as shown in Figure 1. Initially, we dipped the tips of the ABS filaments into acetone. As the ABS tips softened upon contact with acetone, we were able to seamlessly join them to other ABS parts without the need for adhesives. This technique allowed us to create various shapes of microchannels with precision and ease as shown in Figure 1. To commence the fabrication process, we cleaned a Petri dish with hexane and positioned the ABS-based micro-channel in the exact centre of the dish.

Subsequently, we prepared a mixture consisting of 10 parts of PDMS and 1 part of cross-linker, following the same procedure as previously outlined. The thoroughly mixed PDMS-curing agent blend was poured over the micro-channel within the Petri dish as shown in Figure 2. We then placed the Petri dish containing the micro-channel-PDMS assembly into a hot air oven set at 60°C for a duration of 1 hr. This ensured the solidification of the PDMS material, resulting in the formation of a robust micro fluidic channel structure. After the completion of the solidification process, we removed the Petri dish from the hot air oven and allowed it to cool down. Once cooled, we carefully cut along the edges of the Petri dish using a blade. Subsequently, we

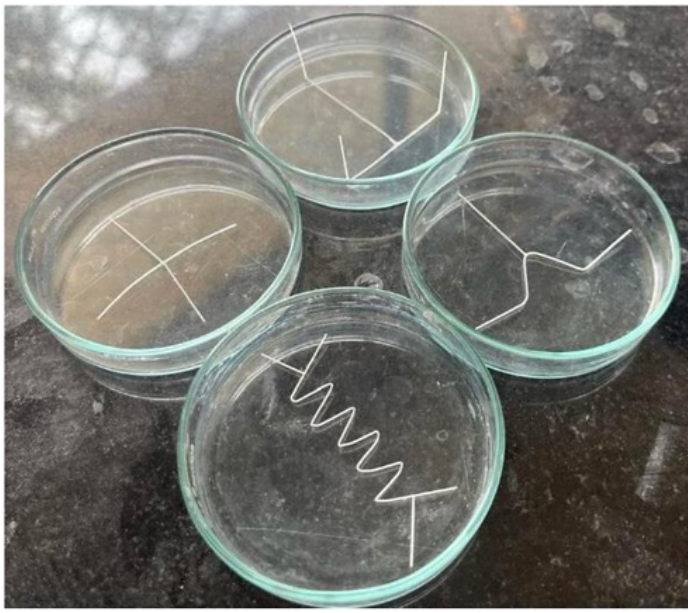

Figure 1: Fabrication of various shapes of molds by using ABS.

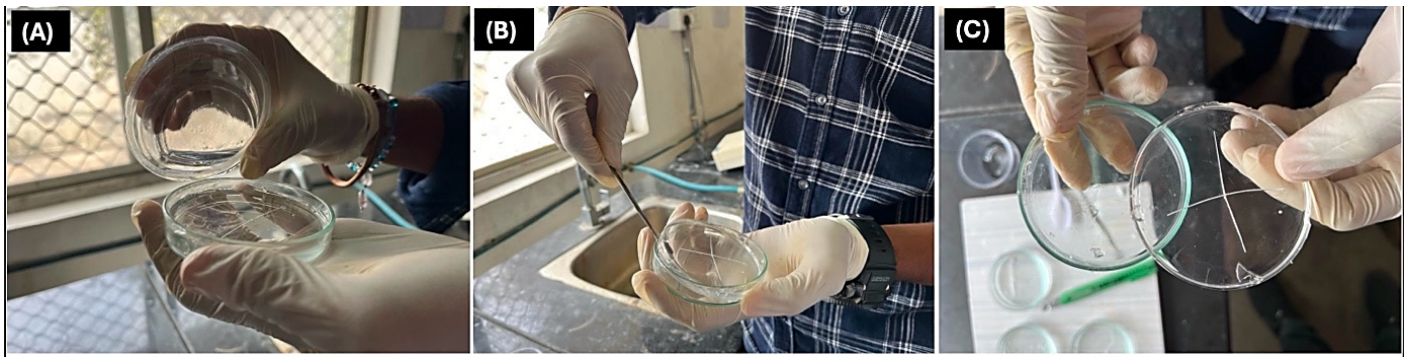

Figure 2: Images show that fabrication of microchannels by using ABS. Image (A) shows 10:1 ratio of PDMS and crosslinker mixture was poured on the petri dish mould in which ABS filament is there. Image (B) shows the PDMS was solidified by keeping the liquid mould in hot air oven for 1 hr at 60°C. After the solidification the PDMS is peeled off from petridish. Image (C) shows fabricated ABS based PDMS microchannel.

gently poured a small amount of hexane through the cut edges to facilitate the separation of the Petri dish from the PDMS embedded micro-channel. Using a spatula, we delicately detached the microchannel from the Petri dish. This meticulous procedure ensured the successful extraction of the fabricated micro fluidic channel from its mould without causing damage or distortion.

To remove the ABS material from the microchannel, we adopted a targeted approach. Initially, we made a small hole at the end of the microchannel using a hole puncher. This hole served as the entry point for introducing acetone into the channel. Next, we prepared a syringe filled with acetone, ensuring the absence of a needle for safe handling. Placing the injection tip directly over the hole at the end of the channel, we initiated the injection process as shown in Figure 3. As acetone began to flow into the channel, it came into contact with the ABS material embedded within. Upon interaction with acetone, the ABS material gradually softened and disintegrated. We continued to inject acetone into the channel, ensuring thorough coverage until all traces of ABS were effectively removed. This process required patience and precision to ensure complete dissolution of the ABS material. Once the ABS material was successfully removed, the microchannel was rendered free of any obstructive components and ready for use in chemical analysis.

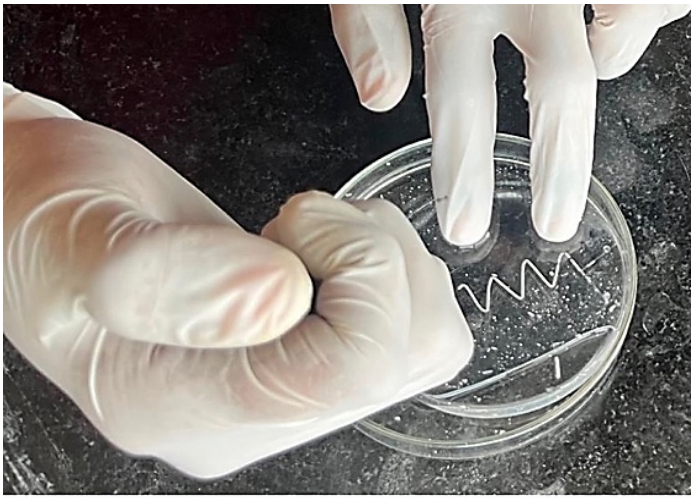

Figure 3: Image shows that removing of ABS using acetone. Acetone was injected from on nozzle forcefully, then acetone dissolves ABS which was pumped out from other nozzle.

Figure 4: Image shows that *Tridax procumbens* plants from Hyderabad, Telangana, South India.

RESULTS AND DISCUSSION

In our chemical analysis utilizing micro-channels, we have opted for the Mayer's test to determine the presence of alkaloids in *Tridax procumbens* leaf extract. *Tridax procumbens*, a medicinal plant showed in Figure 4 renowned for its various health benefits such as anti-inflammatory properties, pain relief, antioxidant activity, diuretic effects, digestive health, and wound healing, holds significant promise in the realm of natural medicine. To conduct the test, we require *Tridax procumbens* leaves and Mayers reagent.

The first step involves extracting the juice from the *Tridax procumbens* leaves. Initially, the Mayer's test was conducted using the bulk method, employing test tubes. A total of 5 mL of *Tridax procumbens* leaf extract was combined with 5 mL of Mayer's reagent in a test tube and thoroughly mixed.

Figure 5: Images show that Mayer's test was done for *Tridax procumbens* extract by conventional method i.e in the test tube. It confirms that by appearance of Reddish colour with foam. Image (A) shows that initially Mayer's reagent is added to the *Tridax procumbens* extract. Image (B) shows after adding Mayer's reagent the greenish colour extract was started to change its colour to apple red colour. Image (C) shows that Mayer's test was confirmed by forming appeared read colour with form.

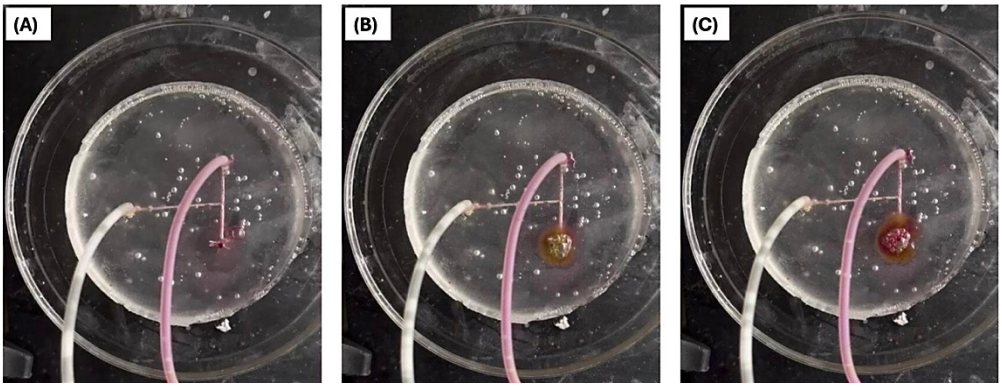

Figure 6: Images show that Mayer's was conducted for *Tridax procumbens* extract in microchannel. Image (A) shows Injecting *Tridax procumbens* leaves extract from one nozzle and Mayer's reagent from another nozzle parallelly. Image (B) shows they mix at T-joint and started to change its colour with form immediately due to molecular mixing at T-joint. Image (C) shows 20 µL of Mayer's reagent is sufficient to confirm Mayer's test within in 1 sec.

The outcome of this experiment revealed the formation of a reddish-brown colour with foam. Subsequently, the same experiment was replicated utilizing microchannels as shown in Figure 5.

Subsequently, two injections (without needles) are prepared and connected with butterfly Intravenous (IV) tubes. These injections are then filled with the *Tridax procumbens* leaf extract and the Mayers reagent respectively. Following this preparation, the tubes are connected to the micro-channel system as shown Figure 6 (A). The next phase entails pumping both the Mayers reagent and the leaf extract into the microchannel. Upon interaction, the resultant mixture exhibits a reddish-brown hue along with the formation of a distinct precipitate, indicative of the presence of alkaloids Figure 6 (C). It's noteworthy that in this experiment, we've utilized only 20 µL of both the Mayers reagent and the *Tridax procumbens* leaf extract. This meticulous approach ensures precise analysis while conserving resources and cost in this way, *Tridox procumbens* extract can be analyzed and characterized rapidly and cost-effectively using micro-channels.

CONCLUSION

In this work, it was demonstrated the fabrication of microchannels for drug analysis by a simple and flexible method.

Our approach aimed to overcome the challenges associated with traditional microfluidics fabrication techniques, making the technology more widely applicable, especially among researchers and practitioners with limited micro-fabrication expertise.

Using straightforward synthetic methods and inexpensive materials, we demonstrated the feasibility of fabricating microchannels that could facilitate drug screening.

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CONFLICT OF INTEREST

The authors declare that there is no conflict of interest.

ABBREVIATIONS

PDMS: Polydimethylsiloxane; **ABS:** Acrylonitrile Butadiene Styrene; **ECM:** Electrochemical Machining.

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