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Abstract

Fabrication of an Ultrathin PMMA Foil for Sensing Applications in Microfluidic Systems †

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Abstract: This research work focuses on the fabrication of ultrathin polymethylmethacrylate (PMMA) foils using a spin coating process of in anisole dissolved PMMA on a water-soluble polyvinyl alcohol (PVA) foil. Currently, layer thicknesses as low as 1 µm can be achieved and even thinner layers appear to be possible. Sensors and actuators can be applied to the foils and directly integrated into the center of the channel of a polymer-based microfluidic chip. Specifically, the foil acts as a supporting structure that helps to position the sensor in the center of the channel. Thermal sensors, in particular, benefit from the low heat capacity of the foil. This will improve the performance and the accuracy of these sensors of which the impact on the fluidic flow is minimized.

Keywords: ultrathin foil; PMMA; microfluidic; sensor integration; low heat capacity; time constant; fast thermal response

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1. Introduction

To monitor the current state of a microfluidic system, it is necessary to integrate sensors into the system. Many flow sensors are based on thermal anemometry, because it is the most reliable technique to measure the fluidic flow velocity [1]. The thermal time constant of all thermal-based sensors will increase with the heat capacity of the sensors and sensor mounts [2]. A higher time constant leads to a higher time delay between the measured and the true value. An obvious way to optimize such sensors is therefore to keep the heat capacity as low as possible. To do so, a process for fabricating ultrathin polymethylmethacrylate (PMMA) foils was devised utilizing spin coating and a water-soluble substrate foil. Such thin PMMA layers have already been produced using a spin coating process [3], but only as a coating and not as a free-standing foil.

2. Fabrication and Results

2.1. Fabrication

The fabrication steps of the ultrathin PMMA foil are shown in Figure 1A. First, a piece of water-soluble polyvinyl alcohol (PVA) foil is put onto the inner part of a laser-cut PMMA tension ring (Figure 1A(a)). Next, the PVA foil is clamped using the outer tension ring; see Figure 1A(b). The PVA foil is covered with a thin PMMA–anisole layer using a spin coating process (Figure 1A(c)). The thickness of the layer depends on the weight ratio of the PMMA–anisole solvent and the settings of the spin coater. The layer becomes thinner if the concentration of PMMA in the solvent is reduced and if the rotation speed of the spin coater is increased. Figure 1A(d) shows the drying of the sample in an oven at 60 °C for 20 min to evaporate the anisole. Clamping to the smaller tension rings (Figure 1A(e)) is necessary in order to clamp the PMMA layer too and thus to prevent the detachment of the PMMA foil from the clamping rings after dissolving the PVA substrate layer, which takes place in a water-filled glass container for 30 min (Figure 1A(f)). After drying the ultrathin

PMMA foil at room temperature (or in the oven), it is ready for use. Nonetheless, for easier handling, it is still clamped to the tension rings. During or after the fabrication procedure, it is possible to integrate sensors, e.g., by screen printing sensor structures onto the PVA or PMMA foil.

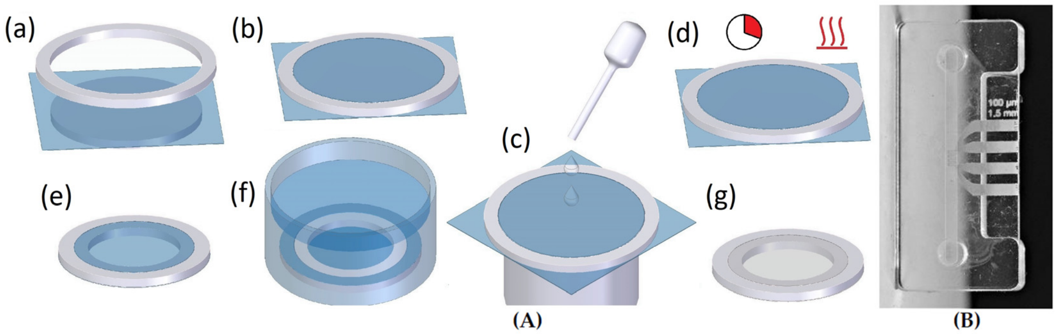

Figure 1. (**A**) Fabrication procedure of an ultrathin PMMA foil. (**a**) Cutting and placing of the PVA foil. (**b**) Clamping of the PVA foil into laser-cut PMMA tensions rings. (**c**) Spin coating of a PMMA layer. (**d**) Curing process for solvent evaporation. (**e**) Clamping to smaller tension rings. (**f**) Dissolving of the PVA foil in a water-filled glass container. (**g**) Drying of the foil at room temperature or in the oven. (**B**) Fabricated sensors using the ultrathin PMMA foil and screen-printed electrodes.

2.2. Results

By using the ultrathin PMMA foil as substrate for an anemometric sensor (see Figure 1B), the thermal time constant of a screen-printed temperature sensor integrated into a PMMA-based microfluidic chip could be improved by a factor of about 15 compared to a similar fabricated sensor using the thinnest commercially available PMMA foil that we found (featuring a thickness of 150 µm).

3. Discussion

In this paper, the fabrication procedure of an ultrathin PMMA foil was shown. Using this process, foils with thicknesses as low as 1 µm could be fabricated. The employment of such thin foils as a mounting or base material for thermal sensors in microfluidic channels leads to a significant reduction of the heat capacity and thus to significantly reduced thermal reaction times.

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