TRANSFER BONDING OF MICROSTRUCTURES AND FABRICATION OF FRAGILE PDMS MEMBRANES USING WATER DISSOLVABLE FILM

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ABSTRACT

We present water-dissolvable sacrificial film as a versatile and low-cost method for solving two distinct problems in microfabrication: 1) the transfer bonding of structurally unconnected components and 2) the fabrication and handling of fragile PDMS structures.

KEYWORDS: Polyvinyl Alcohol, Transfer Bonding, Polydimethylsiloxane Microsystems, Microfabrication

INTRODUCTION

Batch transfer bonding of (structurally unconnected) microcomponents is a generic microfabrication method [1,2] based on a (wafer-level) pick-and-place method in which the microstructures are transferred from a source substrate, via a transfer carrier, to a destination substrate. In previous methods, the adhesion of the microstructures to each subsequent substrate must be stronger than to the previous surface (source substrate adhesion < carrier adhesion < destination substrate adhesion), which requires an appropriate choice of the material surface properties, and/or a change of these surface properties, e.g. through a plasma treatment (Figure 1, top).

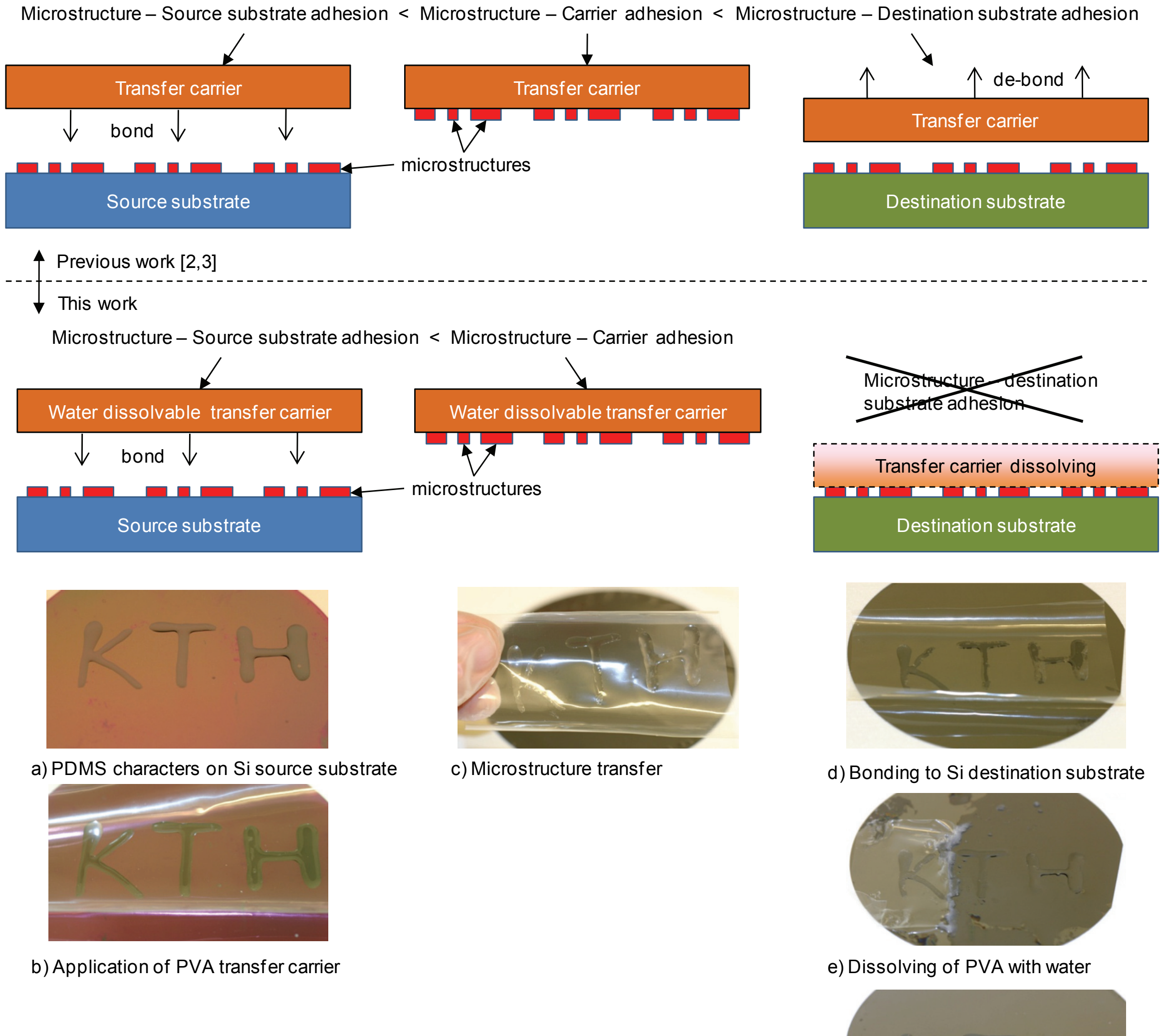
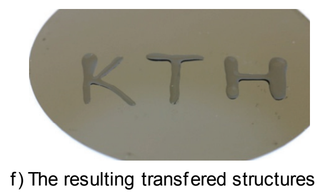


Figure 1: Illustration of the previous [1,2] transfer bonding method (top) and the novel approach using a water dissolvable transfer carrier, demonstrated by the 4" wafer-level based transfer of three mechanically unconnected PDMS structures using PVA (bottom).



Another challenge relates to the fabrication of thin, large area, suspended PDMS membranes. Such structures occur in microfluidic devices such as separation devices [3]. The fabrication of such suspended fragile PDMS features, e.g. their demolding and transfer, is a difficult and typically low-yield process.

TRANSFER BONDING

Here we introduce the use of a water-dissolvable film as a temporary carrier for transfer bonding of microstructures. We use polyvinyl alcohol (PVA, The Fishing Bag Ltd, UK) as an example material, which is a low-cost, very hydrophilic material that dissolves in water but also shows good chemical resistance to non-water-based solvents. PVA has previously been used as a sacrificial material for microstructuring [4]. We developed a method for the transfer of microstructures to a destination substrate with any surface adhesion properties, using a water dissolvable transfer carrier (Figure 1, bottom). As a demonstration, unconnected PDMS structures (cm-sized characters “K”, “T” and “H”) were transferred from one oxidized 4” silicon wafer to a second, natively oxidised, 4” silicon wafer.

FRAGILE PDMS MICROSTRUCTURE FABRICATION

Additionally, an entire process for the fabrication of separated PDMS components with large and thin suspended membranes, based on the use of a water-dissolvable film, was designed and successfully tested (Figure 2):

1) PDMS prepolymer is casted onto a conventional mold stack consisting of: i) a 75 x 25 mm^2 microscope glass slide or a 4” silicon wafer substrate; ii) a dual-height SU8 layer; and iii) a Teflon coating for facilitated release.
2) A 60 µm thick PVA film is rolled onto a glass/quartz plate (75 x 25 mm^2 microscope glass slide or a 5” quartz plate) to ensure PVA surface flatness. After heating to 75 °C, the PVA adheres weakly to the plate.
3) The PVA is clamped against the prepolymer and the mold, where the dual-height mold ensures an excellent layer thickness control. When using excess prepolymer, air bubbles trapped between the PVA and the prepolymer are easily pressed out.
4) The PDMS is cured at 75 °C (hotplate/oven).
5) After curing, the glass plate is easily removed by manual lifting off.
6) The PVA-PDMS stack is peeled off from the mold, e.g. with a pair of tweezers, in which the PVA film protects any fragile PDMS features and preserves the position of all PDMS features.
7) The PVA-PDMS stack is simply rolled down onto the destination substrate (here tested: plain microscope glass slide and natively oxidised, 4” silicon wafer), without the need for further pressure.
8) The PVA is dissolved in water...
9) …leaving the PDMS structures intact.

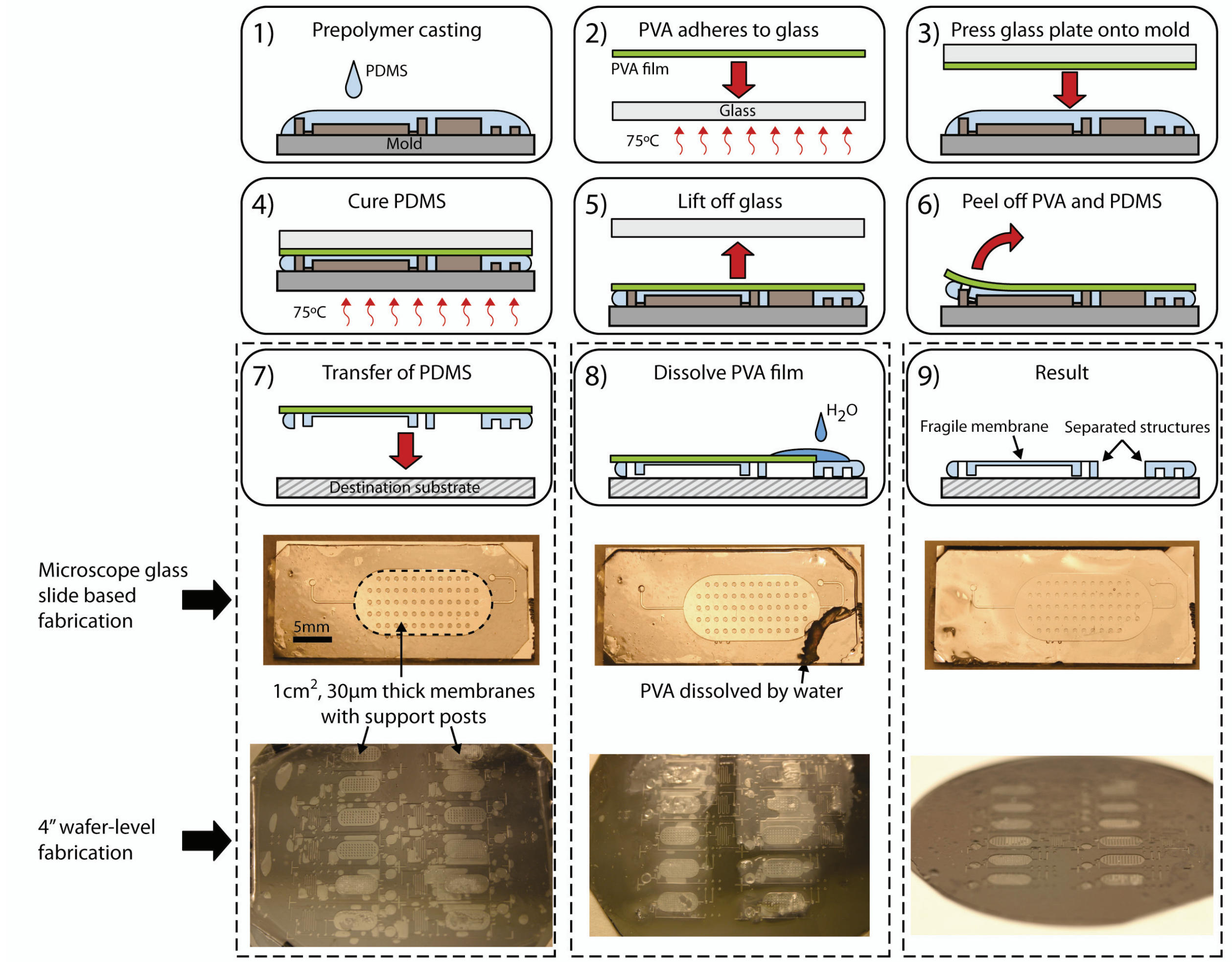


Figure 2: Schematic of the fabrication, mold release and transfer of fragile and separated PDMS structures using PVA as a water dissolvable transfer carrier and structural support (top), and pictures of the implementation of the technology for SU8 mold-to-microscope glass slide (middle) and 4” SU8 mold-to-Si wafer (bottom) transfer.

Successful transfer and release of PDMS structures was made using two substrate sizes. A 8 x 20 mm^2 microfluidic chip with a 30 µm thick and 1 cm^2 area suspended membrane, supported by an array of microposts, was successfully fabricated on a microscope glass slide (Figure 2, middle), and twelve such chips were batch fabricated on a 4" mold and transferred to a 4" silicon wafer (Figure 2, bottom).

RESULTS AND DISCUSSION

Our novel approach has a number of distinct benefits over previous methods:

- The water dissolvable material alleviates problems related to polymer-to-mold stiction when used as an intermediate layer during curing.
- The dissolvable film protects from contamination and mechanically strengthens and protects fragile features during handling.
- Unlike previous methods, the adhesion of the microstructures to the destination substrate is a non-critical parameter, because the transfer carrier is removed through dissolving, instead of de-bonding, after transfer, hence not requiring additional surface preparations.
- The transfer bonding does not require elevated temperatures nor organic solvents, all of which would limit the use of this method in combination with biofunctionalised surfaces.

CONCLUSION

We successfully demonstrated a novel method for batch transfer of microstructures, keeping the inter-position of disjoined structures, and for the handling of fragile structures during their fabrication, without the need for organic solvents, surface preparations such as plasma treatment, or elevated temperatures. Both methods are based on the use of a water dissolvable transfer carrier and were demonstrated with PVA as the dissolvable material.

ACKNOWLEDGEMENTS

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