THERMOPLASTIC ELASTOMERS (TPE) BLOCK COPOLYMERS, A NEW MATERIAL PLATFORM FOR MICROFLUIDICS : PROOF OF CONCEPT FOR COMPLEX SIPHON VALVING ON CD

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ABSTRACT

Using commercially available SEBS (styrene)-(ethylene/butylene)-(styrene) block copolymers, we demonstrate that thermoplastic elastomeric TPE represented an opportunity to solve the equation *PDMS + TP = TPE*, meaning a way to possess a material solution that is transparent, biocompatible and flexible as PDMS and has thermoforming processing characteristics of TP like PMMA. We demonstrate excellent replication and enhanced de-moulding capabilities using SU8 mold, we report easy reversible bonding capabilities for all based CDlab thermoplastics device. Through single and double siphon valving strategy, we finally demonstrate sequential flows of three functional reagents in hybridization column.

KEYWORDS: Thermoplastic elastomers, Block Copolymer, Microfluidic CD, siphon valving.

INTRODUCTION

Hot embossing of thermoplastic (TP) materials (PMMA, PC,...) appear to be promising avenues for prototyping and industrial requirements. But high quality microstructured mold generation, high aspect ratio structure replication and de-molding remain problematic while post-bonding operations may be difficult and costly. The other polymer based technology is the widely used PDMS soft lithography, allowing high quality replication and easy assembly. However this technology is time and power consuming and limited to low volume prototyping. Here, we report the use of a novel class of low cost polymer for microfluidics, as a demonstration, we have selected *transparent and soft PDMS-like* (styrene)-(ethylene-butylene)-(styrene) (SEBS) tri-block thermoplastic elastomer to fabricate microfluidic CD-like system [1T]. The selected biocompatible SEBS material is a phase-separated copolymer having two glass transition temperatures corresponding with respective homopolymers (fig. 1a). The first phase consists of hard polystyrene (PS) nanometric cluster (10-30 nm) domains, 3D organized and distributed in a 85% rubber matrix of (ethylene-butylene) (EB) (fig. 1b). With TPE introduction, we assert and demonstrate the following advantages i) no pre-required compounding and vulcanization steps; ii)

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amenability for thermoforming with high-throughput hot embossing; iii) high quality replication.

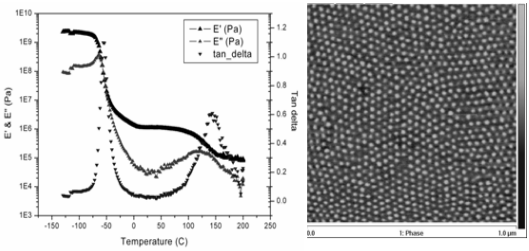

Figure 1.(a) SEBS Dynamic mechanical thermal analysis spectra, Tensile Modulus = 1.3 MPa@RT (b) AFM phase image of 15 % Styrene contents in SEBS.

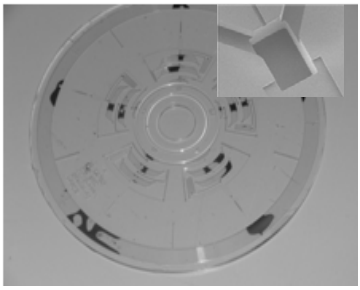

Figure 2.Thermoforming replication of SEBS microfluidic CD.

EXPERIMENTAL

The master mold for TPE CD thermoforming was fabricated by standard SU-8 photo-lithography. Versaflex SEBS thermoplastics elastomers material was purchased from GLS Inc.. Prior microstructuration a TPE roll of 3.0 mm thick, 150 mm wide and few tenths meters long was obtained by extrusion. Compare to PDMS, soft TPE can be used without pre-compounding steps and shaped roll can be store and then materials use on demand. Hot embossing experiments were carried on an EVG 520 HE equipment using a embossing temperature of 140 ^{o}C and an uniform force of 2.3 kN is applied for 3 min over 6'' mold. De-embossing is performed manually by peeling-off the polymer layer from the mold as easily it can be accomplished with PDMS from master. Fabricated structures show well defined shapes and excellent surface quality, measured TPE roughness is 1.5 and 3.0 nm for respectively surfaces in contact with Si and SU8 mold parts. Observed mold stability over embossing runs (50), is largely due to the fact that de-moulding can be easily performed according to elastomeric properties of TPE, which can locally be stretched.

Figure 2 displays optical and SEM images of high quality all thermoplastics CDlab, microfluidic network is composed with 2 levels structures depth of 25 and 250 µm and minimum features of 15µm, three reagents chambers are connected to a hybridization column and five units are integrated on a CD (fig. 3). SEBS materials, similarly to PDMS, form spontaneous and intimate surface contact, allowing fully efficient reversible bonding on poly(cyclo)olefin polymer substrate. Prior assembling, in order to ensure convenient siphoning , SEBS has been exposed to oxygen plasma and we obtained advancing and receding contact angles of 65 ± 2° and 21 ± 4°, respectively. Additionally, PCO surface modification was accomplished in a two steps process, involving ozone treatment and sulfonation chemistry [2] allowing to obtain advancing and receding contact angles of 38 ± 2° and 11 ± 3°, respectively.

RESULTS AND DISCUSSION

Each hybridization unit contains a volume of 2µl sample and 6µl of washing and rinsing buffers that are sequentially driven through the column (fig. 3). All reagents are released from reservoirs at t_0 upon spinning. The sample flows through the column first, while both buffers are blocked using a combination of siphon valves (inserted extracted image fig 3). Once hybridization sample is passed, a first rest period allows washing buffer to flow via hydrophilic capillary effect and then pass over the siphon valve loop, while rinsing buffer remains in between siphon valve cascade (fig. 3b), 0.05% sodium dodecyl sulfate (SDS) contains in washing buffer induced a siphon propagation nearly two time faster compare to rinsing buffer. Spinning is then resumed and once washing buffer has flowed through the column, a second rest period is implemented to allow rinsing buffer to be released in the chamber.Table 1 reports operations, spinning frequency and timescale characteristics for specific steps completion, all steps are completed within less 10 minutes period.

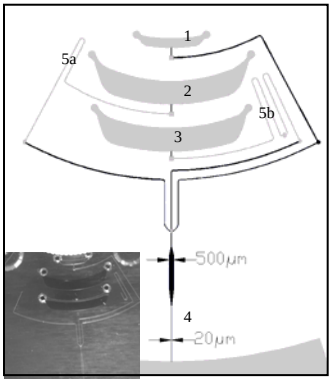

Table 1 : CD spinning sequences

Operations	Speed (rpm)	Flow Time (s)
a-2µl sample flow	1500	99±11
b - Washing buffer siphoning (t_1) & rinsing buffer siphoning (t_2)	rest	$t_1 = 23±7$ $t_2 = 45±10$
c- 6µl washing flow	1500	154±13
d-Rinsing buffer siphoning	rest	63±16
e- 6µl rinsing flow	1500	127±14

Figure 3.(a) (1),(2) and (3) are reservoirs for DNA sample, washing and rinsing buffers respectively, (4) hybridization column, (5a) and (5b) are respectively single and double siphon valve structures (b) Image extracted from digitized movie few seconds after first rest period.

CONCLUSION

Through discussed SEBS block thermoplastic elastomer, we have somehow solved the simple equation, *PDMS+TP=TPE.* With selected *transparent and soft PDMS-like* SEBS tri-block thermoplastic elastomer we have fabricated a fully functional microfluidic CD-like system including complex siphon valving.

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