Lab-on-a-Chip
European Congress

EXPERIMENTAL CHARACTERIZATION OF A METHOD TO REVERSIBLY BOND MICROFLUIDIC DEVICES THROUGH MAGNETIC FORCES

Francesco Piraino[1], Matteo Moretti[2,3], Alberto Redaelli[1], Marco Rasponi[1]

[1] Bioengineering Department, Politecnico di Milano, Milan, Italy
[2] Gruppo Ospedaliero San Donato Foundation, Milan, Italy
[3] IRCCS Galeazzi Orthopaedic Institute, Milan, Italy

Introduction

Traditionally, PDMS microfluidic devices are bound to glass substrates in a permanent way. However it is often desirable to directly access their content.
Although different methods for reversible bonding have been proposed [1,2], so far none revealed satisfactory sealing in common applications. We proposed a new method to overcome this limitation.

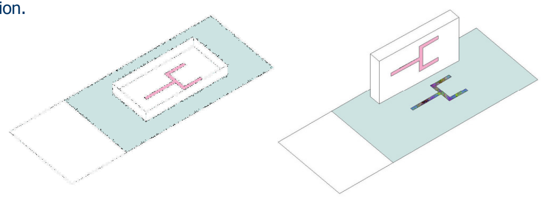

***Figure 1.** Schematic concept for the reversible bonding.*

Materials and methods

A PDMS layer containing microchannels forming a Y-shaped fluidic path was fabricated by means of soft-lithography techniques. Two resists were used: SU8-50 (MicroChem Corp) for 75µm height and 100µm width channels and AZ-4562 (AZ Electronic Materials GmbH) for 25µm height and 50µm width channels. A second layer of PDMS surrounded by a suspension of iron powder and PDMS was bound to the previous one. Finally, the device was coupled to a glass slide with a magnet underneath.
To experimentally characterize the device four device configurations were tested: i) magnet applied during the whole experiments (PAM); ii) magnet only applied for 60 minutes before experiments (TAM); iii) no magnet so that bonding was only due to PDMS/glass surface interactions (NoM); iv) permanent bonding obtained by means of plasma treatment (PPB).
In order to identify the maximum static pressure PAM, TAM and NoM could withstand a precision pressure regulator (IR2010, SMC Corp) was used. Pressure slopes were applied at increasing discrete steps of 5kPa/min. The maximum pressure value for each configuration was determined at a point where color label/air interface in the input tubes started moving towards the device, corresponding to a leakage occurrence.
To assess the maximum flow rates that PAM, TAM and NoM could withstand a Harvard Apparatus syringe pump (Natick, MA, USA) was used. For the three configurations, color label was perfused through the channels at increasing flow rates with steps of 10µl/min until 100µl/min and steps of 50µl/min from 100 until 400µl/min, finally with steps of 100µl/min until 1000µl/min. Maximum sustainable flow rates were determined at the point where leakages appeared macroscopically or under microscope.
To estimate the hydraulic resistance of the PAM and PPB devices a precision pressure regulator was used to apply accurately a pressure to a closed reservoir containing color label. The pressure applied was linearly increased from 10 to 50kPa, in steps of 10kPa. Flow rates were determined by measuring the weight of the accumulated liquid volume, collected at the outlet.
Maximum pressure and flow-rate values for the experiments carried out are presented as mean ± SD. Tests for statistical significance were made using ANOVA test with $p<0.05$.

Results and discussion

Figure 2 shows the results of the static leakage experiments carried out in order to evaluate the bonding strength of magnetic forces. PAM devices withstood a maximum pressure of 58.3±2.9kPa. This value was significantly attenuated by magnet removal (TAM devices had a maximum pressure rate of 28.3±2.9kPa). A further decrease was observed when no magnet was applied at all; indeed NoM devices, relying only on van der Waals adhesion of PDMS to glass withstood a value of 18.3±5.8kPa.

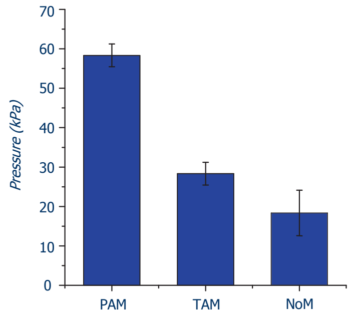

***Figure 2.** Results of the static leakage experiments.*
**p<0.05 vs PAM. #p<0.05 vs TAM.*

Table 1 shows the maximum flow rate achievable by each configuration tested. As for the NoM devices, consistent leakages were observed after 367±29µl/min. The liquid outflow occurred randomly. PAM and TAM devices were able to sustain significantly higher flow rates. Indeed, leakages were observed at flow rates as high as 967±58µl/min and 667±58µl/min, respectively.
In order to study the degradation of the sealing performances over repeated usage, single devices were tested up to five times. The results (also reported in Table 1) shows that all the configurations underwent a progressive degradation with different percentage of flow rate loss. NoM faced a 40.9% with a final maximum flow rate equal to 217±58µl/min. Both TAM and PAM presented similar percentage loss (30.0% and 27.6%) with final maximum flow rates equal to 467±115µl/min and 700±173µl/min respectively.

	Maximum flow rate [µl/min]	**Maximum flow rate @ 5th use [µl/min]**
PAM	967±58	700±173 (- 30.0%)
TAM	667±58	467±115(- 27.6%)
NoM	367±29	217±58 (- 40.9%)

***Table 1.** Results of the dynamic leakage experiments*

Figure 3 shows the results of the hydraulic characterization carried out in order to understand whether possible channel deformations induced by magnetic forces translated into significant variation of the channel hydraulic resistance. As it can be seen at low pressure values (10-20kPa) PAM devices had higher hydraulic resistances. At 30kPa, the two configurations provided the similar flow rates (285±5µl/min for PAM and 296±14µl/min for PPB), demonstrating therefore similar hydraulic resistance. By further increasing the external pressure, the flow rates measured within PAM overcome those in the PPB, this depending most likely on a lower hydraulic resistance of the device.

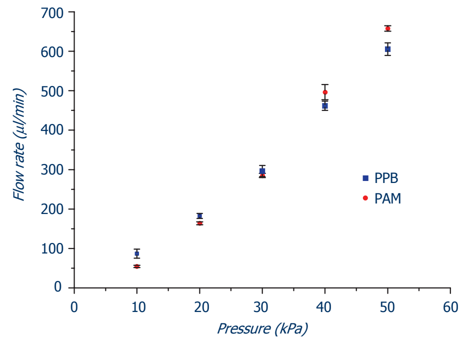

***Figure 3.** Results of the hydraulic characterization experiments*

Conclusions

In conclusion the proposed method allows a straightforward application for several classical biological and tissue engineering investigation techniques within microfluidic devices.

Acknowledgements

This study was supported by a Cariplo Foundation's grant and by the Progetto Roberto Rocca.

References

[1] Rafat, M., Raad, D. R., Rowat, A. C. and Auguste, D. T., 2009, "Fabrication of reversibly adhesive fluidic devices using magnetism" Lab on a Chip, 20 (9): 3016-3019.
[2] Khademhosseini, A., Yeh, J., Eng G., Kazi, H., Borenstein, J.,Karp, J., Farokhzad, O., Langer. R., 2005, "Cell docking inside microwells within reversibly sealed microuidic channels for fabricating multiphenotype cell arrays" Lab on a Chip, 5 (12): 1380-1386.

francesco.piraino@polimi.it