SAMs VAPOR DEPOSITION: A READY TO USE FUNCTIONALIZATION TECHNOLOGY FOR MONITORING WETTABILITY PROPERTIES IN MICROFLUIDIC DEVICES

R. Courson[1,2*], M. Fouet[1,2], P. Joseph[1,2], F. Mesnilgrente[1,2], V. Conédéra[1,2] and A.M. Gué[1,2]
[1]CNRS, LAAS, Toulouse, FRANCE and [2]Univ. de Toulouse, Toulouse, FRANCE

ABSTRACT

In this paper, we report the possibility to modify the wettability of polymer microchannels by vapor deposition of Self-Assembled Monolayers. We used silicon dioxide coating to obtain hydrophilic layer and combination of silicon dioxide and 1H,1H,2H,2H-Perfluorodecyltrichlorosilane to create hydrophobic layer.

KEYWORDS: SAMs, Vapor phase deposition, Microchannels, Hydrophilic, Hydrophobic

INTRODUCTION

Monitoring wettability properties is a major concern in microfluidics and many studies have been devoted to surface functionalization technologies by grafting self-assembled monolayers on flat surfaces or inside microchannels [1-4]. For polymer devices most processes are realized in the liquid phase [3], which often requires several steps (liquid injection to avoid bubbles, rinsing after the process,…), and is not easy to do in parallel. An easy and fast approach, suited to the treatment of a large number of pieces, is thus still missing. Vapor phase deposition is an attractive alternative, but until now it was only demonstrated for silicon/glass microchannels [4]. We propose a simple and low cost vapor deposition method enabling the modification of all polymer devices (polyimide, epoxy, PDMS…) and so the monitoring of microchannels wettability.

EXPERIMENTAL

Microchannels (200µm wide, 20µm high and 2cm long,) presented in Figure 1 were manufactured using standard PDMS soft lithography or by laminating epoxy based photoresists. Complete devices were introduced in the SPD (Surface Preparation Deposition) equipment (Memsstar) and deposition performed. Deposition in microchannel was demonstrated and the uniformity of the deposited layers was evaluated by studying the capillary filling of channels with various liquids.

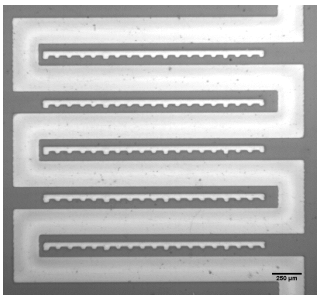

Figure 1: Optical image of the microfluidic device made with one layer of dry film photoresist DF-1005 (5µm thick) and two layers of DF-1020 (20µm thick). Lamination and photolithography techniques were used to fabricate microchannel network. Scale bar is 250 µm.

Silicon tetrachloride ($SiCl_4$) and water were injected in the SPD reactor with experimental parameters given in Table 1: water hydrolyzes $SiCl_4$ giving birth to silanol groups which react with the sample surface to form a hydrophilic silicon dioxide layer. To obtain a hydrophobic surface 1H,1H,2H,2H-Perfluorodecyltrichlorosilane (FDTS) and water were used (Silicon dioxide was first deposited onto the

polymeric surface as a bonding layer). Deposition was made at 40°C and low pressure. Modified surfaces were first characterized by static water contact angle measurement: a wettability angle of 25° was obtained for SiO_2, and 110° for FDTS. The treatment is reproducible and stable for more than six months. These values have to be compared to the native contact angle of standard polymers (~80-85°).

Table 1: Experimental parameters for SAM vapor deposition.

	H_2O flow rate (sccm)	*Chamber Pressure (Torr)*	*Deposition time (min)*
SiO_2	40	20	5
FDTS	40	40	5

RESULTS AND DISCUSSION

As shown in Figure 2 meniscus of water is inverted between untreated and SiO_2 modified microchannel proving the hydrophilic modification all along the channel.

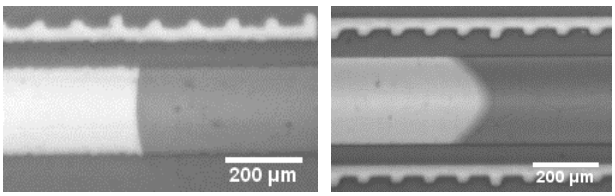

Figure 2: Optical images of water contact angle before (left) and after (right) SiO_2 deposition (microchannel of 20µm depth). The liquids appears in dark.

Figure 3 which reports the values of filling length versus time confirms this result: water filling speed was much higher in microchannels coated with silicon dioxide than with untreated one. For the treatment with FDTS, water did not spontaneously enter the channels, which shows its high hydrophobicity.

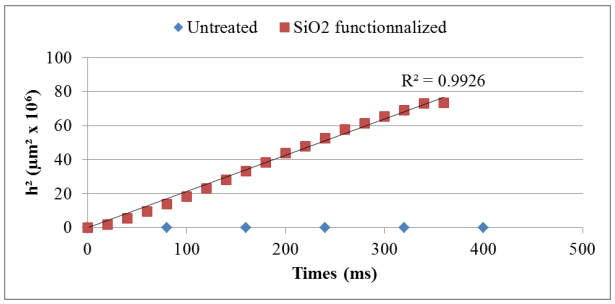

Figure 3: Water capillary filling kinetics in SiO_2 modified channels.

In order to test quantitatively the quality of the FDTS deposition, an analog study was performed with ethanol. Static contact angle was around 10° for untreated layer, 5° with SiO_2 coating and 60° for FDTS. Figure 4 illustrates the meniscus modification between untreated dry film and modified surface. The meniscus did not vary drastically like with water but wettability was clearly decreased.

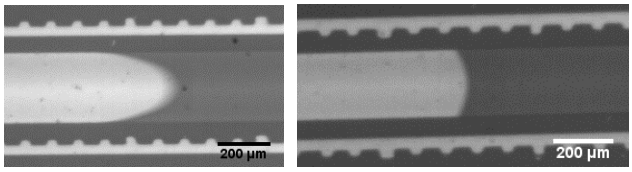

Figure 4: Optical images of ethanol contact angle before (left) and after (right) FDTS deposition (microchannel of 20µm depth). The liquids appears in dark.

Figure 5 confirms this result: ethanol filling speed was much higher in untreated or with silicon dioxide deposition than with FDTS coating.

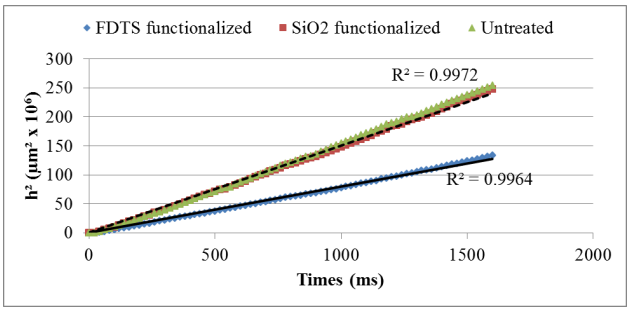

Figure 5: Ethanol capillary filling kinetics for different surface treatments.

Figure 3 and Figure 5 clearly show a meniscus progression (h) following Washburn law [5] (h^2 proportional to time), expected for a constant contact angle.

$$h^2 = At, \quad A = \frac{a\gamma \cos\theta}{3\mu} \tag{1}$$

Where a is the channel depth and μ the dynamic viscosity. It demonstrates that in both cases (FDTS or SiO_2) the deposition was uniform over the entire microchannel length.

CONCLUSION

We have demonstrated the possibility to functionalize polymeric microchannels, with hydrophilic or hydrophobic surface, at the end of the fabrication process by simple and low-cost vapor deposition of self-assembled monolayers.

ACKNOWLEDGEMENTS

This work is supported by French National Research Agency (ANR) in the frame of the PIA – Nanobiotechnology project Digidiag. It was realized in the clean room of LAAS-CNRS member of the French RENATECH network.

REFERENCES

[1] E.V. Moiseeva, A.A. Fletcher and C.K. Harnett, "Thin-film electrode based droplet detection for microfluidic systems," *Sensor Actuat B-Chem*, 155, 408, 2011.

[2] X. Illa, O. Ordeig, D. Snakenborg, A. Romano-Rodrıguez, R.G. Compton and J.P. Kutter, "A cyclo olefin polymer microfluidic chip with integrated gold microelectrodes for aqueous and non-aqueous electrochemistry," *Lab Chip,* 10, 1254, 2010.

[3] T.T. Vu, M. Fouet, A-M Gue and J. Sudor, "A new and easy surface functionalization technnology for monitoring wettability in heterogeneous nano- and microfluidic devices," *Sensor Actuat B-Chem*, 196, 64, 2014.

[4] C. Fang, J.E. Steinbrenner, F-M.Wang and K.E. Goodson, "Impact of wall hydrophobicity on condensation flow and heat transfer in silicon microchannels," *J Micromech Microeng*, 20, 045018, 2010.

[5] E.W. Washburn, "The Dynamics of Capillary Flow," *Phys Rev,* 17, 273, 1921.

CONTACT

*R. Courson; phone: +33 5 61 33 79 41; rcourson@laas.fr