Internationaler Kongress - Forum Life Science 2015, 11./12. März 2015, Technische Universität München - Garching

Controlling cellular adhesion through micro- or nanopatterning of silicone-based surfaces to improve biomedical devices for in vitro based applications

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Motivation

Flexible PDMS-Thin-Films for Biomedical Applications

- Biocompatibility
- Excellent optical transparency
- Low cost producibility

Strong hydrophobicity of PDMS limits usage in some biomedical fields

Nano/Micropatterned and Plasma Treated PDMS-Thin-Films for… [1-3]

- The manipulation of cellular processes
- Lab-on-a-Chip techniques
- Cell-based biosensors
- Topologically patterned cell culture equipment

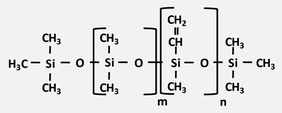
Aim

To improve the cellular adhesive behavior of PDMS thin films by a suitable surface patterning and plasma treatment
To clarify whether biological cells prefer hydrophobic or hydrophilic or dedicated rough surfaces

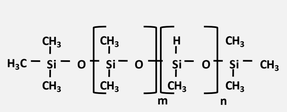
Materials

S-PDMS[4,5]

- Softness and flexibility
- Preparation from the commercially available two component PDMS system*



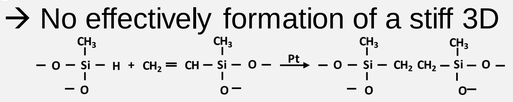
vinyl functionalized linear di-methyl-siloxane [4]



silicon-hydride functionalized linear di-methyl-siloxane [4]

H-PDMS[4,5]

- High durability, high Young´s modulus (H-PDMS: 8-12 MPa; S-PDMS: 2-3 MPa)
- Two-component system* with an additional copolymers and platinum catalyzed system
- Increasing the modulus over the value of the H-PDMS is limited → No effectively formation of a stiff 3D network

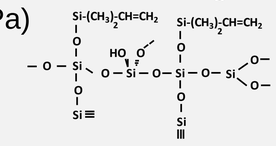


addition reaction of a silicon hydride group and a vinyl group [4]

* Dow Corning GmbH

X-PDMS[4,5]*

- Adding Q-siloxanes to a linear PDMS network → The network is cross-linked in multiple directions
- Increasing of crosslink density and stiffness of the network → Increased Young's modulus (~25MPa)



Q-branched siloxane precursor [4]

* Gelest Inc.

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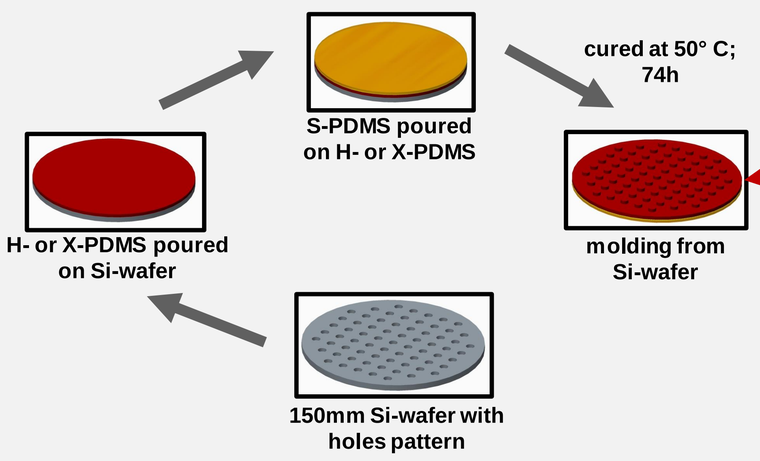
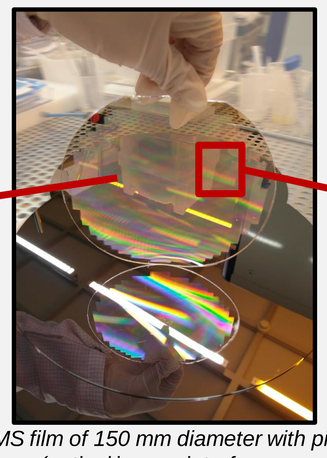
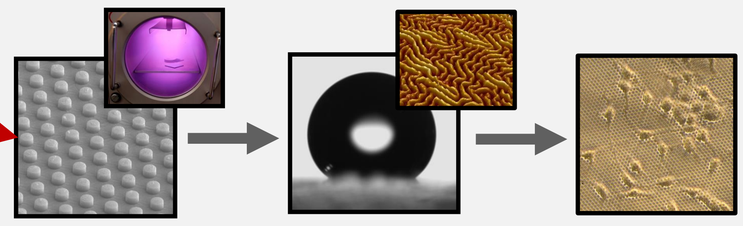
Manufacturing of PDMS-Thin-Films





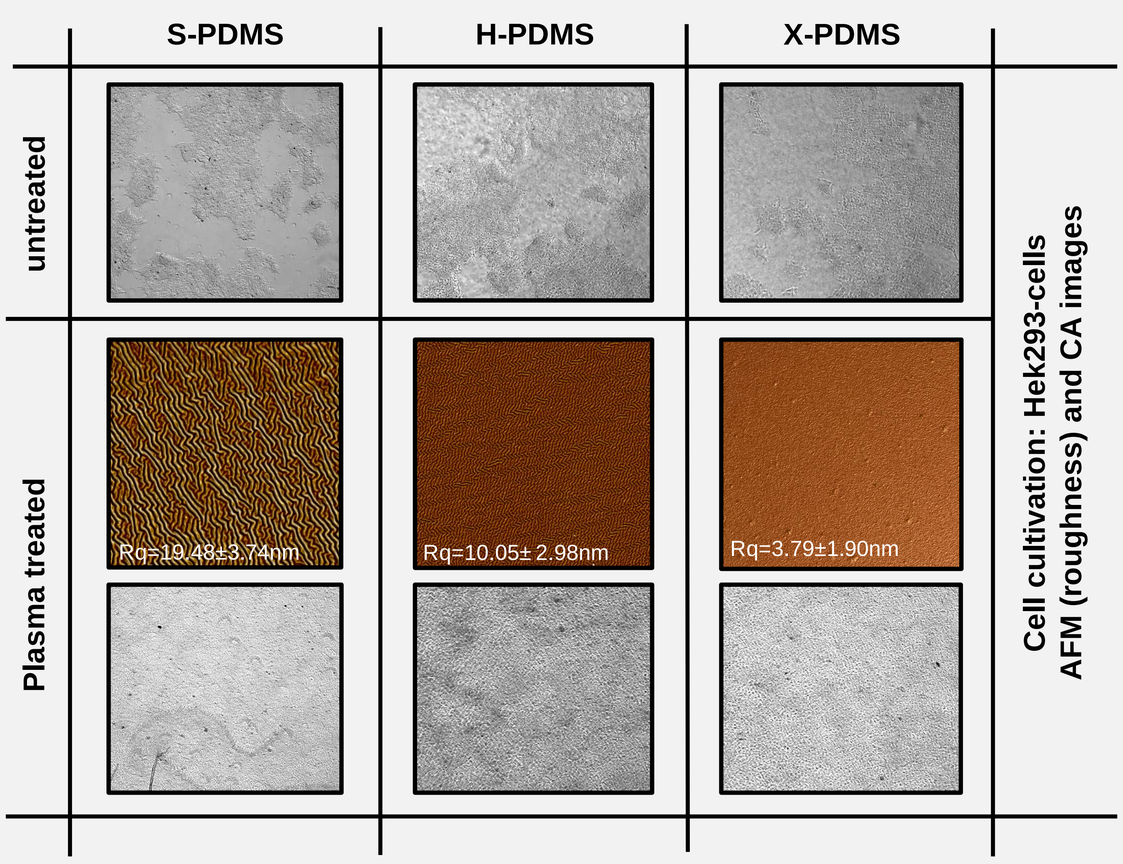
PDMS film of 150 mm diameter with pillar patterns (optical image: interference colors result from the micro-pillar patterns)

Technology **Characterization** **Cell cultivation**

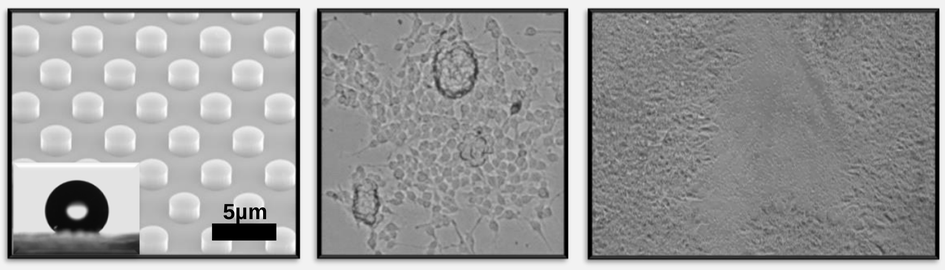


- Surface modification through micro/nano-patterning and plasma treatment (N_2/H_2/150W/10min)
- Characterization by contact angle measurements (CA), SEM analysis and atomic force microscopy
- Cell cultivation: at 37°C in standard tissue culture plates

Results of plain and patterned PDMS-Thin-Films

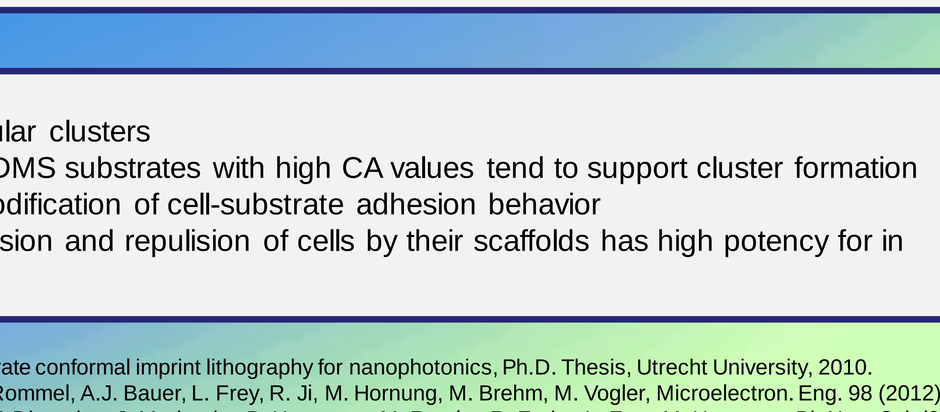


- Minor differences in CA (S: 114.6±0.5°; H: 107.4±1.5°; X: 105.3±1.5° and roughness (all PDMS types 1nm) between untreated S-, H- and X-PDMS → Poor cell adhesion behavior, agglomeration of cells increases
- Differences in Rq values and morphology between plasma treated PDMS types and drastically decrease of CA (0°)
  → Increase of functional groups
  → Higher polar component makes the surface more wettable → No cell cluster and agglomeration, Excellent cellular adhesion behavior



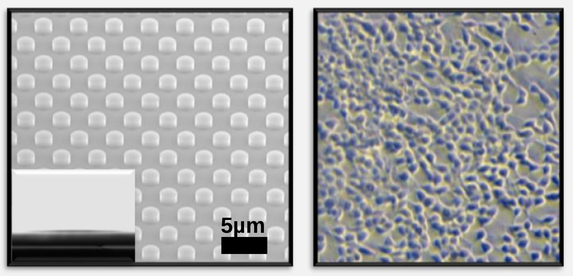
a) Untreated H-PDMS with pillars with a height of 1.8 µm and a contact angle of 138°, b) melanoma cells [6] and c) Hek cells

- Similar cellular adhesion behavior on patterned PDMS for different cell types
- Percentage of cell clusters is decreased despite of high CA



a) Untreated H-PDMS with pillars with a height of 160 nm and a contact angle of 112°, b) melanoma cells [6] and c) Hek cells

- Percentage of cell clusters is increased with CA decreasing in comparison to patterned PDMS with higher pillars



Pillars with a height of 1.8 µm and a water contact angle of 0° after plasma treatment

- Excellent cellular adhesion behavior of Hek cells on pillar patterned and plasma modified PDMS surfaces.
- No agglomeration or cell clusters

Summery

- Treatment of PDMS films with N_2/H_2 plasma decreases CA values and formation of cellular clusters
- There is no proportional relationship between CA and cell cluster formation, although PDMS substrates with high CA values tend to support cluster formation
- Patterning of the surfaces with dedicated geometry leads to an increase of CA and a modification of cell-substrate adhesion behavior
- This work has a high technological impact since regulated and topologically stable adhesion and repulision of cells by their scaffolds has high potency for in vitro as well as in vivo applications[6]

[1] H.M.L. Tan, H. Fukuda, T. Akagi, T. Ichiki, Thin Solid Films 515 (2007) 5172–5178.
[2] X. Li, N. Wu, Y. Rojanasakul, Y. Liu, Sens. Actuators, A 193 (2013) 186–192.
[3] J.Y. Park, D. Ahn, Y.Y. Choi, C.M. Hwang, S. Takayama, S.H. Lee, Sens. Actuators, B 173 (2012) 765–771.
[4] M.A. Verschuuren, Substrate conformal imprint lithography for nanophotonics, Ph.D. Thesis, Utrecht University, 2010.
[5] R. Fader, H. Schmitt, M. Rommel, A.J. Bauer, L. Frey, R. Ji, M. Hornung, M. Brehm, M. Vogler, Microelectron. Eng. 98 (2012) 238-241.
[6] M. Scharin, M. Rommel, T. Dirnecker, J. Marhenke, B. Herrmann, M. Rumler, R. Fader, L. Frey, M. Herrmann BioNanoSci. (2014), 4:251-262.