SARFUS: Application to PDMS oligomer diffusion on SiO_2 surface.

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Introduction

Sarfus is used for the investigation of surface diffusion of polydimethylsiloxane (PDMS), a very useful material in many scientific and technological areas. For example, PDMS is used to transfer patterns in soft-lithography[i,ii] (microcontact printing) or as a substrate for microfluidics[iii] and stretchable electronics[iv]. Due to incomplete curing, oligomers can diffuse on a surface and great care has to be taken not to contaminate biological species in microfluidics channels[iii] , for example. Several surface analysis techniques (ToF-SIMS, XPS, contact angle measurement, AFM, SEM) have already been used to characterize surfaces[v] that have been in contact with non-inked PDMS rubber stamps. Rapid visualisation techniques are still lacking in order to check contamination and estimate effects on analyzed structures.

In the present study, we present PDMS diffusion observed with a new technique (SARFUS) that increases the sensitivity of standard optical microscope to a point where it becomes possible to directly visualize nanometric films (down to 0.5 nanometer) and isolated nano-objects in real-time. The technique is based on the use of new nonreflecting surfaces for cross-polarized reflected light microscopy. These surfaces (called Surf) generate a contrast enhancement of about twice the magnitude, extending the application fields of optical microscopy toward the nanoworld.

Thanks to the absence of scanning, tip contact and to the capacity to work at ambient pressure, the dynamic studies of nanometric structures (eg. crystallization, wettability, evaporation, spreading…) are easily accessible and open new potentialities in various fields such as, for example, thin layers, surface treatment, self-organized structures, Langmuir-Blodgett films, biochips, lithography and nanopatterning, carbon nanotubes, nanowires....

A 3D reconstitution software (Sarfusoft) and certified calibration standard enable the access to optical thickness, roughness… of the samples. The technique can also be designed for integration in existing equipment (AFM, RAMAN…) for nano-structures pre-localization.

The present work is focused on the oligomer diffusion from 2 kinds of PDMS stamps on SiO_2 substrates.

Experimental part

Sample preparation

Dow Corning Sylgard 184 silicone rubber stamps are processed by mixing silicone polymer and curing agent in a 10:1 weight ratio. After degassing this blend under reduced pressure, the mixture is poured on flat or patterned surfaces to obtain stamps after 8 hours of curing at 80°C. Once extracted from their mould, the PDMS stamps are cleaned by dipping them 4 times during 10 minutes in a HPLC grade hexane bath at room temperature.

Surface analysis and imaging

Optical images are realized using Sarfus technology. In this study, the topmost layer of the Surf substrates is SiO_2 (`Standard Surf'). Optical images are obtained on a LEICA DM4000 optical microscope and collected via a SONY 3CCD camera. The 2D images are treated with Sarfusoft (Nanolane software) and after calibration, 3D images are generated.

During this study, Surfs covered with PDMS stamps were kept in clean and dark area at room temperature.

Results and discussion

Oligomer transfer was performed from a stamp with ridges spaced by 310 µm that are 30.4 µm wide and 119.6 µm high (Figure 1).

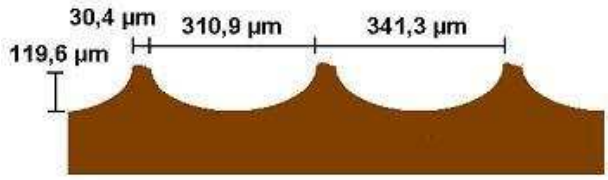
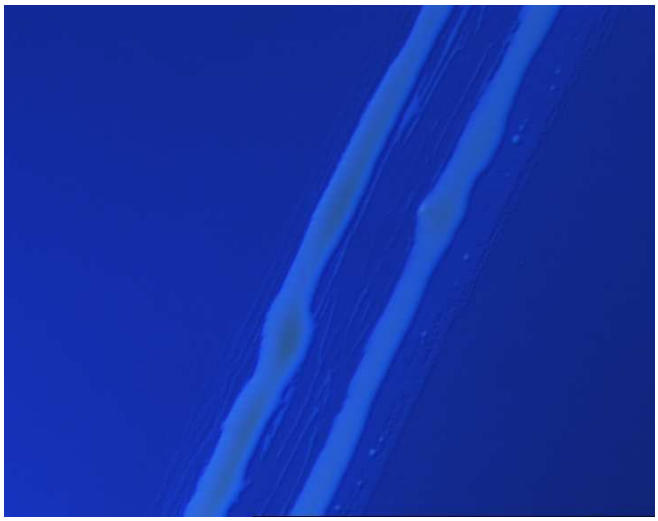
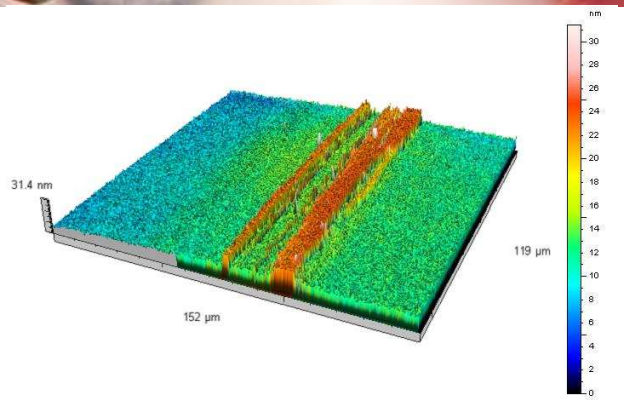


Figure 1: Scheme of the patterned stamp 310µm.

After a 2 minute contact, the patterned PDMS leaves an imprint of two separated lines instead of one waiting single line (Figures 2 and 3).





Figures 2 and 3: 2D and 3D Sarfus image of the patterned Surf (310 µm stamp).

These two discrete lines are explained by a vertical side PDMS transfer as shown on Figure 4.

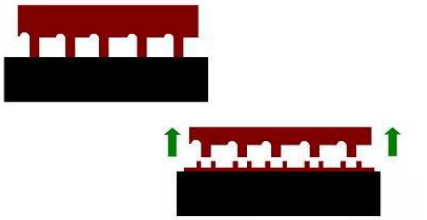


Figure 4: Scheme of the PDMS transfer from patterned stamp 310 µm towards the Surf.

The mean heights of both lines are about 19 nm (Figure 5) and lateral diffusion of matter is already visible (Figure 2) meaning that matter diffusion occurs very quickly (probably due to small oligomer PDMS fragments). The flow is not homogeneous but is characterized by structures parallel to the mean line. The thickness of the flow goes from 10 to 3 nm and its width is around 60-70 µm.

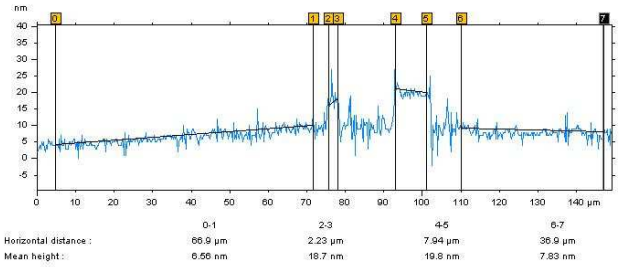


Figure 5: Section profile the patterned Surf (310µm stamp) after a 2 minute contact.

After a 40 day contact, both PDMS lines show strong increase of their thicknesses up to 40nm (Figure 6) whereas the lateral PDMS diffusion flow is wider (> 100 µm) and higher (from 15 to 19nm) than previously. Thus, the stamp seems to continue to deliver PDMS oligomer versus time.

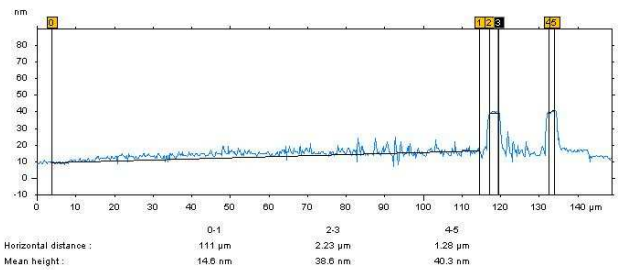
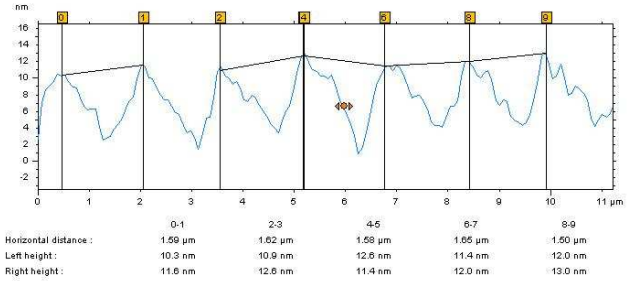
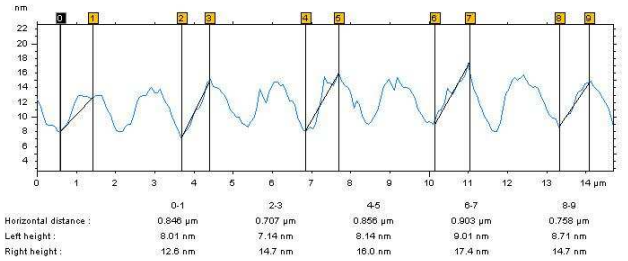


Figure 6: Section profile of the patterned Surf (310µm stamp) after a 40 day contact.

The same experience is performed with a stamp presenting ridges spaced by 1.6 µm that are 200 nm wide and 200 nm high. The height of the deposited PDMS ridges is estimated to about 11 nm with an average spacing of about 1.6 µm (Figure 7).

After a 40 day contact, the line height has increased up to 13nm whereas spaces between grooves are unchanged (Figure 8). Average height difference between holes and peaks is about 4.9 nm. This difference is lower than previously (9.1nm) meaning that PDMS oligomer has diffused between lines to increase holes thicknesses.





Figures 7 and 8: Section profile of the patterned Surf (1µm stamp) after a 2 minute and a 40 day contact.

Conclusion

The Sarfus technique has demonstrated its ability to easily and rapidly observe and characterize diffusion of PDMS from a stamp towards a SiO_2 surface as well as its lateral diffusion. The 310 µm stamp leaves an imprint of two separated lines due to vertical PDMS transfer from the grooves. Studies versus time have shown that after 40 days, the thickness of the line and the diffusion area have increased. This demonstrates that a continuous flow of matter coming from the stamp and going towards the surface is present. These observations provide us with a better understanding of the transfer and diffusion of PDMS oligomers on substrates.

Contribution/advantages of Sarfus

- Direct and fast visualisation of the quality of the stamp
- Capacity to analyse soft materials
- Analyse at room temperature and atmospheric pressure
- Non-invasive/non contact technique

References

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