Femtosecond Laser-Textured Moulds for High-Precision PDMS Surface Engineering

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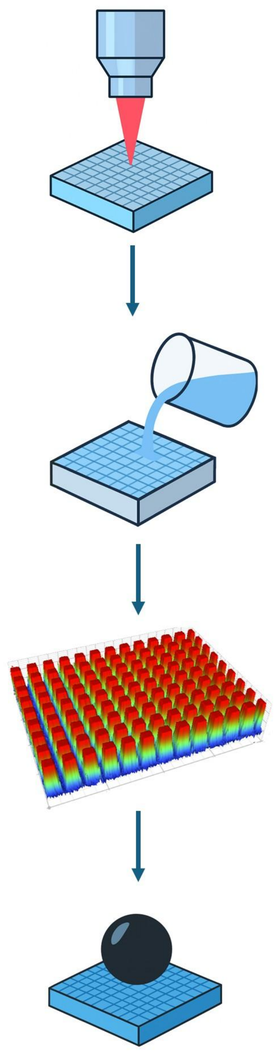
Introduction

Surface microstructuring of polymers like polydimethylsiloxane (PDMS) is essential for an advanced fluid control in biomedical and microfluidic systems. Although Soft Lithography is widely used, it often relies on mould fabrication processes that are complex, time-consuming and inflexible.

In this work, we present a femtosecond laser-based approach for the rapid and mask-free fabrication of aluminum moulds, eliminating the need for chemical agents. The laser-induced structures consist of grid-like patterns, precisely engineered by adjusting the hatch distance and number of scan repetitions. Replication fidelity and contact angle measurements were performed to assess the reproducibility of the features and the tunability of the resulting superhydrophobic surfaces.

Process Overview



- TruMicro Femto **Laser texturing** of Aluminium AA2024 mould, 5×5×0.1 cm^3 in size
- **PDMS replication** by casting and curing for 3h at 60°C of SLYGARD elastomer (1:10)
- **Surface analysis** by using ZEISS GeminiSEM 480 electron microscope and Bruker Countour x100 profilometer
- **Contact angle analysis** by using a DataPhysics OCA25 and long-term stability assessment

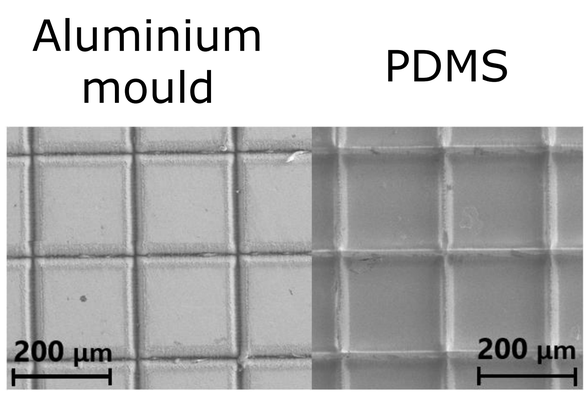
Aknowledgements

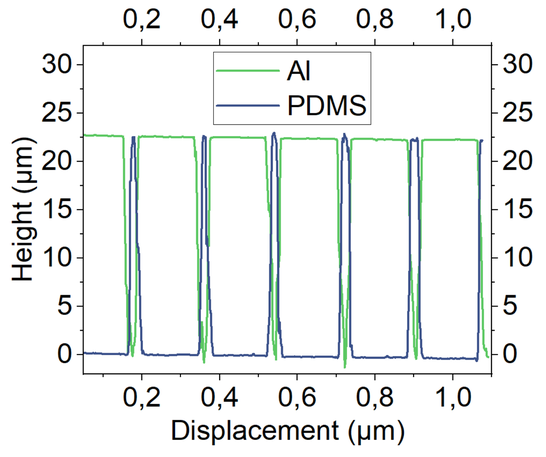
This work was supported by MUR in the framework of the PRIN 2022 PNRR Project (grant number: Prot. P2022LMRKB) and the project "Quantum Sensing and Modeling for One-Health (QuaSiModO)" (CUP:H97G23000100001).

Contacts and Infos

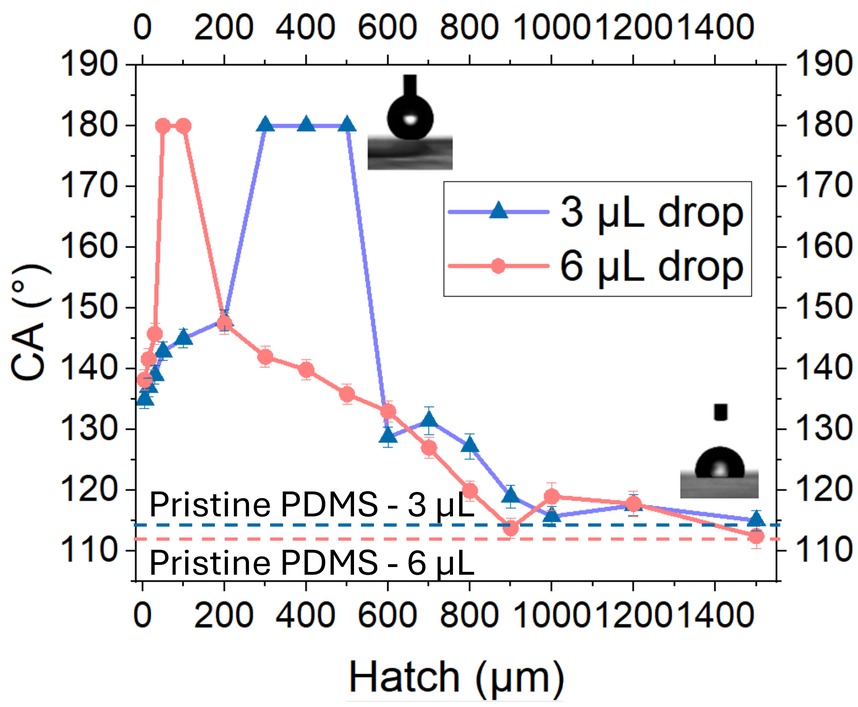
Results & Discussion

- **High-fidelity surface replication**
  Microstructures were accurately transferred from laser-textured aluminum moulds to PDMS. The relative replication error was found to be ~ 2%, as confirmed by SEM and profilometry.





- **Microstructure-dependent wettability**
  Contact angles varied with hatch distance and number of laser scans, reaching superhydrophobicity (CA > 150°) at 30 scans and 100–500 µm spacing, depending on the droplet volume.
- **Volume effect on wetting behavior**
  6 µL droplets reached superhydrophobic conditions at lower hatch distances than 3 µL ones, likely due to enhanced air retention.



- **Stable surface performance over time**
  Wettability properties remained consistent after four months, indicating excellent durability.

Conclusions

Fs-laser texturing enabled the fabrication of aluminum moulds with controlled microstructures. Accurate PDMS replication led to tunable surface wettability, governed by hatch distance and scan number. Surface functionality remained stable over four months, confirming the robustness of the approach.