2-Step Photolithography for Fabrication of High Aspect Ratio SU-8 Rings

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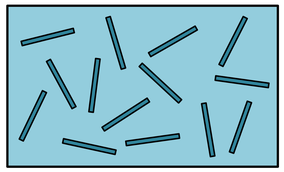
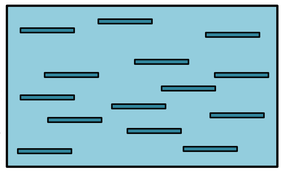
Motivation

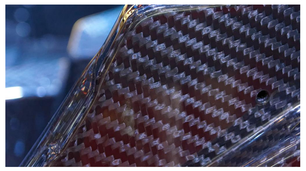


Isotropic:
Particles are at various angles of rotation



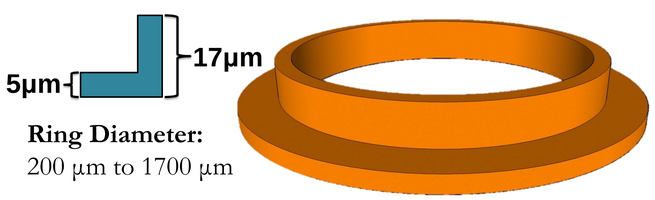
Anisotropic:
Particles are parallel, aligned along a single axis

Anisotropically ordered particles provide benefits, like increased strength/flexibility in carbon fiber or Kevlar.



However, achieving anisotropic ordering is difficult, because particles tend to distribute fairly randomly

All particles are expected to rotate in fluid flow., but there exist some shapes that should, in theory, reach an equilibrium orientation and cease rotation entirely. Rings with "L" shaped cross sections are one such shape.

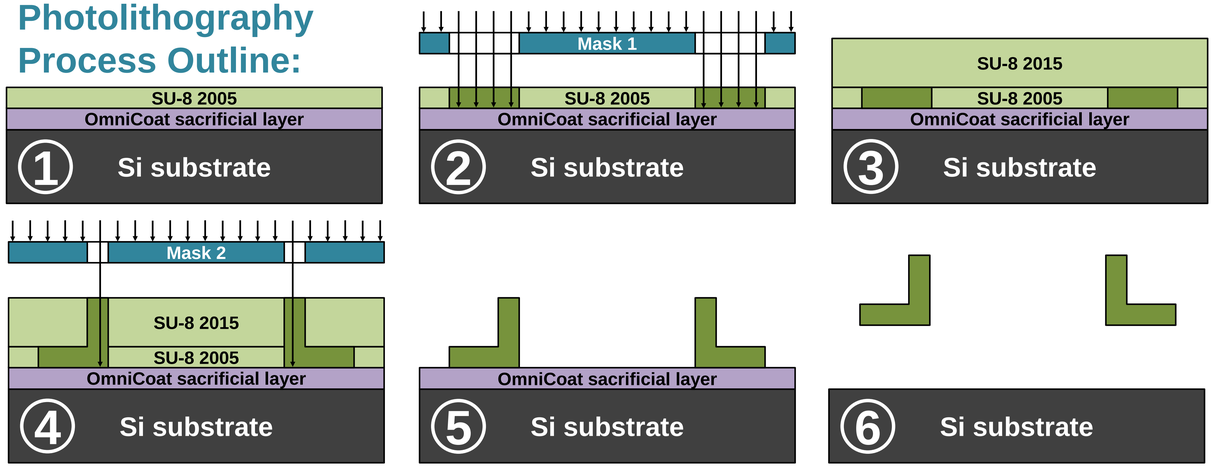


Ring Diameter:
200 µm to 1700 µm

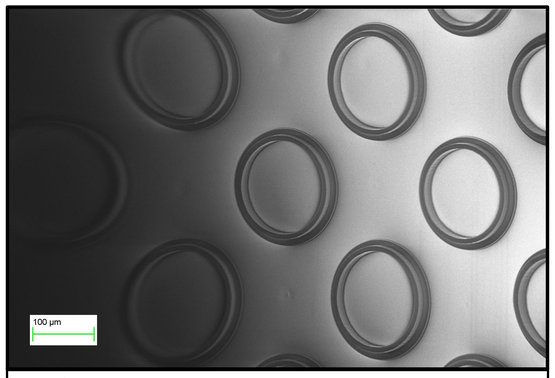
Results

For this project, we have designed a process to physically fabricate particles of this shape out of SU-8 photoresist. This process can now be used in future research, to produce more of these particles and experimentally observe the equilibrium behavior predicted.

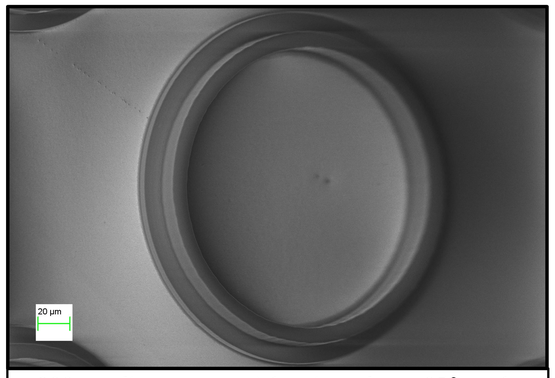
Photolithography Process Outline:



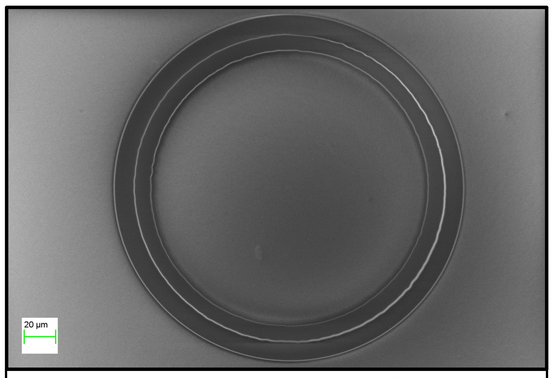
1. A sacrificial layer of OmniCoat is spun onto a silicon wafer, followed by a 5µm layer of SU-8 2005
2. The SU-8 2005 is exposed to UV light with a mask to form the bottom portion of each ring
3. After a post bake step to ensure the first layer's stability, a 12µm layer of SU-8 2015 is spun on top
4. The newly added SU-8 2015 is exposed using a second mask, in order to build the upper part of each ring
5. SU-8 developer is used to dissolve away unexposed SU-8, leaving an OmniCoat surface covered in rings
6. The OmniCoat is dissolved in Remover PG, freeing the ring particles from the wafer's surface



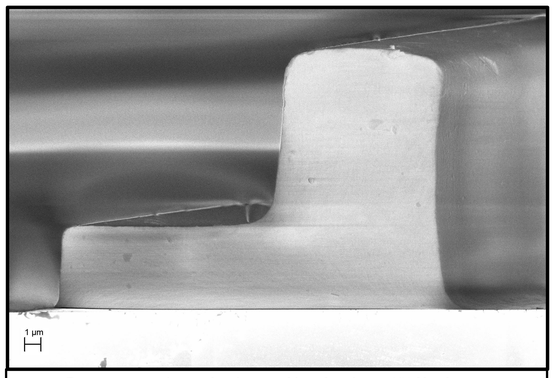
Rings arranged as they appear on the wafer



200µm diameter particle, viewed at a 35° angle



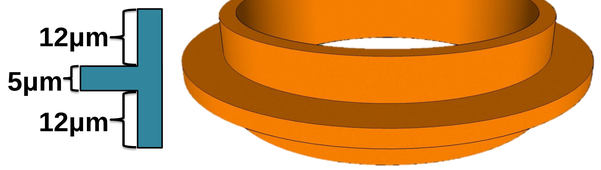
200µm diameter particle, viewed from above



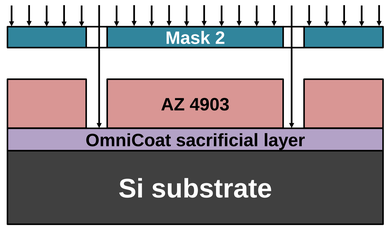
Cross sectional view, displaying "L" shape

Other Explorations:

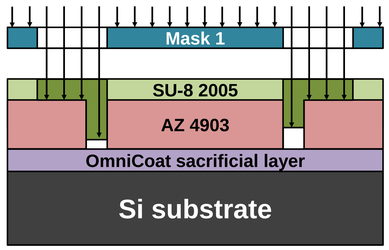
There exists another, more desirable particle shape which possesses what's known as "fore-aft symmetry".



This symmetry causes the particle to resist drifting motion, making it easier to view for experimental study.



We made attempts to fabricate this shape by building "trenches" out of a positive photoresist such as AZ 4903, and then filling those trenches with SU-8.



Preserving the ring structure proved to be quite difficult due to solvent diffusion at boundaries, and inability to fill the trench to the entire depth.

Conclusion

- "L" shaped rings of aspect ratio 12 to 100 have been built, and shown to be structurally stable during lift-off
- Work on fore-aft symmetric particles provides insight for future attempts to create-ring shaped particles with an overhang

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References

Badaire, Stéphane, Cécile Cottin-Bizonne, and Abraham D. Stroock. "Experimental investigation of selective colloidal interactions controlled by shape, surface roughness, and steric layers." Langmuir 24.20 (2008): 11451-11463.
Bohl, Benjamin, Reinhard Steger, Roland Zengerle, and Peter Koltay . "Multi-layer SU-8 lift-off technology for microfluidic devices." Journal of Micromechanics and Microengineering 15.6 (2005): 1125.
Carbon fiber image: https://commons.wikimedia.org/wiki/File:%22_13_-_ITALIAN_automotive_engineering_-_Alfa_Romeo_4C_chassis_-_monocoque_carbon_fiber_DxO_12.jpg
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