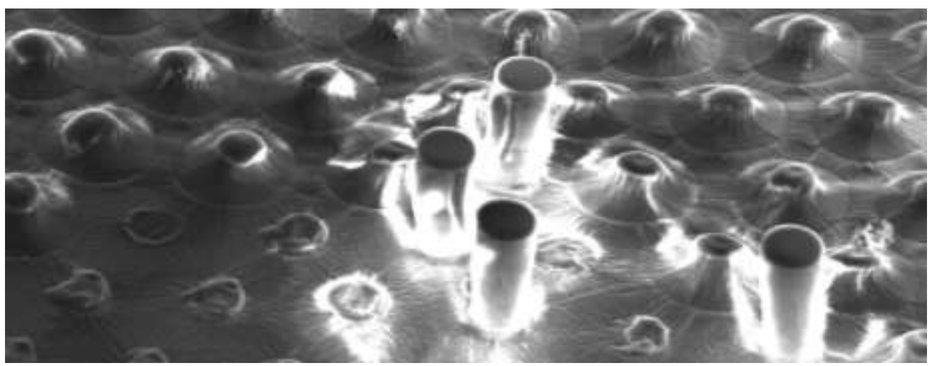
Creating Adhesive Samples of Methacrylate based Shape Memory Polymers with Bioinspired Micropatterned Surfaces



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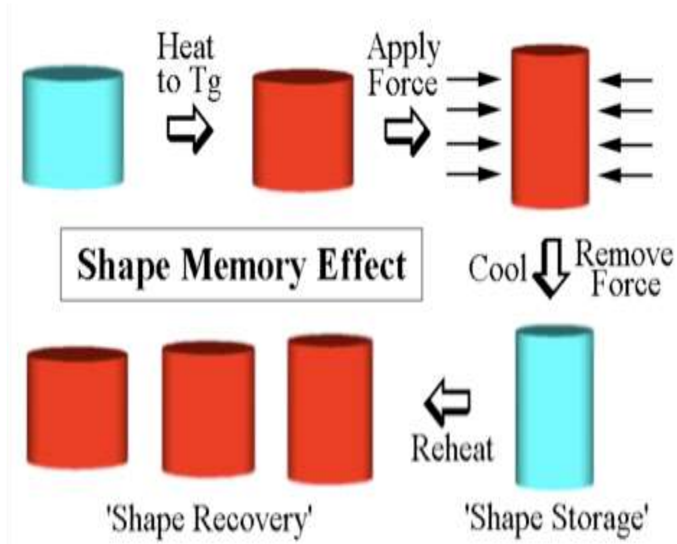
Shape Memory Polymers

- A polymer with the ability to be heated and cooled through its transition stage to retain a new shape, and return to its original shape upon reheating to the transition point.

- Using cross linkers and linear builder molecule chains, Shape Memory Polymers (SMPs) retain their shape due to chemical, rather than physical, properties.

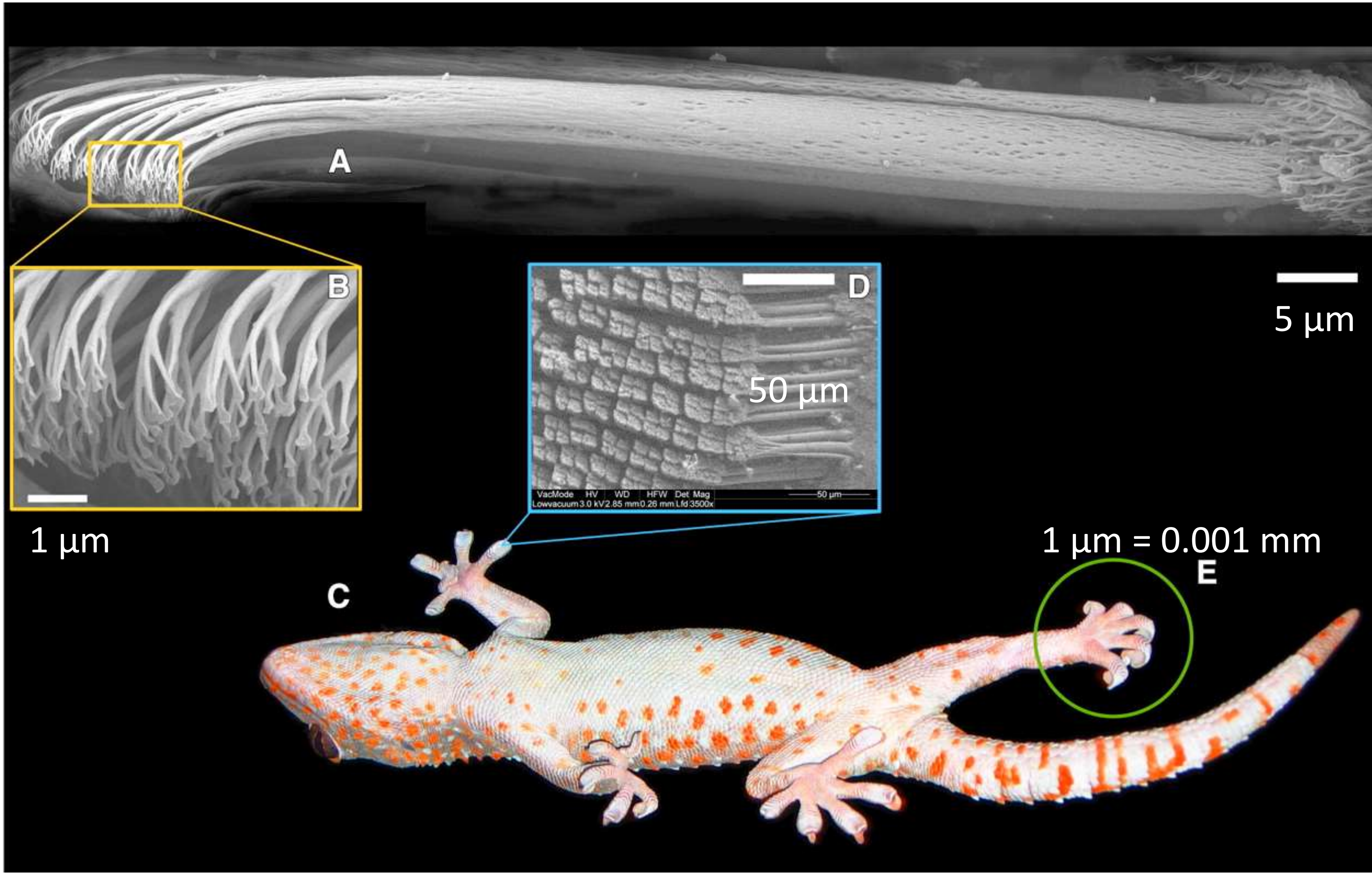


Bioinspired Micropatterned Surfaces

- Micron-sized pillars are used by many insects and reptiles to adhere and then easily detach themselves from most types of surfaces
- The remarkable properties of these micro sized pillars (or hairs) is based on a complex physical geometry, chemistry, and mechanical stiffness that draws on intermolecular forces to adhere the exterior to seemingly impossible angles and surfaces.

(a) Close up of geckos foot (b) SEM close up of micron-sized pillars on geckos foot

- Gecko feet have small hairs called setae
  - Fibrillar structures (i.e. long and skinny) that fan into smaller spatula
    - Geometrically very compliant allowing for good contact with rough surfaces
    - Cumulative van der Waals forces of all spatula enough to support gecko



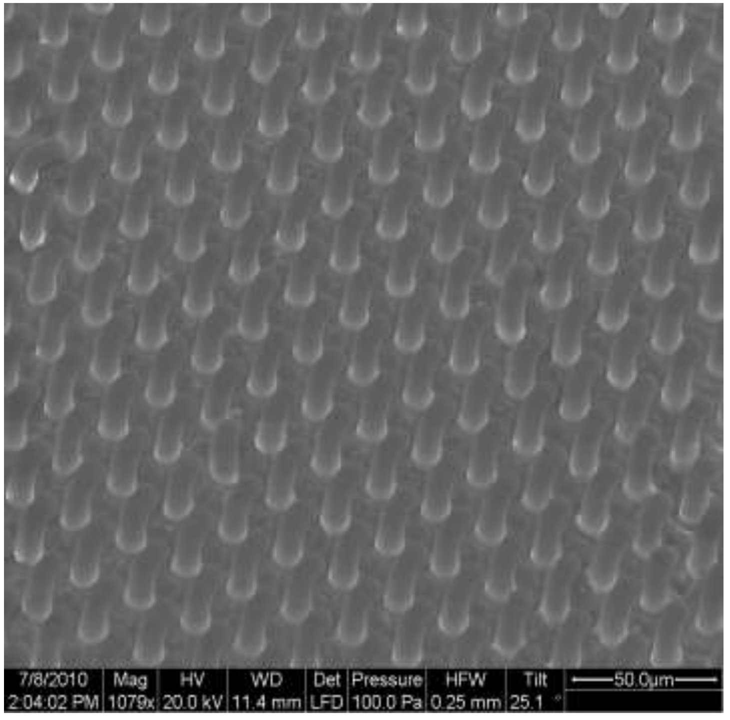
Purpose

- To make micropatterned surfaces using SMPs, using their dramastic change in storage modulus with temperature to create ‘switcheable adhesion’.

- Preliminary tests using the surface in Figure 2 demonstrated this.

Purpose

Fig 2: An SEM picture of a well-formed adhesion sample. Micro pillars are well formed and even.



Micropatterned Switcheable Adhesive Surfaces

- Using photolithographic forms, it is possible to mold a field of similar sized hairs
- Using shape memory polymers, a surface would be soft and adhesive at 50 degrees Celsius, and to hard to be adhesive at room temperature (or below).
- By using shape memory polymers, the structure and adhesive ability would not be compromised by repeated changes in temperature and phases.

Dynamic Mechanical Analyzer Tests

- To test changes is phases, DMA tests were run of The SMP consisted of crosslinkers poly(ethylene glycol) dimethacrylate (PEGDMA with a molecular weight of Mn=550 and di(ethylene glycol) dimethacrylate (DEGDMA) 95%, and linear builder tert-Butyl acrylate (98%) (tBA). The crosslinker was a mix of a 7:3 ratio of PEGDMA to DEGDMA, and the photoinitiator or thermal initiator used was added as 0.1% of the total weight. The ratio of crosslinker to tBA was changed to range from 1:99 to 80:20.

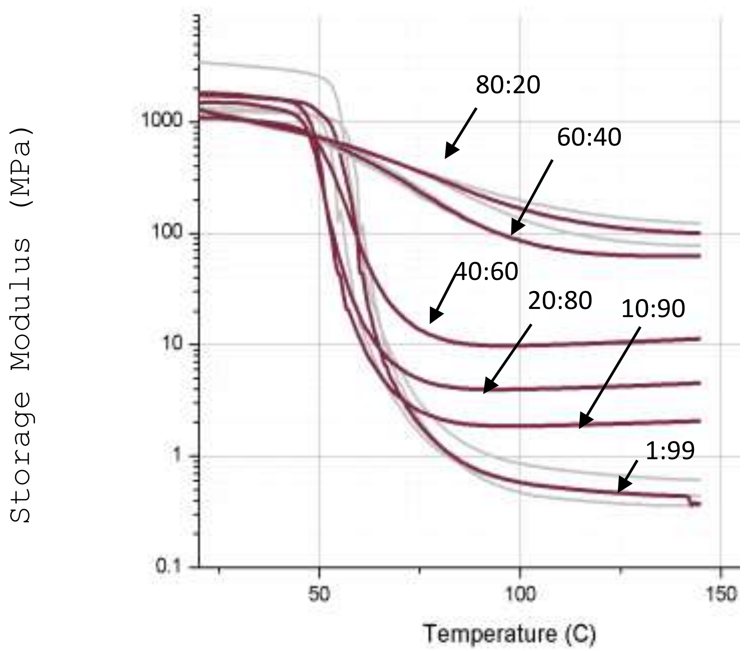
- Finding a SMP with a storage modulus between 1 and 10 MPa and a glass transition phase around 50-60˚C

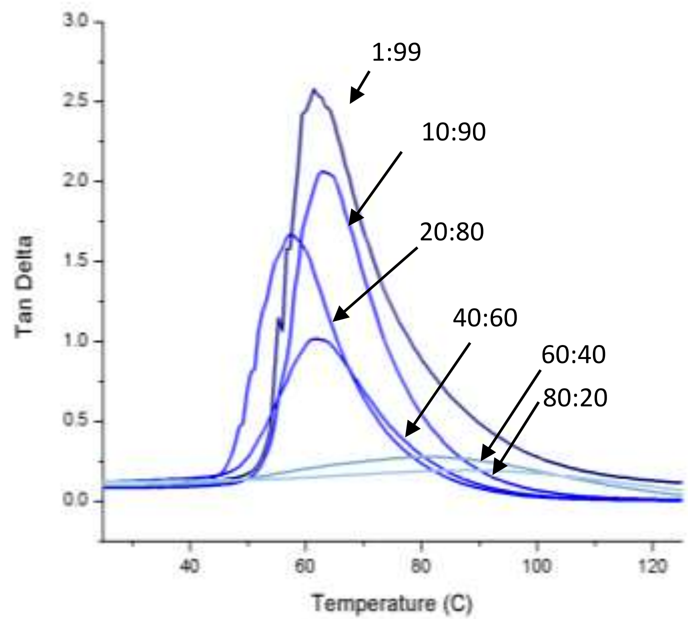
- A ratio of 20:80 crosslinker to tBa linear building was found to show the desired qualities and was used in all subsequent research

Dynamic Mechanical Analyzer Tests

Figure 2 (a) shows graphs of the average storage modulus for various SMP ratios of crosslinker to tBA in dark, with light grey lines representing individual tests that were used to obtain the average data.

Figure 2 (b) Shows the Tan Delta graphs of various SMP ratios. The high point on each curve represents the glass transition point, Tg.





Molding Process

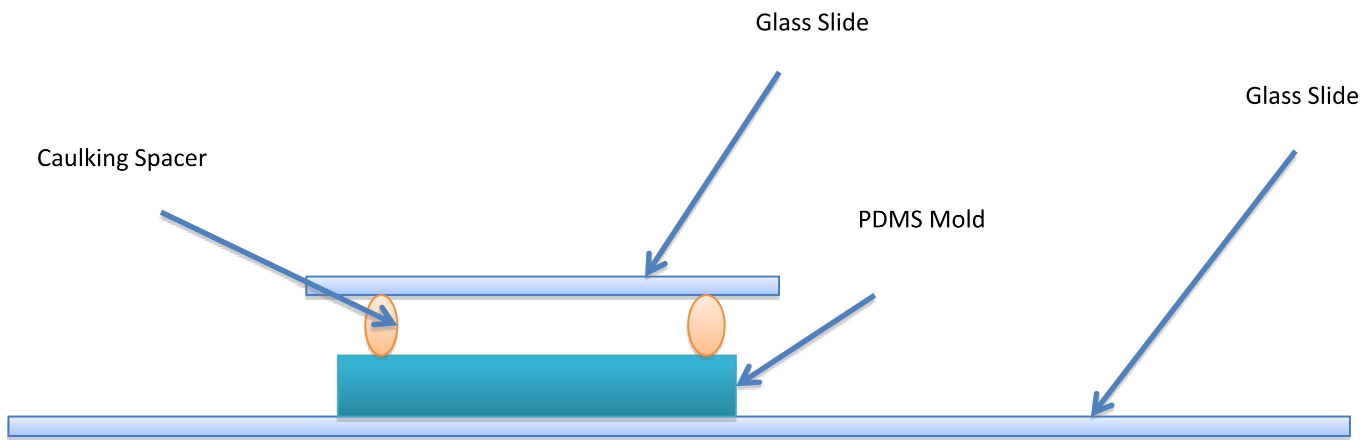
- Photolithographic silicate plates with the micropillared surface were created by our collaborators at the Leibieniz institute for New Materials in Saarbrucken, Germany.
- PDMS (Sylgard-184 silicon elastomer) molds were created from the plates, and were salinized before use using a Nalgene desiccator with a vial of 30-50µl 1H, 1H, 2H, 2H-Perflourooctyltrichlorosilane and 2 ml n-Hexane puriss

Molding Process

- A new molding process had to be developed
- 6+ processes tried
  - Greases
  - Caulking
  - UV light setup
  - Attachment methods
  - Glass slide set-up
  - Thermal/UV Curing

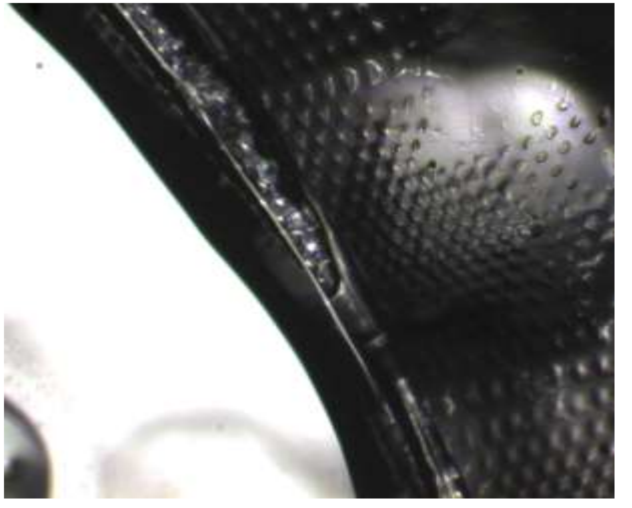
Molding Process

a side view of the basic, and primarily used, molding set up.



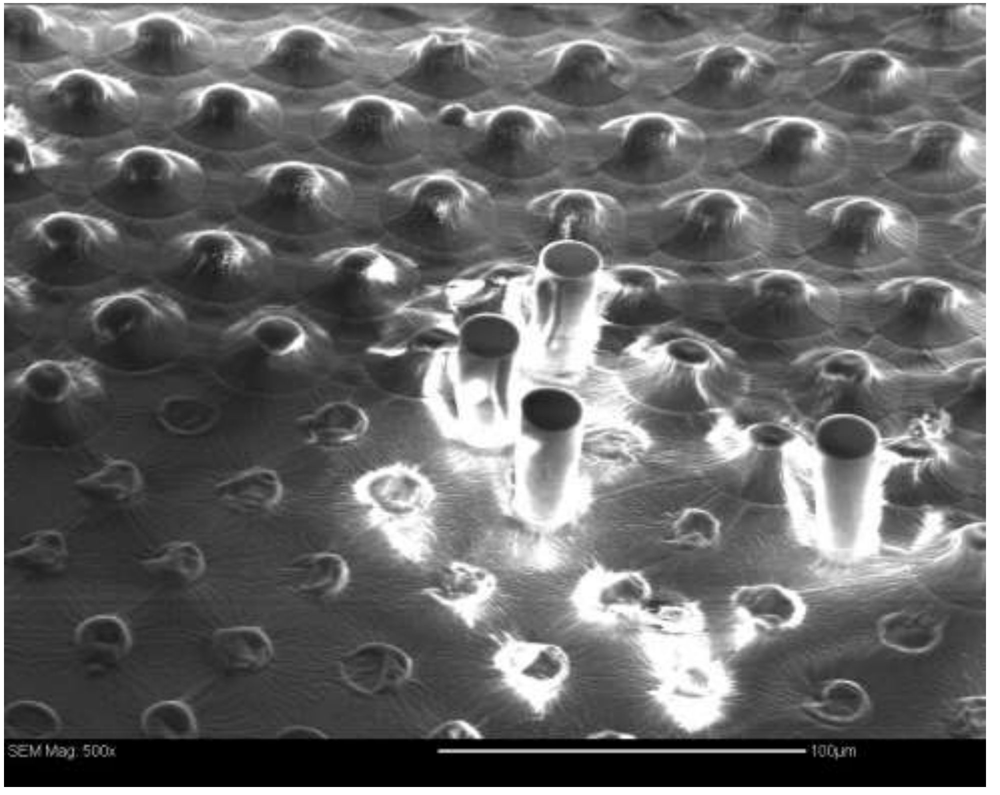
Molding Process

Fig. 4: a concave sample with small and incomplete pillar formations. Picture taken with an optical microscope.



Molding Process

Fig 6: SEM pictures showing several well-formed pillars in fields of torn pillars. Pillars are also shown that tore off and fell onto surface.



Molding Process

- The primary problem we faced was an inability to remove samples without tearing, and to keep samples from pulling out of molds before the process was completed

- To overcome this, many different procedures were tried

Molding Process

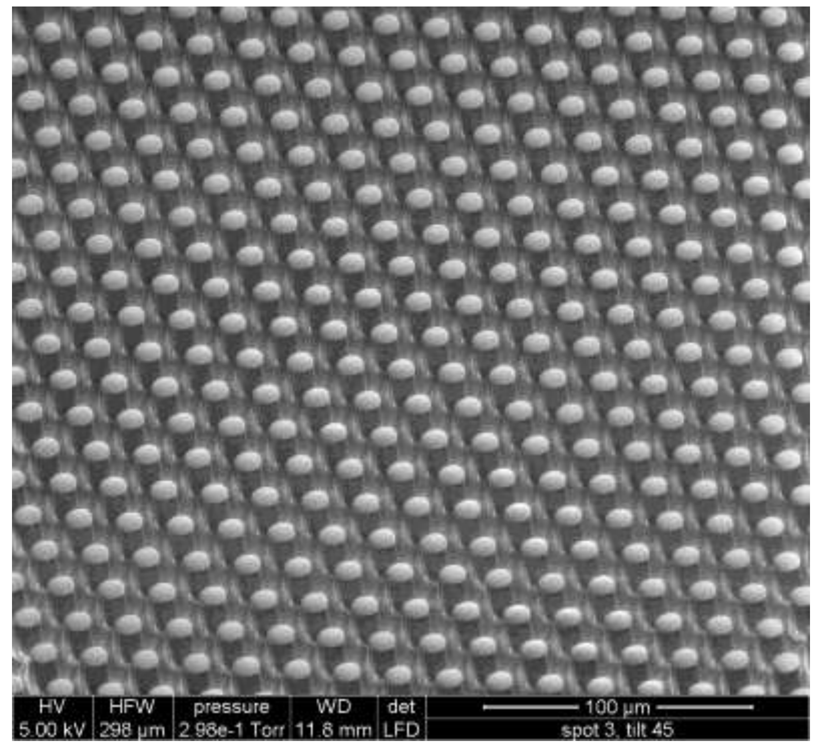
- Greases
- Caulking Methods
- UV light setup
- Compression
- Cooling
- Salinization of molds
- Thermal Curing

Molding Processes

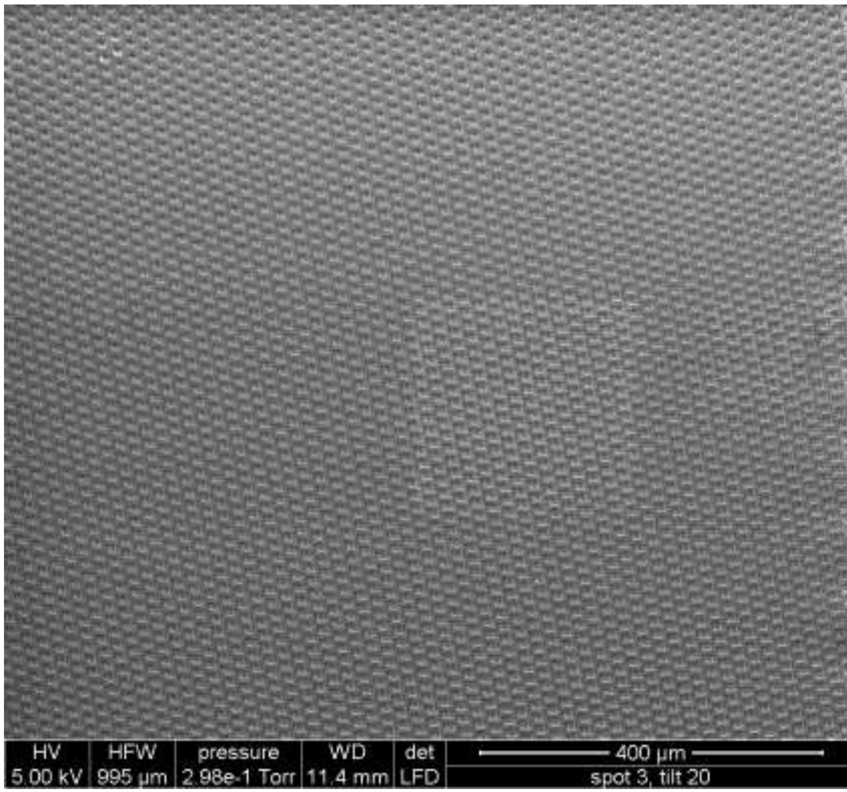
- Finally, using thermal initiators, a process was formed
  - Thermal initiators allowed the process to occur over several days, creating a more stable reaction

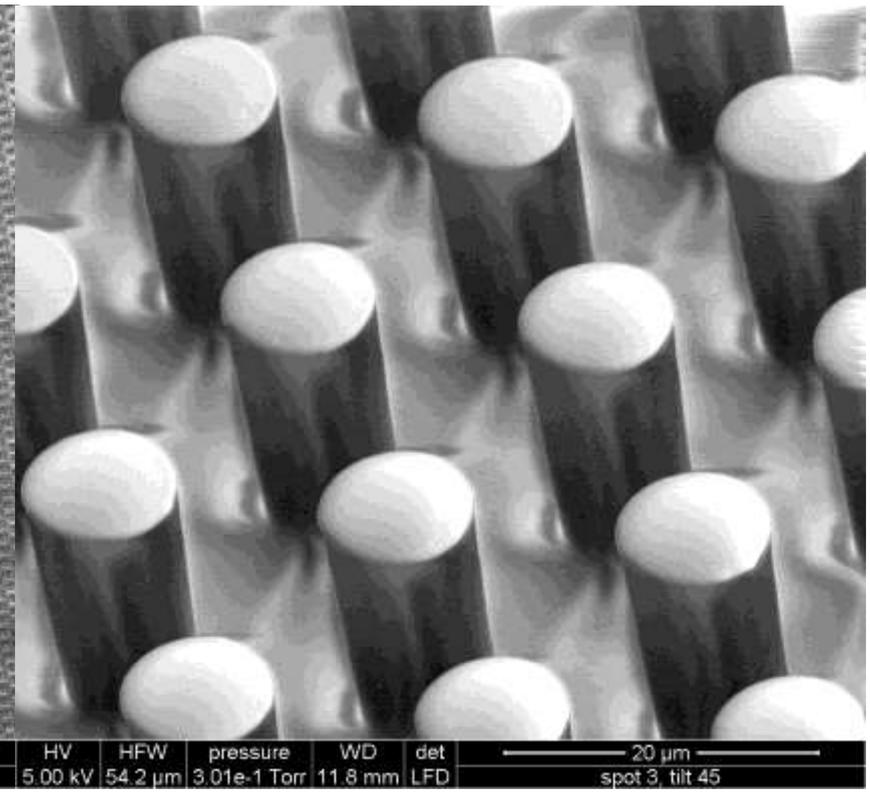
Final Results

Fig 7 Complete Pillar Fields Created using these processes



Final Results





Conclusion

- A successful process for creating switchable adhesive surfaces was found, and the experience gained provides a firm understanding of the project and the use of shape memory polymers and micropatterned adhesive surfaces.