Surface Topography Measurement using GelSight Elastomeric Sensor

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What is GelSight?

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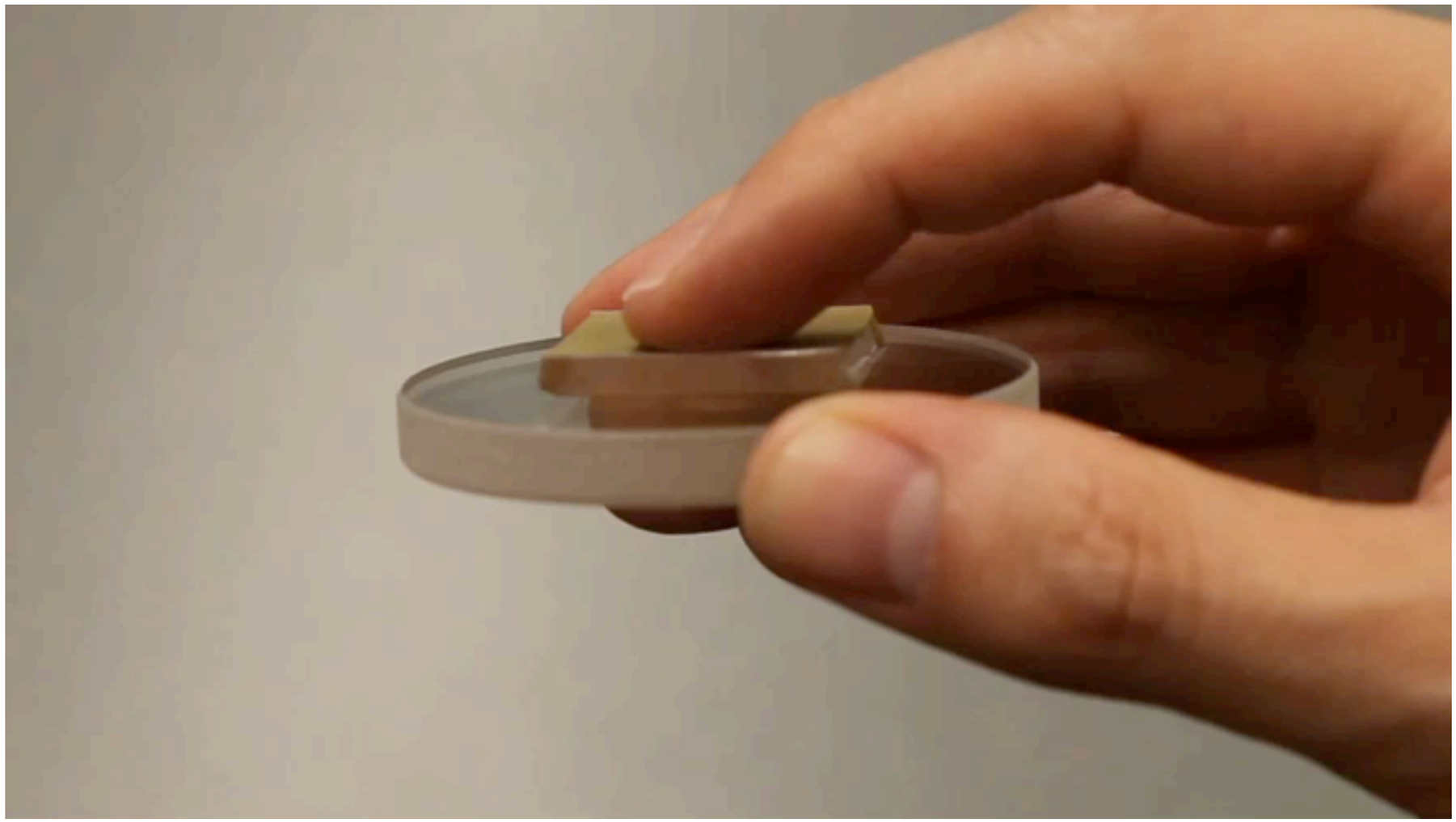
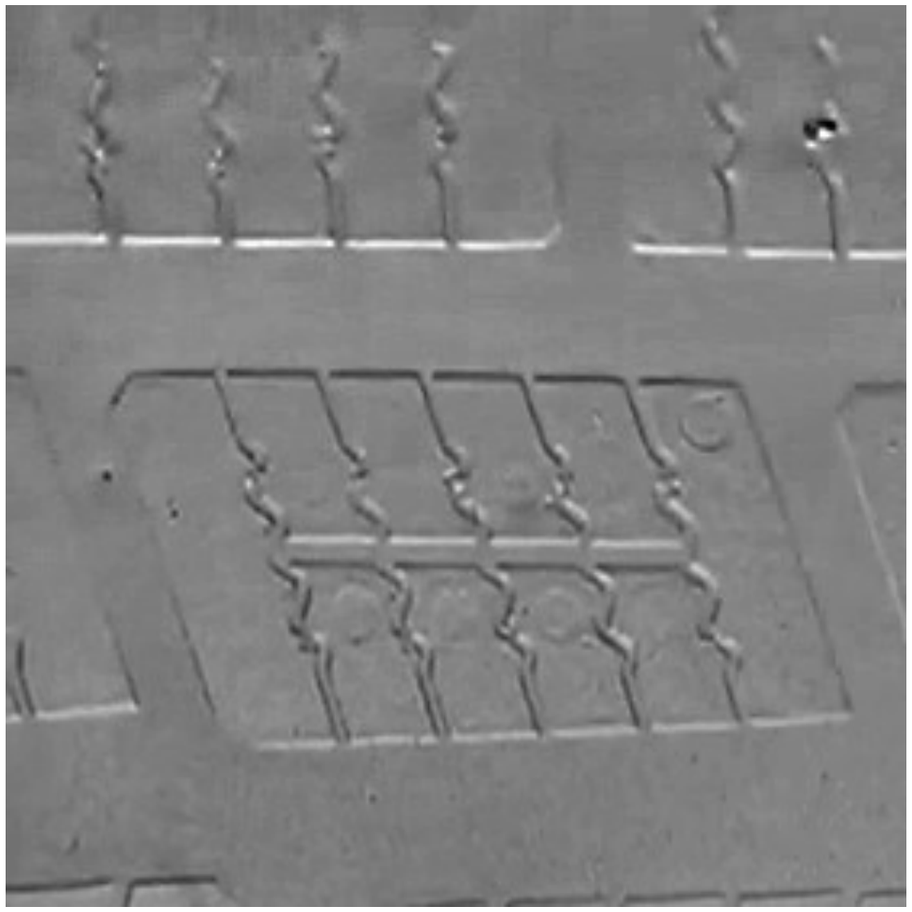


Why is it difficult to measure surface geometry?

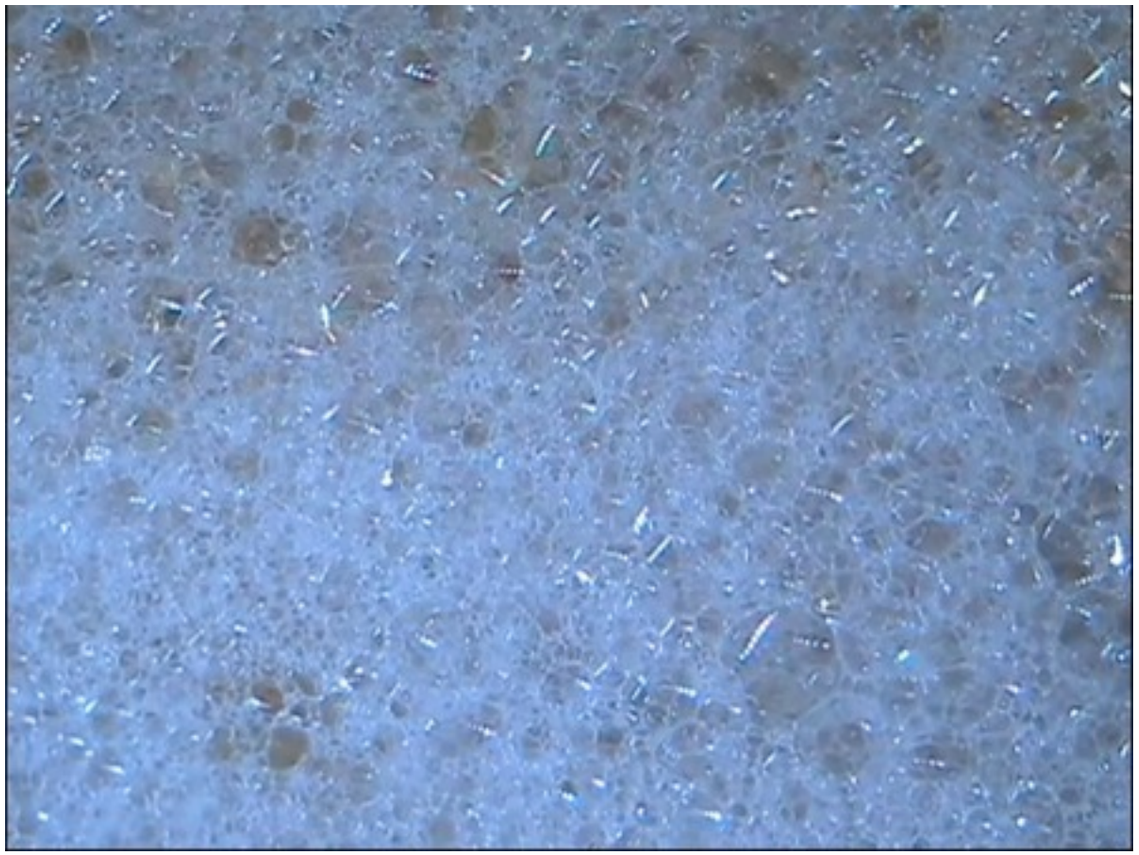
Emery board

Hard elastomer



Tire tread

Soft elastomer



Soap bubbles

Bubbles touching GelSight

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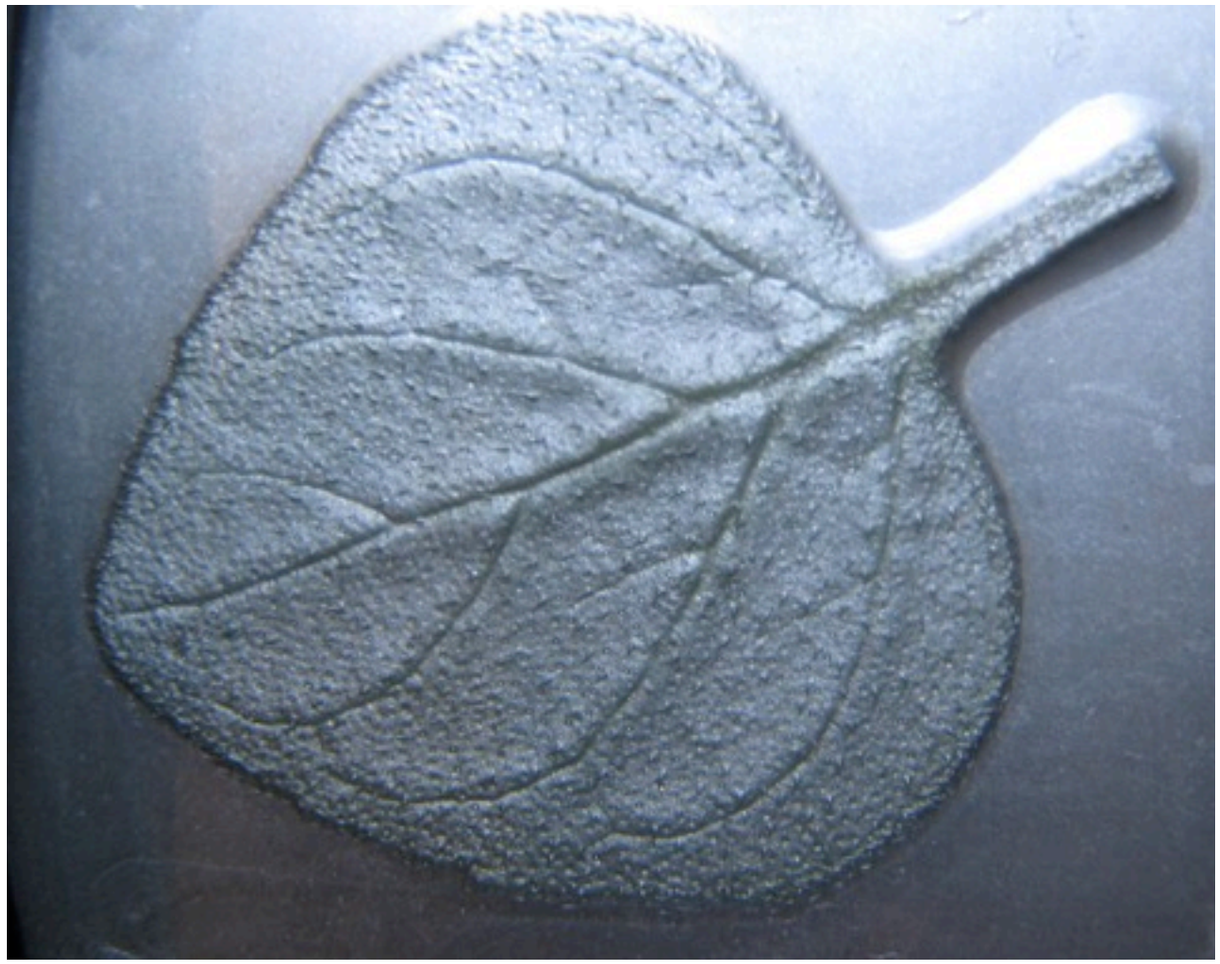
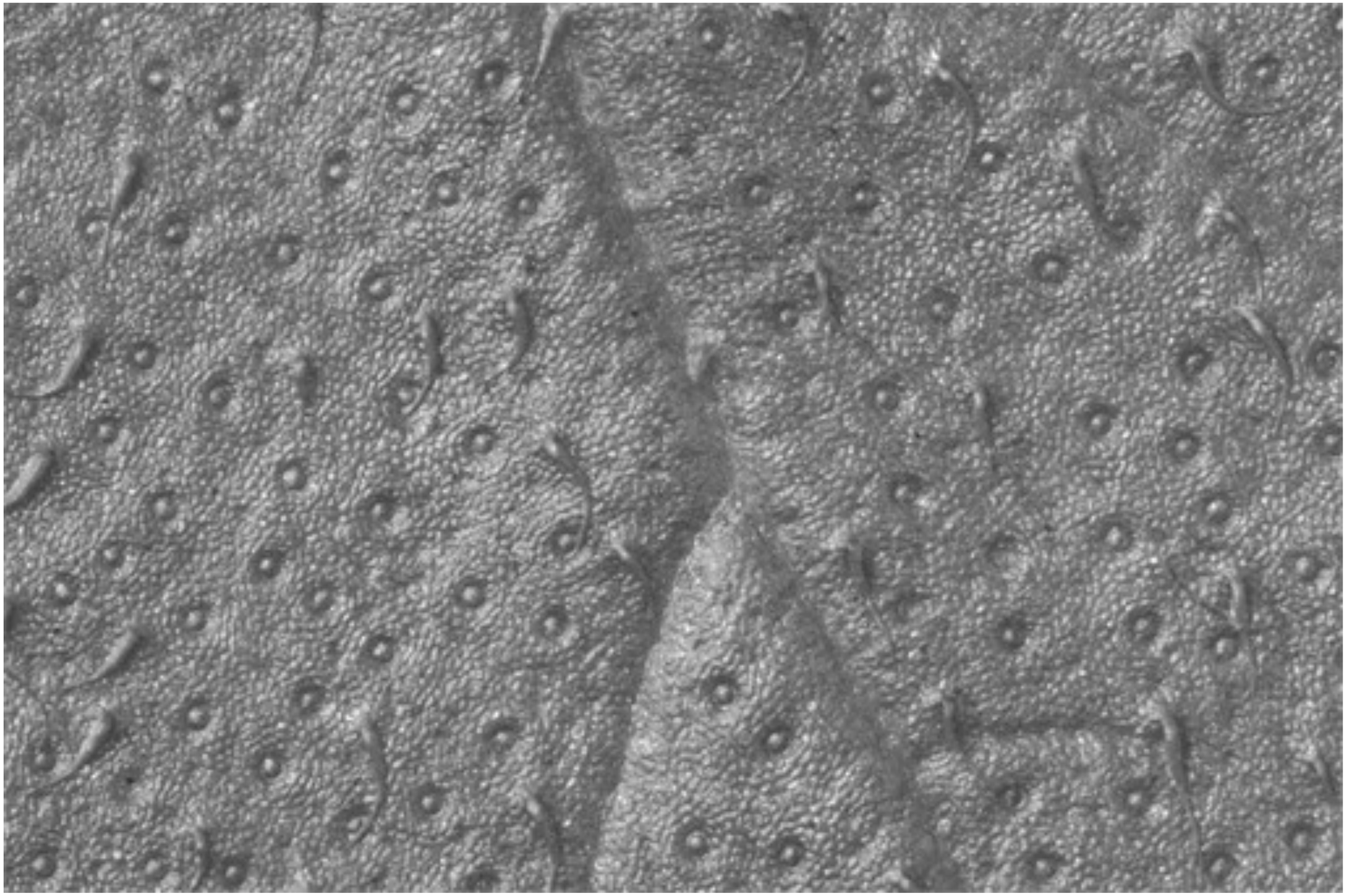
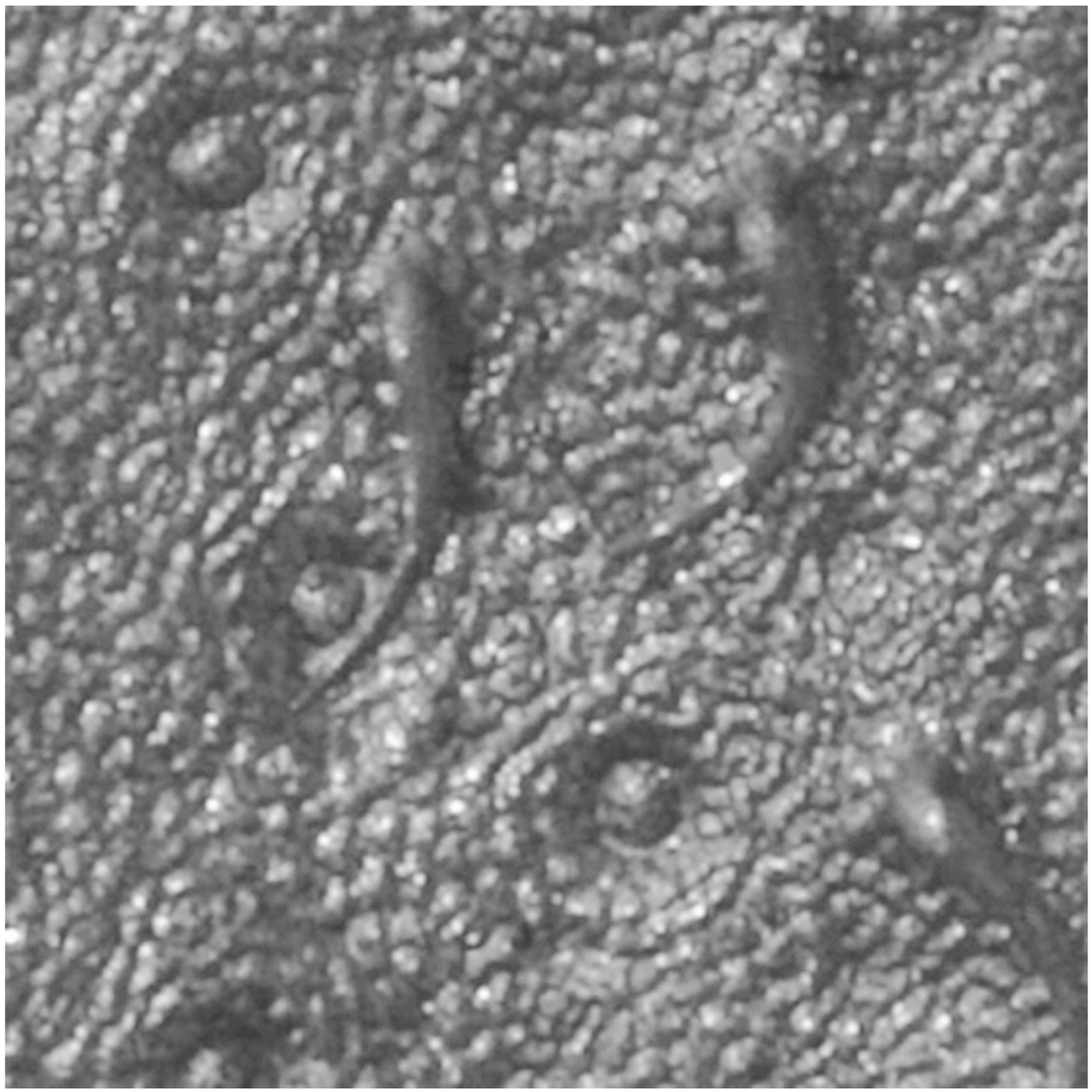
Oregano leaf



Oregano leaf: close-up



Oregano leaf: close-up



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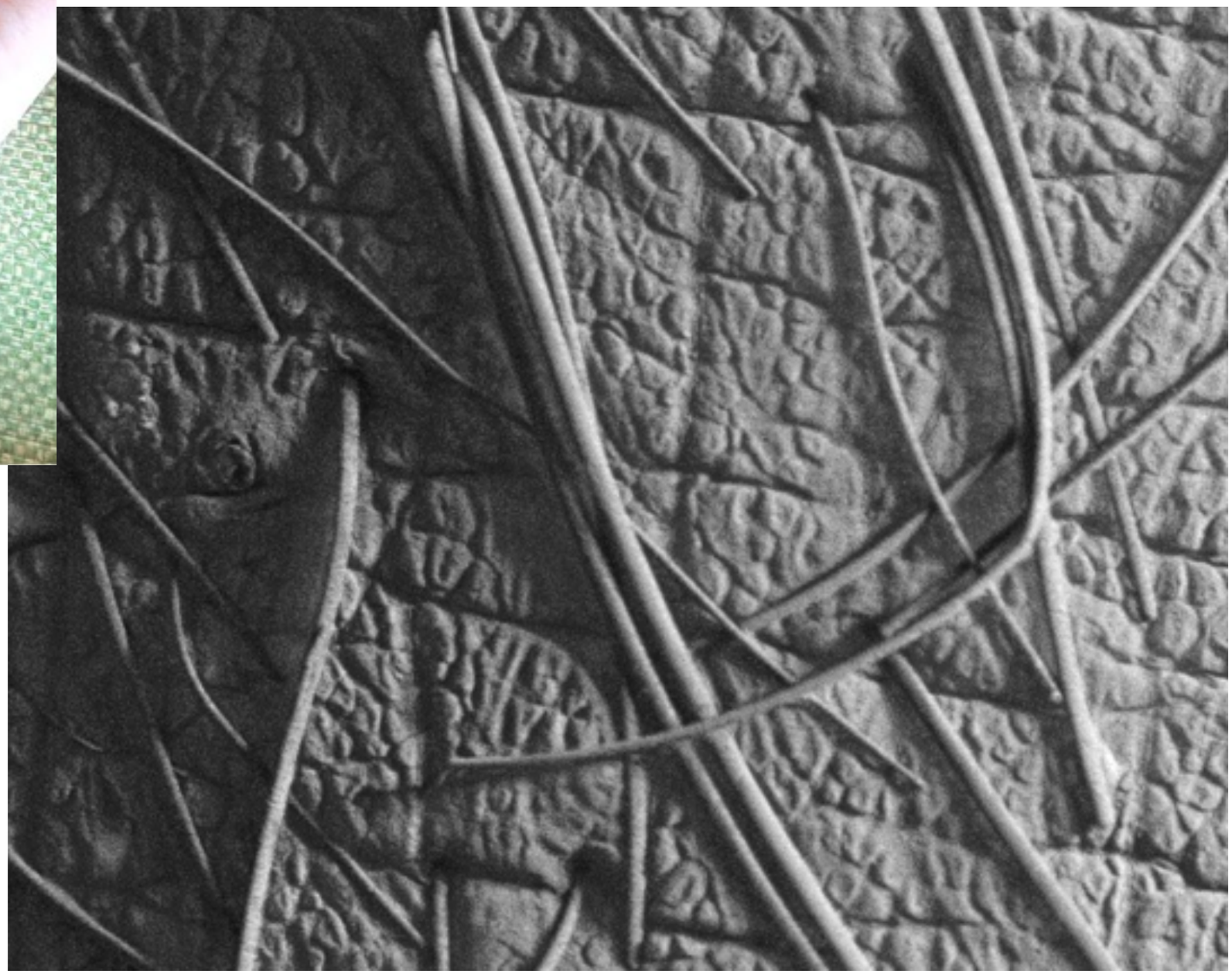
Skin topography



How does GelSight work?

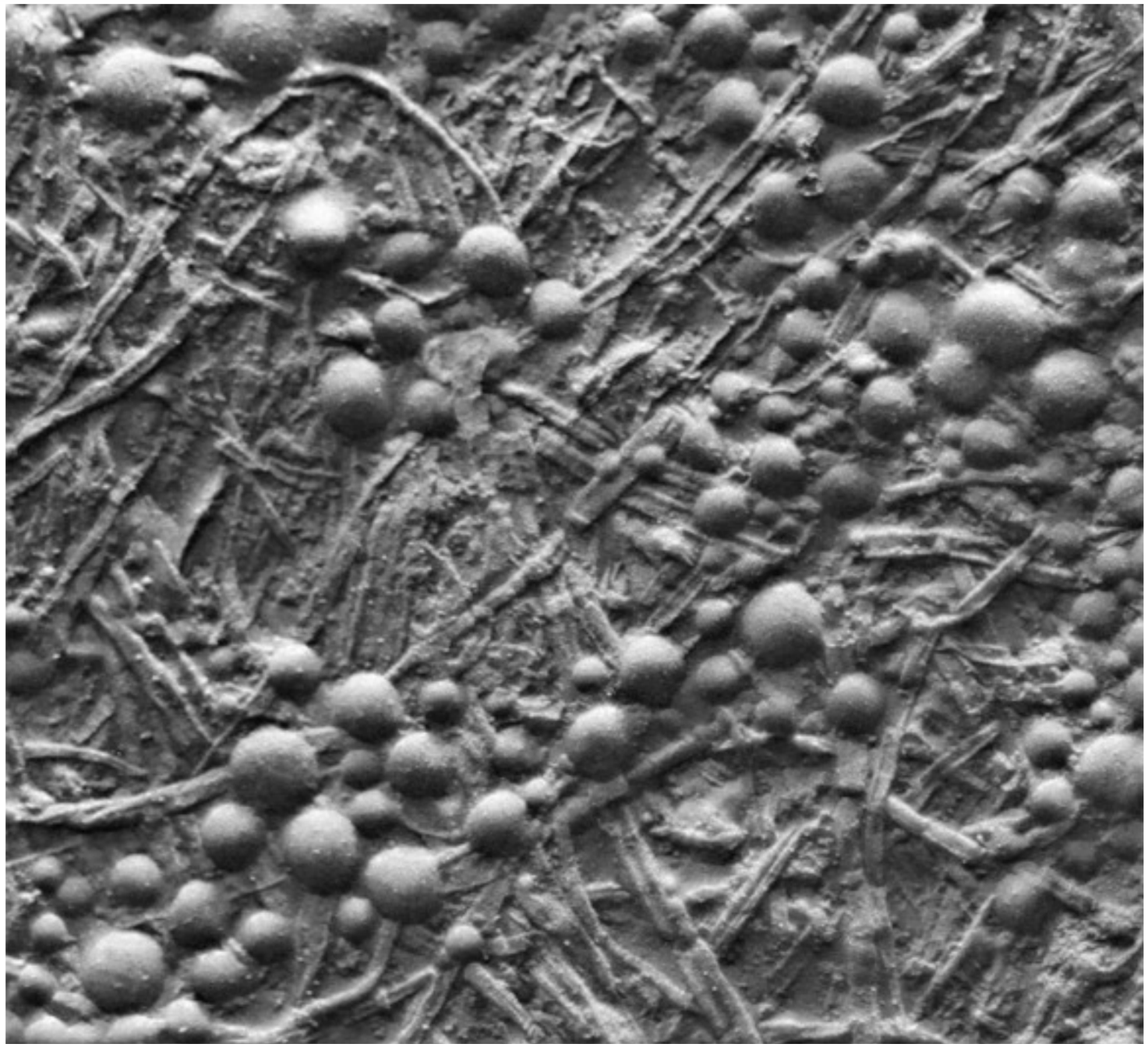
- The gel is visco-elastic.
- Under pressure it flows, filling the holes.
- The specimen is “coated” with a layer of thin elastic paint.

Peacock feather

Direct view

GelSight view

Glue droplets on Post-it note

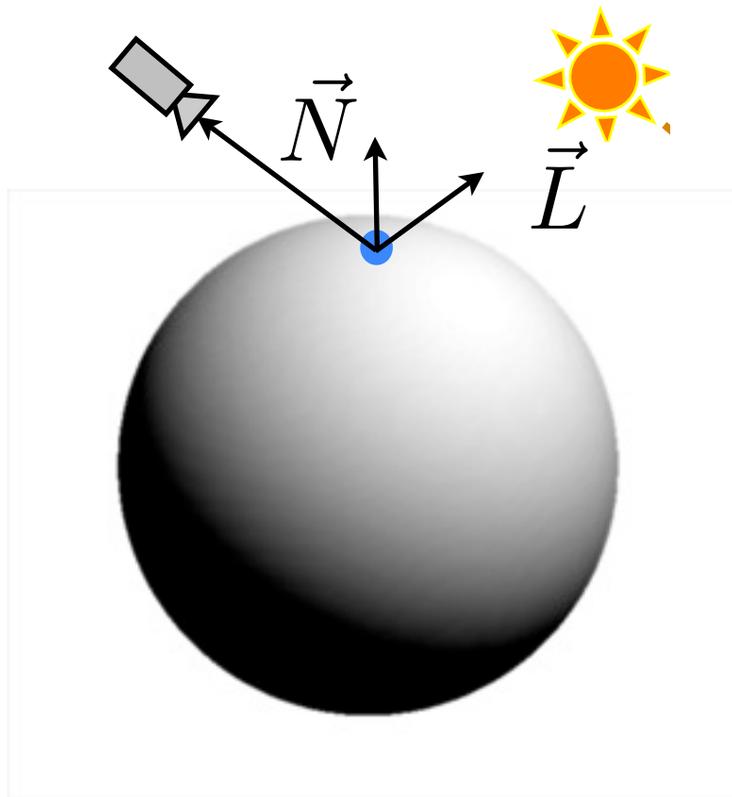


Measuring 3D shape with GelSight

Classic computer vision problem: “shape-from-shading”

Diffuse (Lambertian) shading

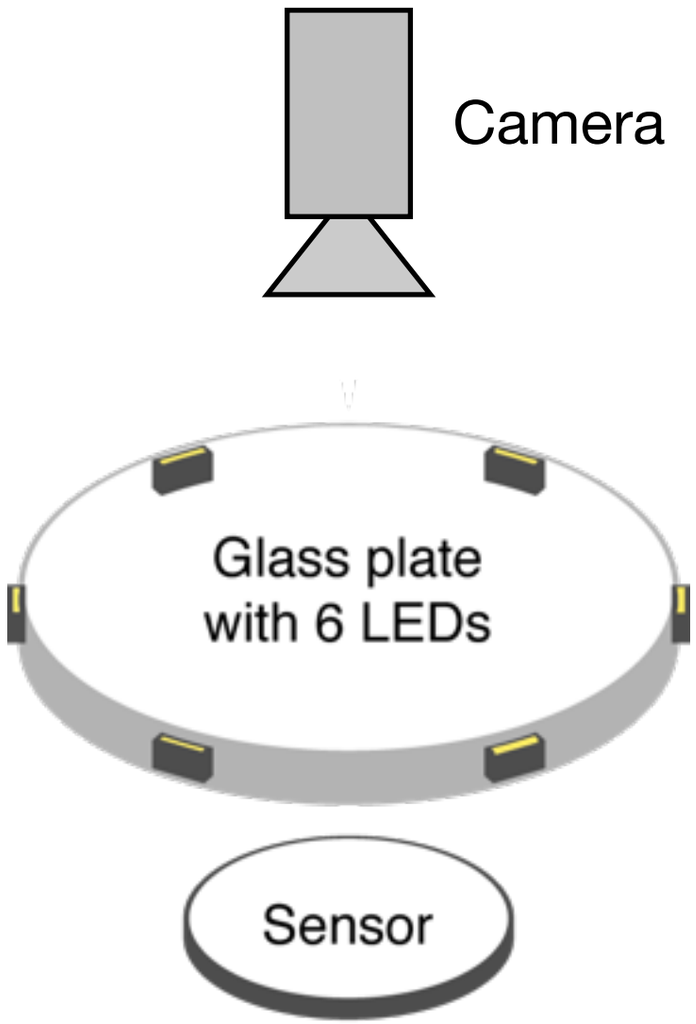
$$I = \alpha \vec{L}^T \vec{N} + c$$

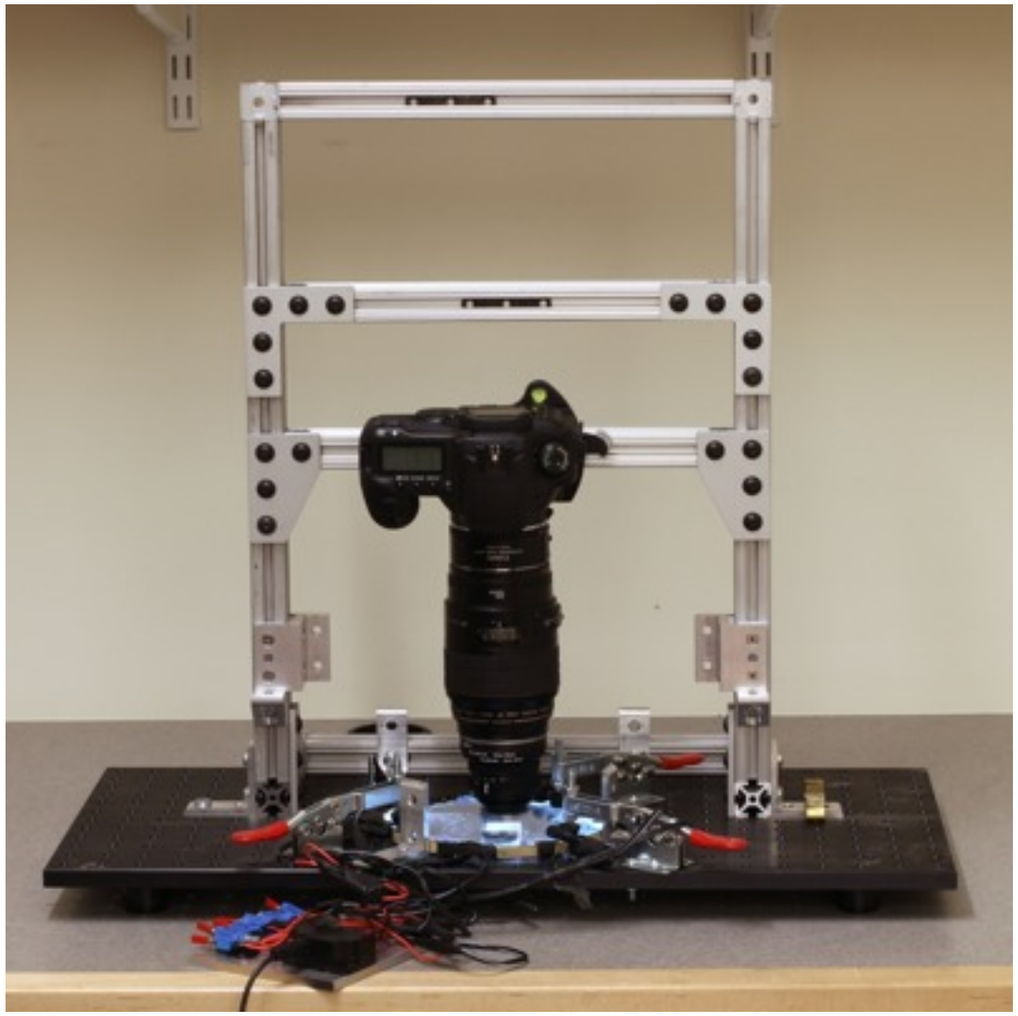


If there are multiple images with different light sources

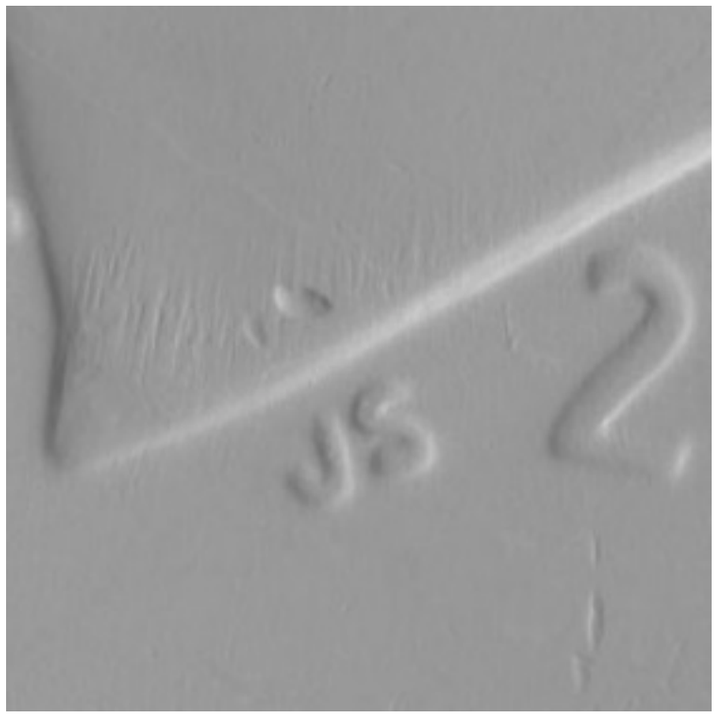
$$\begin{bmatrix} I_1 \\ \vdots \\ I_N \end{bmatrix} = \alpha \begin{bmatrix} \vec{L}_1^T \\ \vdots \\ \vec{L}_N^T \end{bmatrix} \vec{N} + c$$

Setup





Surface Topography Measurement



Dime under sensor 3D Rendering Close up

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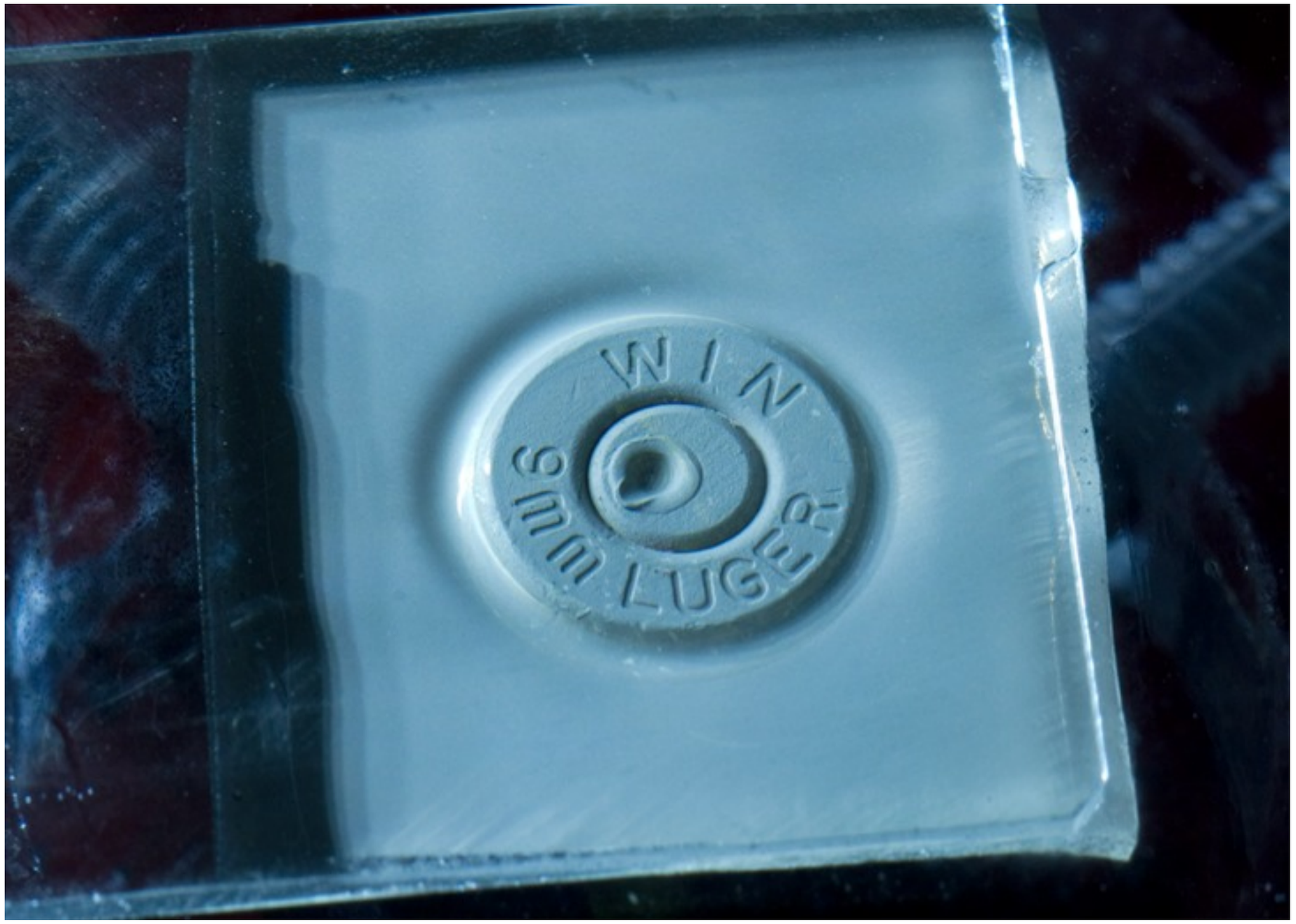
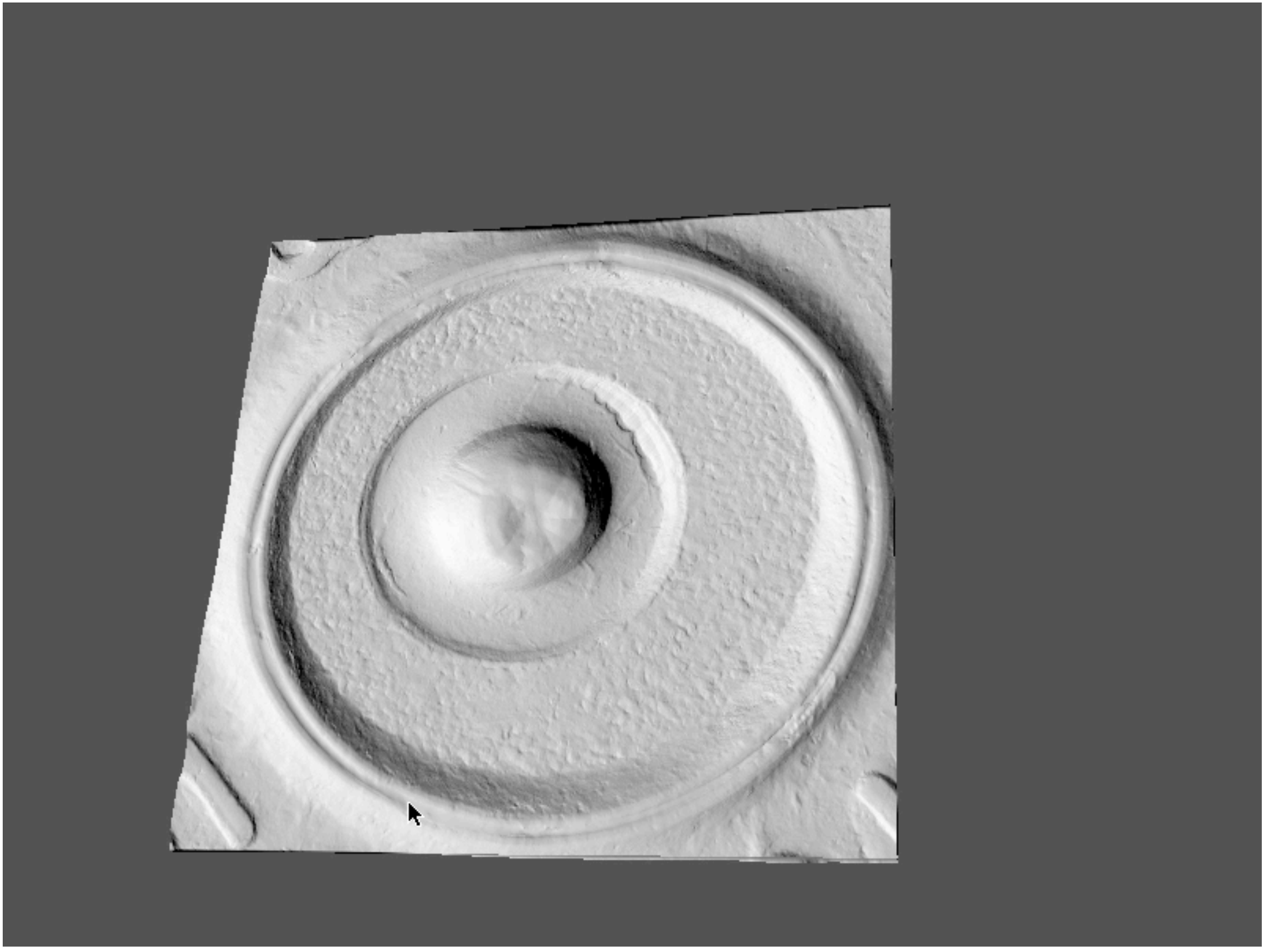
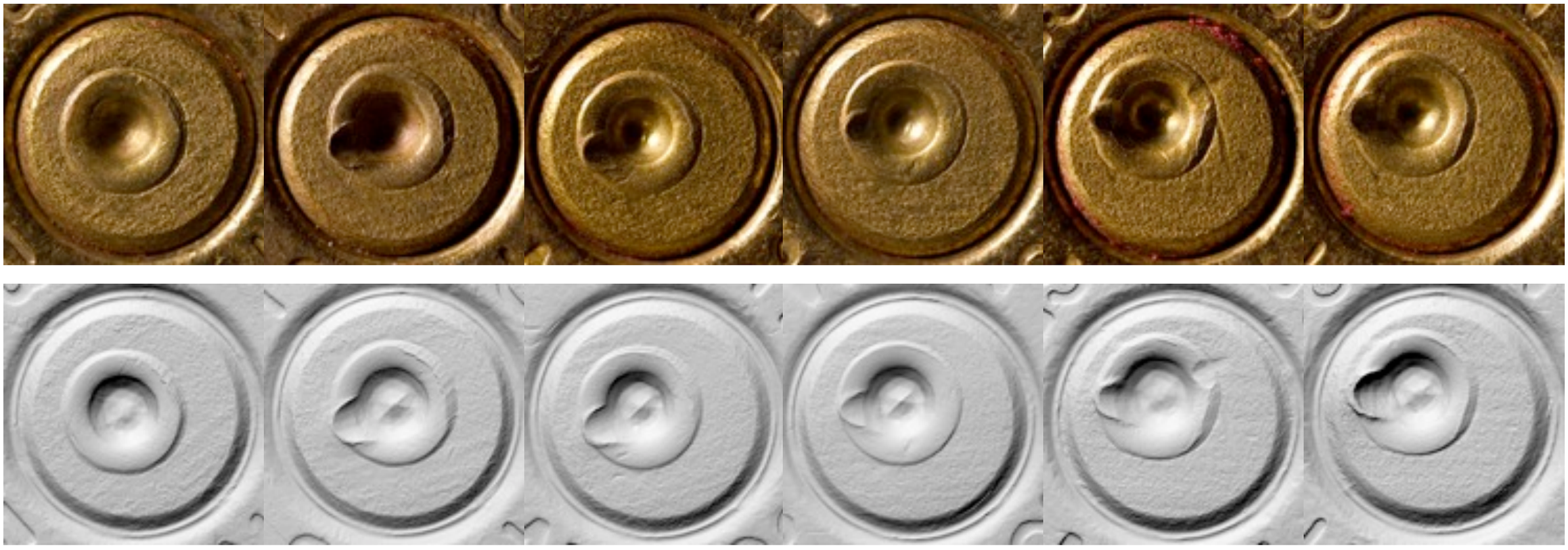
GelSight measurement of cartridge cases



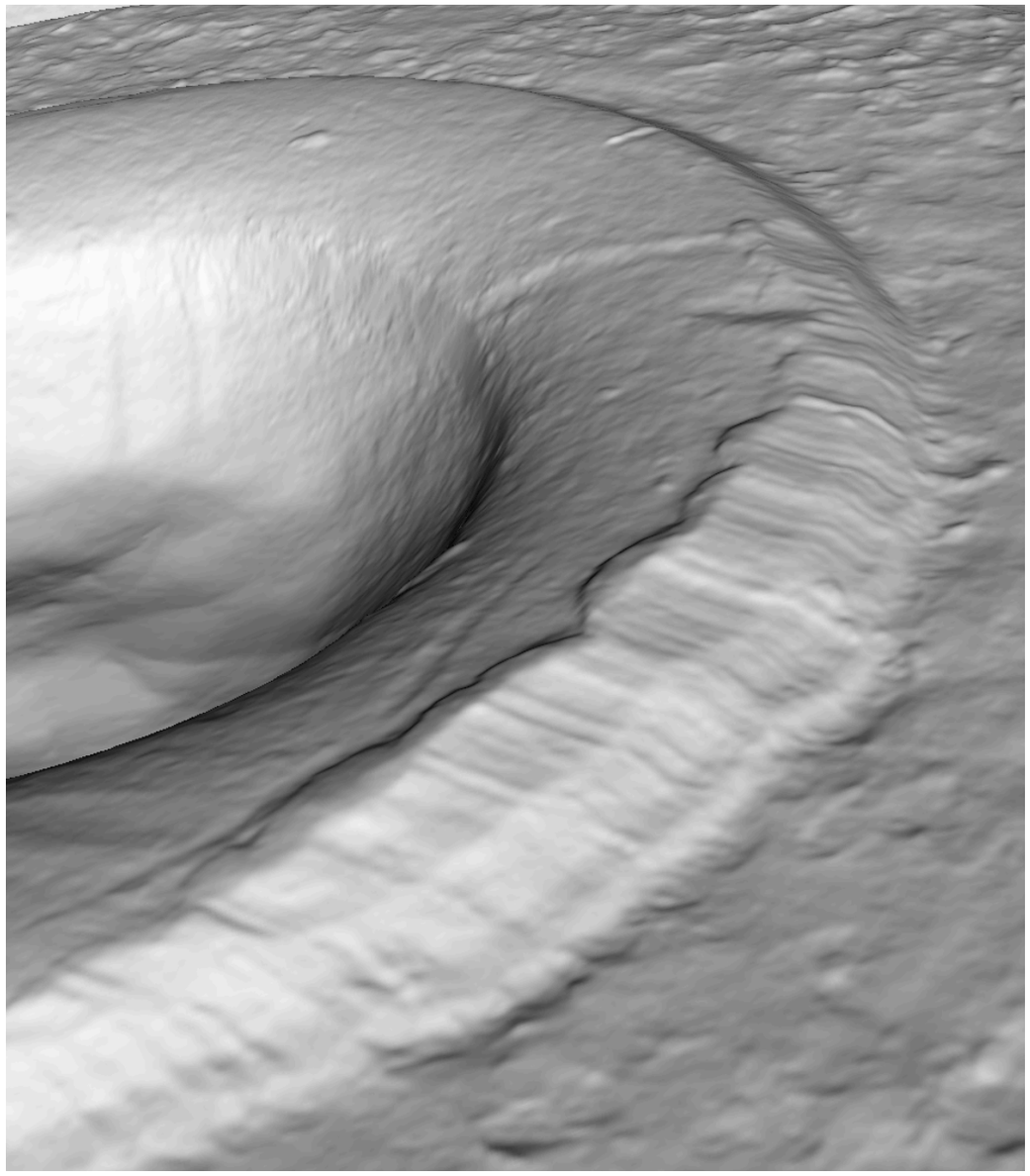


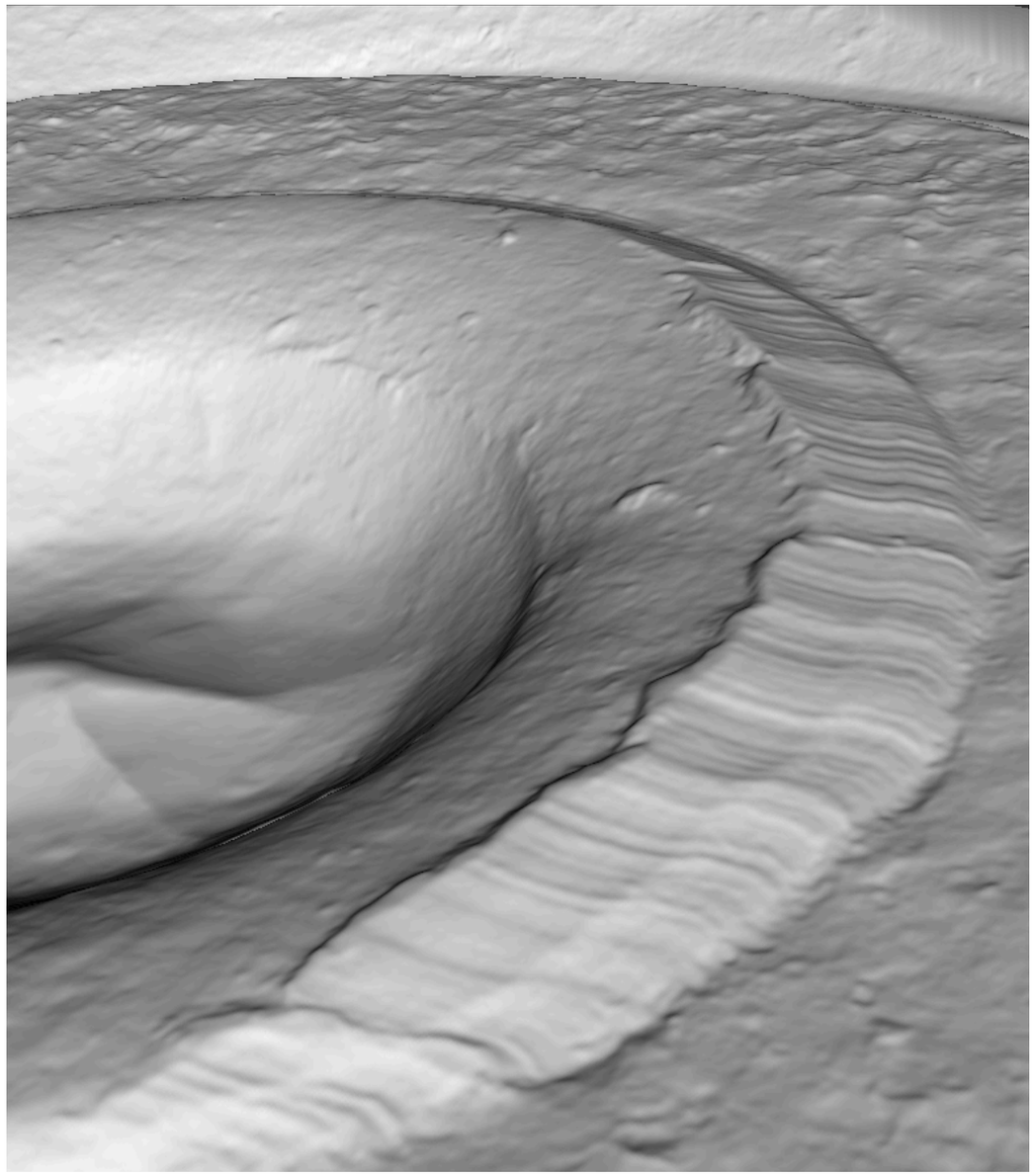
GelSight measurement of cartridge cases

We measured the breech face impressions on six fired cartridge cases from three consecutively manufactured firearms



GelSight measurement of cartridge cases





Matching of breech-face impressions

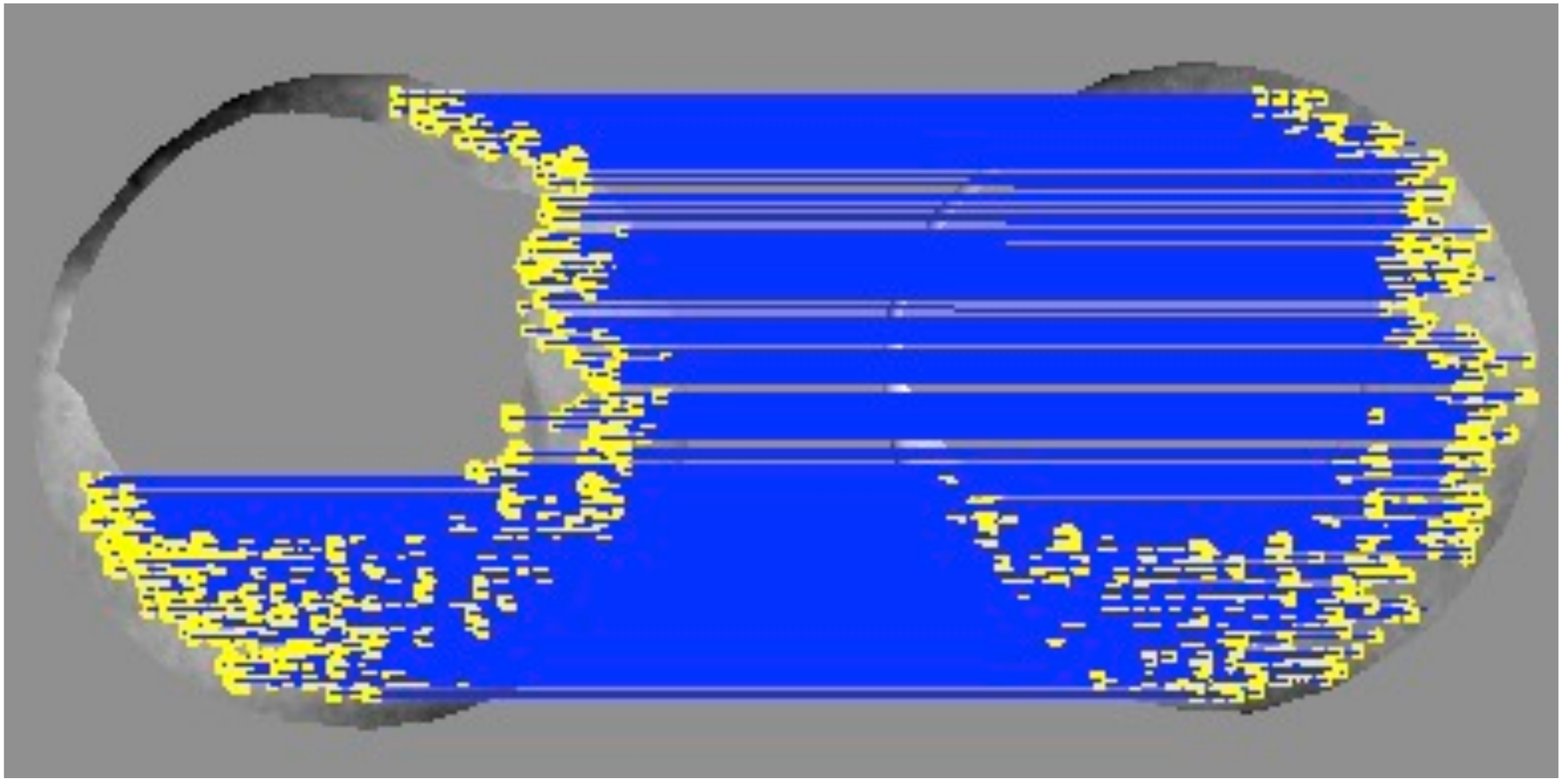
Matching GelSight measurements of breech-face impressions

- Select *feature points* on the 3D surface which are identifiable and invariant to moderate amounts of scaling and changes in impression depth

- Match impressions by matching these feature points

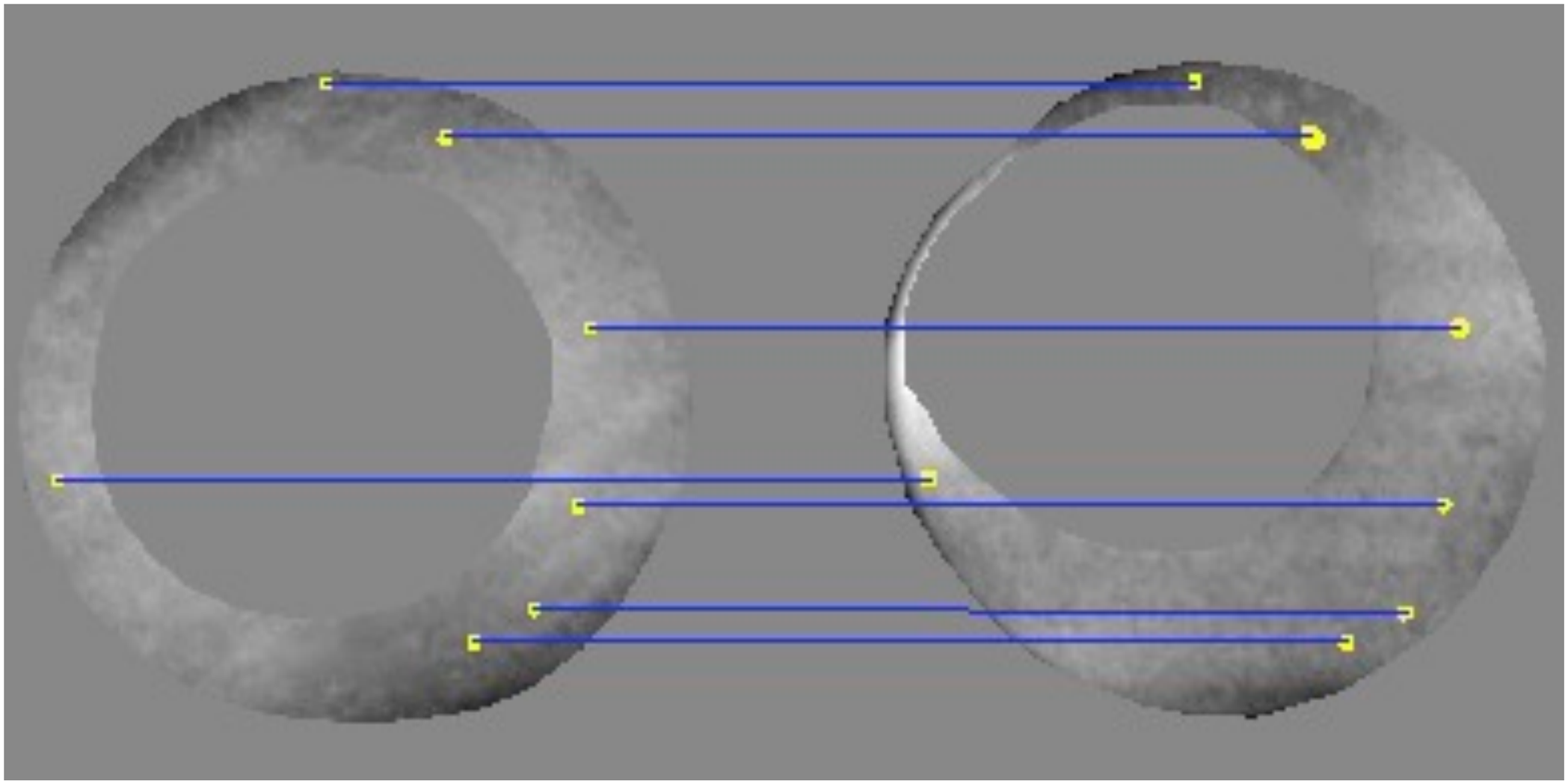
Matching of breech-face impressions

Correspondence of features (match)



Matching of breech-face impressions

Correspondence of features (non-match)



Matching of breech-face impressions

	B1	B2	C1	C2	D1	D2
B1	-	350	0	15	7	8
B2	356	-	14	10	12	7
C1	6	13	-	456	19	10
C2	16	11	491	-	11	5
D1	10	8	10	20	-	553
D2	0	3	7	13	570	-

Conclusions

GelSight sensor provides a new way of looking at surfaces

- Non-destructively painting the surface removes material effects

Accurate 3D reconstruction of surface topography

- 3D surface measurement removes influence of lighting

A novel approach for matching breech face impressions with 3D geometry

- Matching feature points provides a high level of distinguishability

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Validation

Lenticular sheet

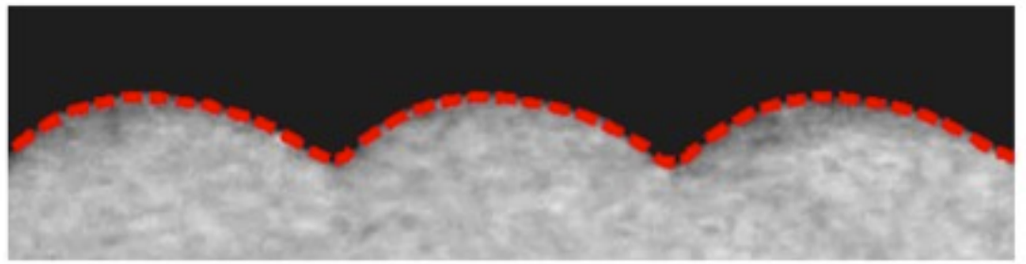
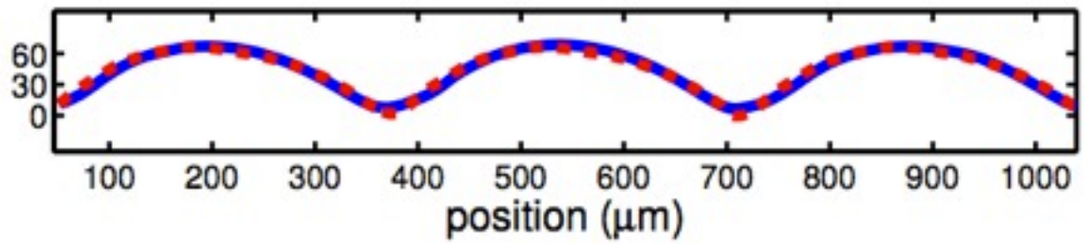


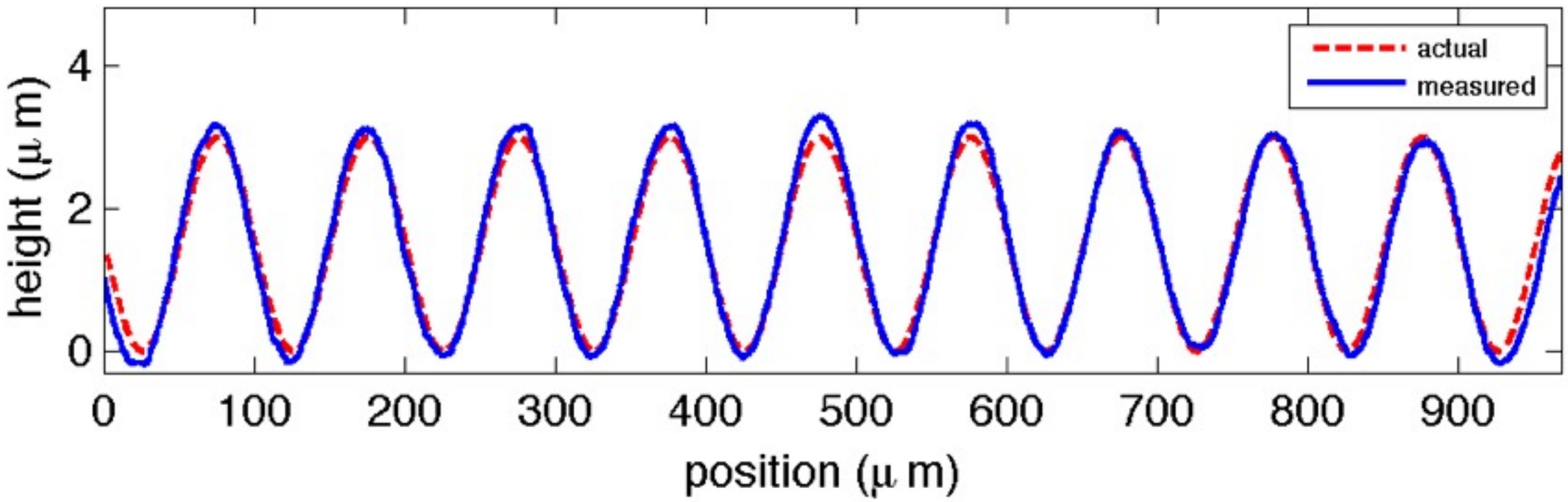
Image of lenticular array with curve fit to profile



Optimized depth profile using our method

Rubert specimens

#530: Period 100µm, Height 3µm



Rubert specimens

#525: Period 135µm, Height 19µm