Feather + Platypus

Waterproof Jacket

Agenda

Overview

Problem

Bio Exploration

Research

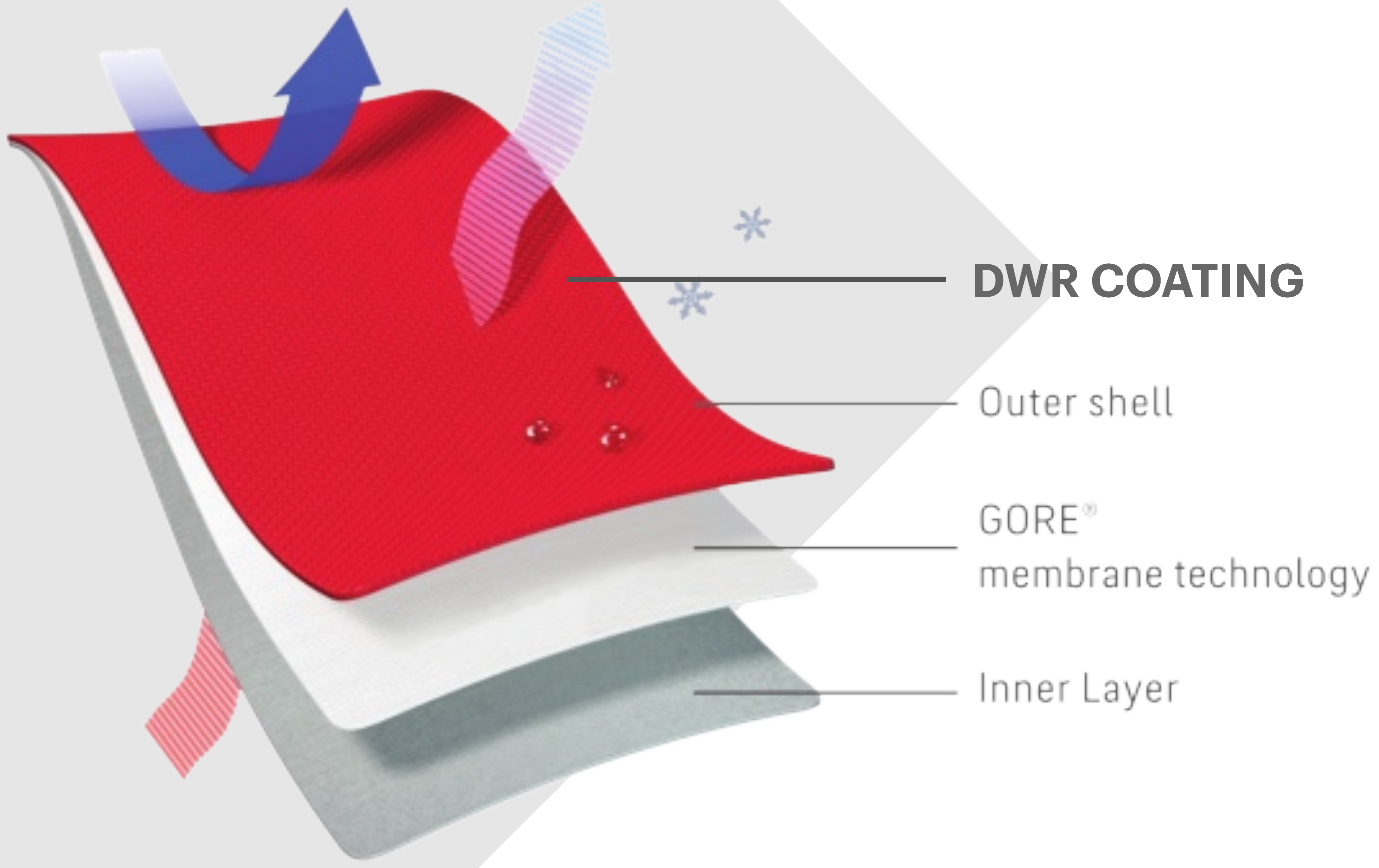
Ideation

Prototyping

Discussion

Overview

CURRENT STATE

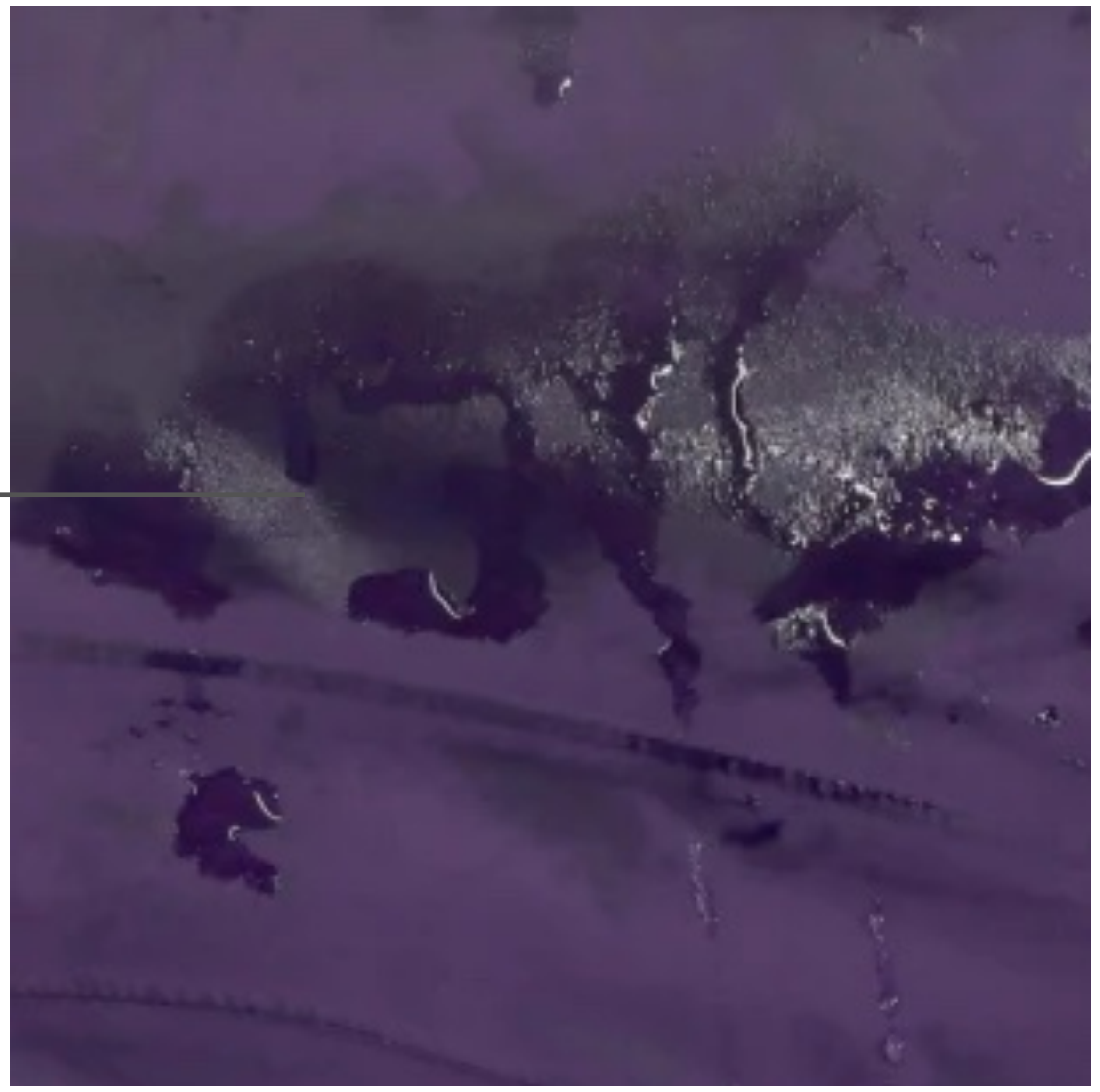


Bio & Synthetic Coatings

Many finishes—including waxes and silicones—will lower the surface tension of a fabric enough to cause water to bead up and disperse rather than saturate. However, they are easily contaminated by dirt and oil and rapidly lose their effectiveness, reducing the effective lifetime of a garment.

Problem

COATING VISUAL



Old or Dirty DWR Coating

Water seeps through outer layer causing the garment to fail and be trashed.

Newly Applied DWR Coating

Water sits and sheds off the garment keeping the person dry.

CURRENT DWR

Bad

Long-chain (C8) fluorocarbon-based treatment

Perfluorinated Chemicals (PFC) a forever chemical that has been linked to cancer. These chemicals have been banned by the EPA and phased out of many products around 2013.

Better

Shorter-chain (C6) fluorocarbon-based treatment

Perfluoroalkyl or polyfluorinated substances were thought to be a replacement for C8. However, they still contain trace amounts of non-polymer PFOAs and are still a hazard.

Best

Teflon EcoElite

A type of DWR made from 60% renewable resources and is designed to work with existing fluorinated finishes. This helps to lower the carbon footprint but not eliminate it.

KEY QUESTION

Is a treatment or a material structure better?

Bio Exploration

FUNCTIONS NEEDED

Hydrophobic Properties

The structure, material, or coating should cause water to “stand” or “bead” and quickly shed without soaking into the material.

Integration with Many Materials

The structure, material, or coating should work with many materials to broaden the application and replace many coatings.

Renewal Properties

The structure, material, or coating should be cleaned or refreshed to prolong the life span of the product and minimize waste.

Consistent Biodegradation

The structure, material, or coating should breakdown naturally in the environment without additional processing.

MATERIAL FUNCTION MATRIX

Organism	Mountain Goat	Copepod	Platypus	Mantis Shrimp	Pistol Shrimp
Function	Allowed to endure great impacts in the horns from all directions /any impact location	Can penetrate silica body with its teeth when eating	They remain warm and dry in water despite hours of foraging sometimes in near freezing temperatures	Punch with speed that allows cavitation upon impact	Shoot out a cavitation bubble from its claw
Mechanism	Isotrotropic properties arise from radial collapse of laminated, longitudinal tubules	Silica cap on teeth followed by a secondary under-cap of resilin that allows for durability	A layer of thin, long guard hairs protect the dense layer of fur underneath	Alike the pistol shrimp, the mantis shrimp utilizes energy amplification by flexing its muscles to store energy, and then releases the stored energy through similar locking mechanisms in order to force the entire claw of the mantis shrimp to punch with great force, producing a cavitation bubble	By utilizing energy amplification, the pistol shrimp flexes its muscles to store energy, and then releases the stored energy through releasing locking mechanisms and then releasing its top portion of claw in order to shoot water out of the plunger at high speed and pressure
Underlying Principle	Energy/Stress absorption	Impact/stress adsorption / crystal structure	The two-layer coat traps an insulating layer of air to keep their body temperature stable	Cavitation is utilized by creating a high velocity, lowering pressure. This creates a vapor bubble. The surrounding pressure of the water collapses the vapor bubble, which creates a large explosion causing high temperatures and sound signature.	Cavitation is utilized by creating a high velocity, lowering pressure. This creates a vapor bubble. The surrounding pressure of the water collapses the vapor bubble, which creates a large explosion causing high temperatures and sound signature.
Koan	Strong but everywhere	Strong but deformable	Waterproof but furry	Small size of shrimp with extremely large power	Small size of shrimp with extremely large power

PLATYPUS — FUNCTIONAL MATRIX

Function
They remain warm and dry in water despite hours of foraging sometimes in near freezing temperatures

Mechanism
A layer of thin, long guard hairs protect the dense layer of fur underneath

Principle
The two-layer coat traps an insulating layer of air to keep their body temperature stable

Koan
Waterproof but furry

Overview
Problem
Bio Exploration
Research
Ideation
Prototyping
Discussion
Q&A

https://museumsvictoria.com.au/article/the-platypus-a-unique-and-vulnerable-australian/

FEATHER — FUNCTIONAL MATRIX

Function

Feathers keep birds warm and dry while maintaining a surface-to-weight ratio needed for flight.

Mechanism

The feather is made up of a two important components: barbs and barbules. The barbs are the larger, longer stripes of material that give a feather its visible structure. The barbules are tiny and fill in the gaps between the barbs. In tandem, they are able to create surface tension for many sizes or water droplets and even full submersion.

Principle

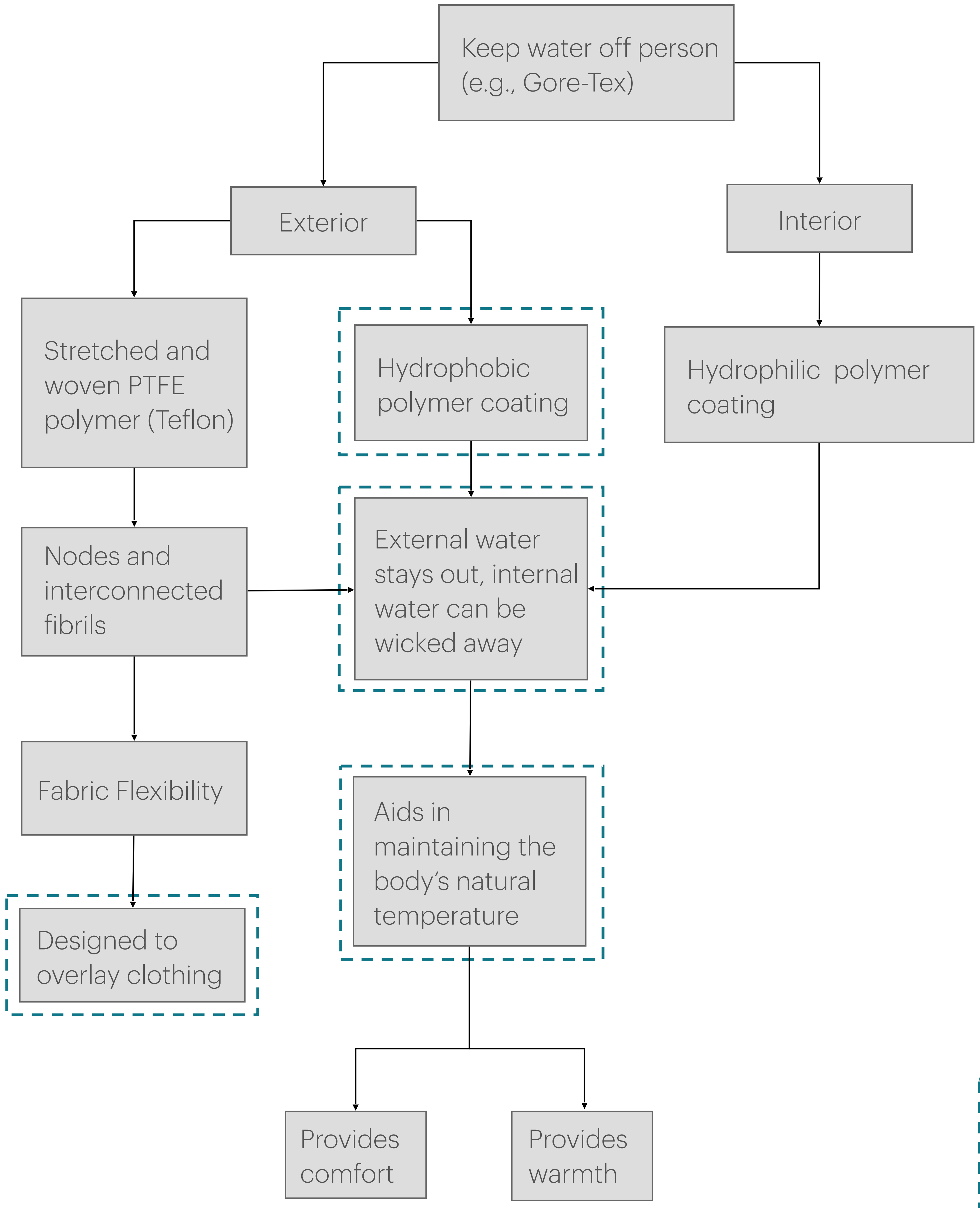
The structure and material of the feather create surface tension, causing water to “float” on the surface and quickly shed off without penetrating into the bird's down-insulating layers.

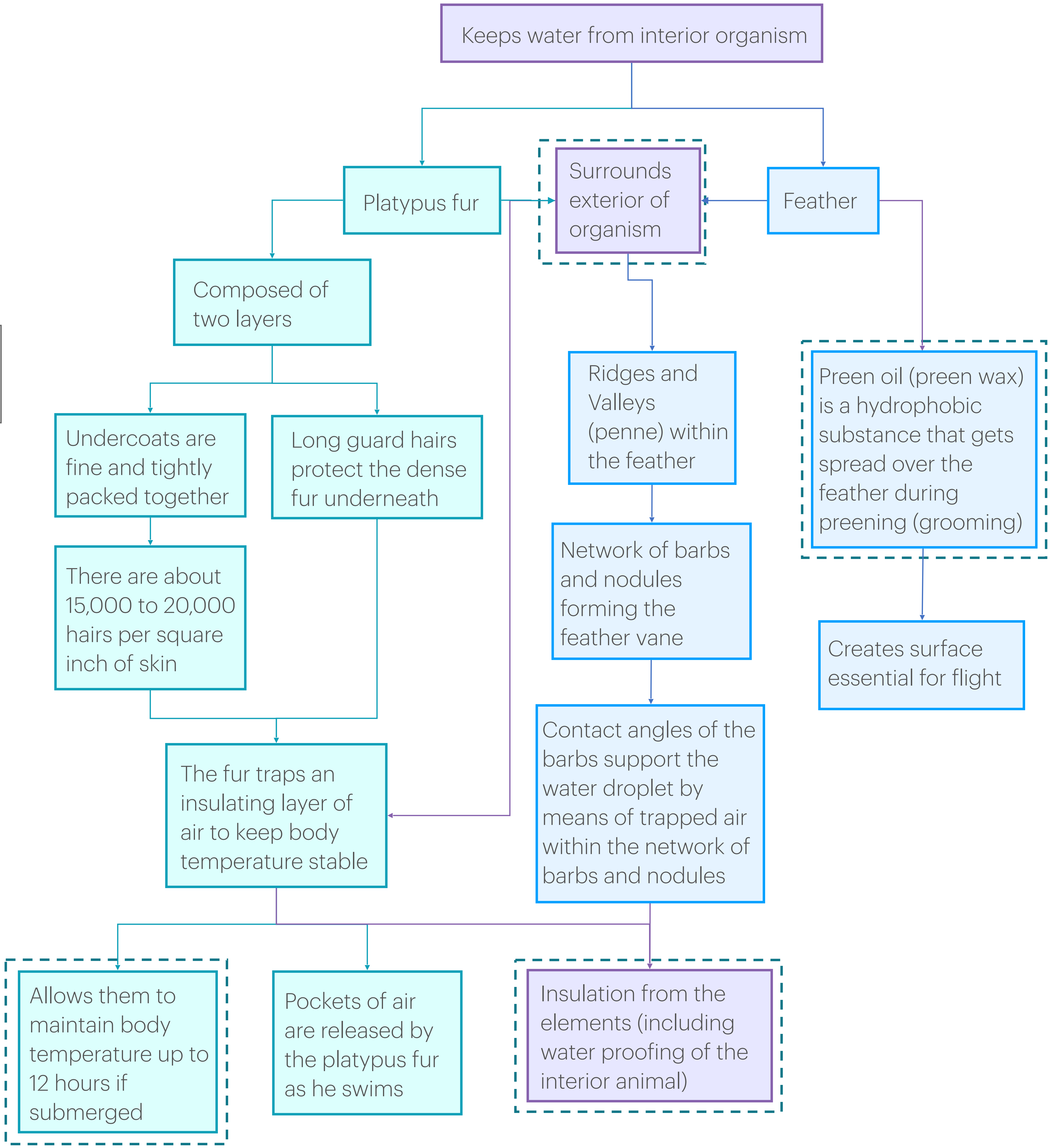
Koan

Light but waterproof.

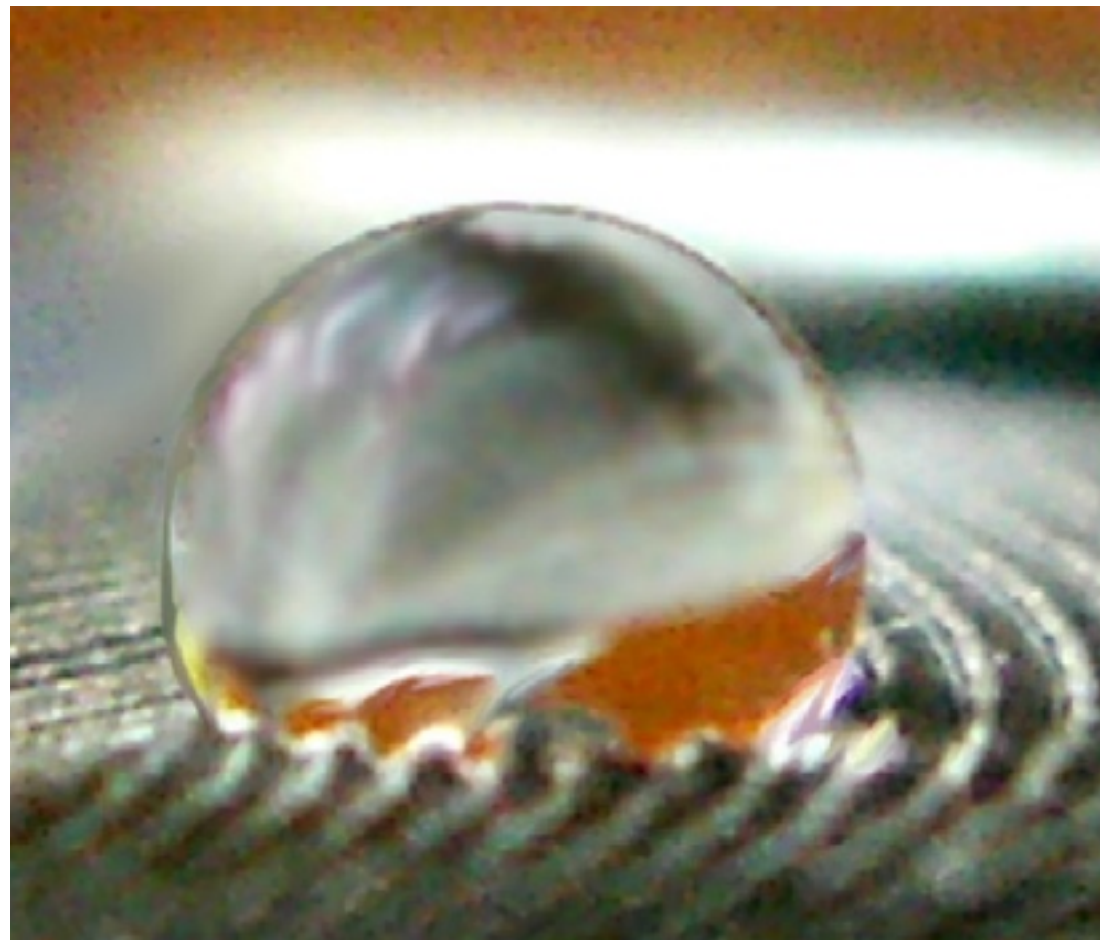
https://northamericanreview.org/open-space/fiction-sharon-hashimoto

FUNCTIONAL DECOMPOSITION



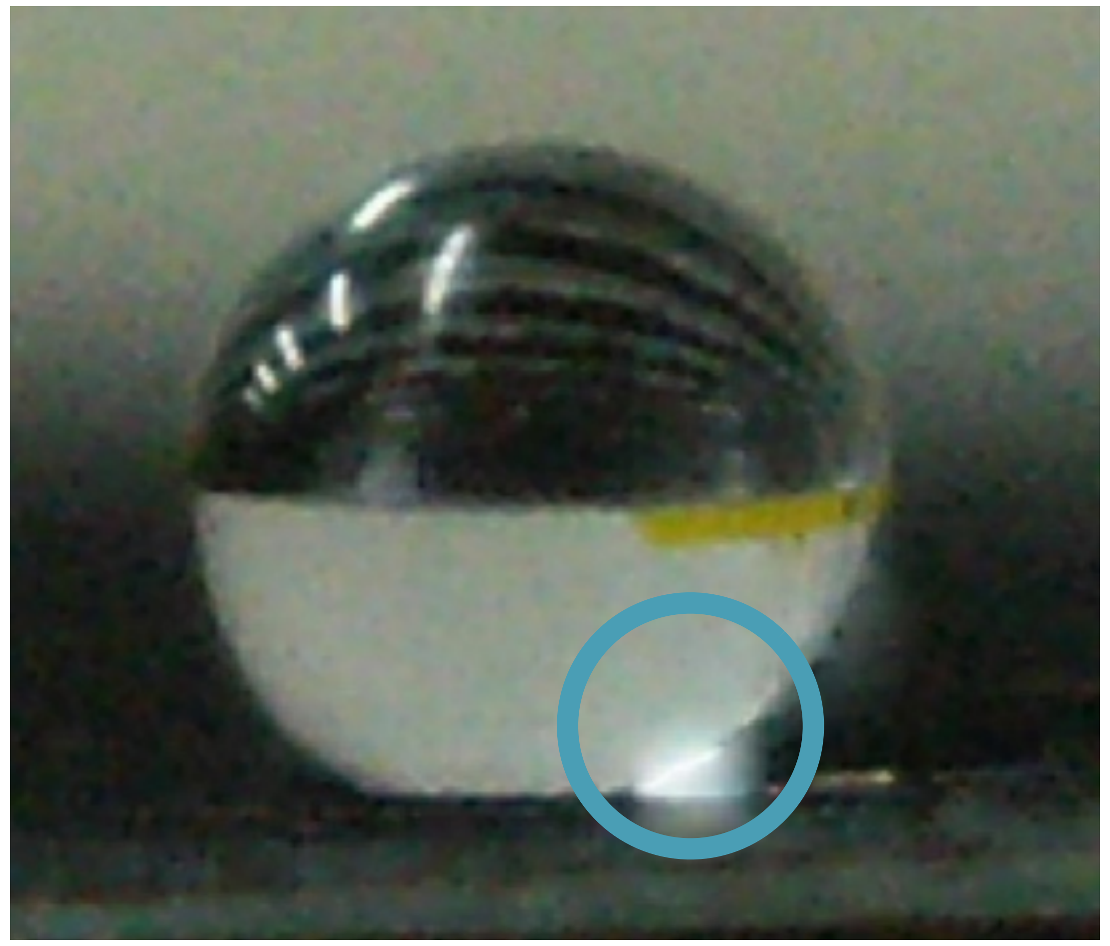


Research



Initial Findings

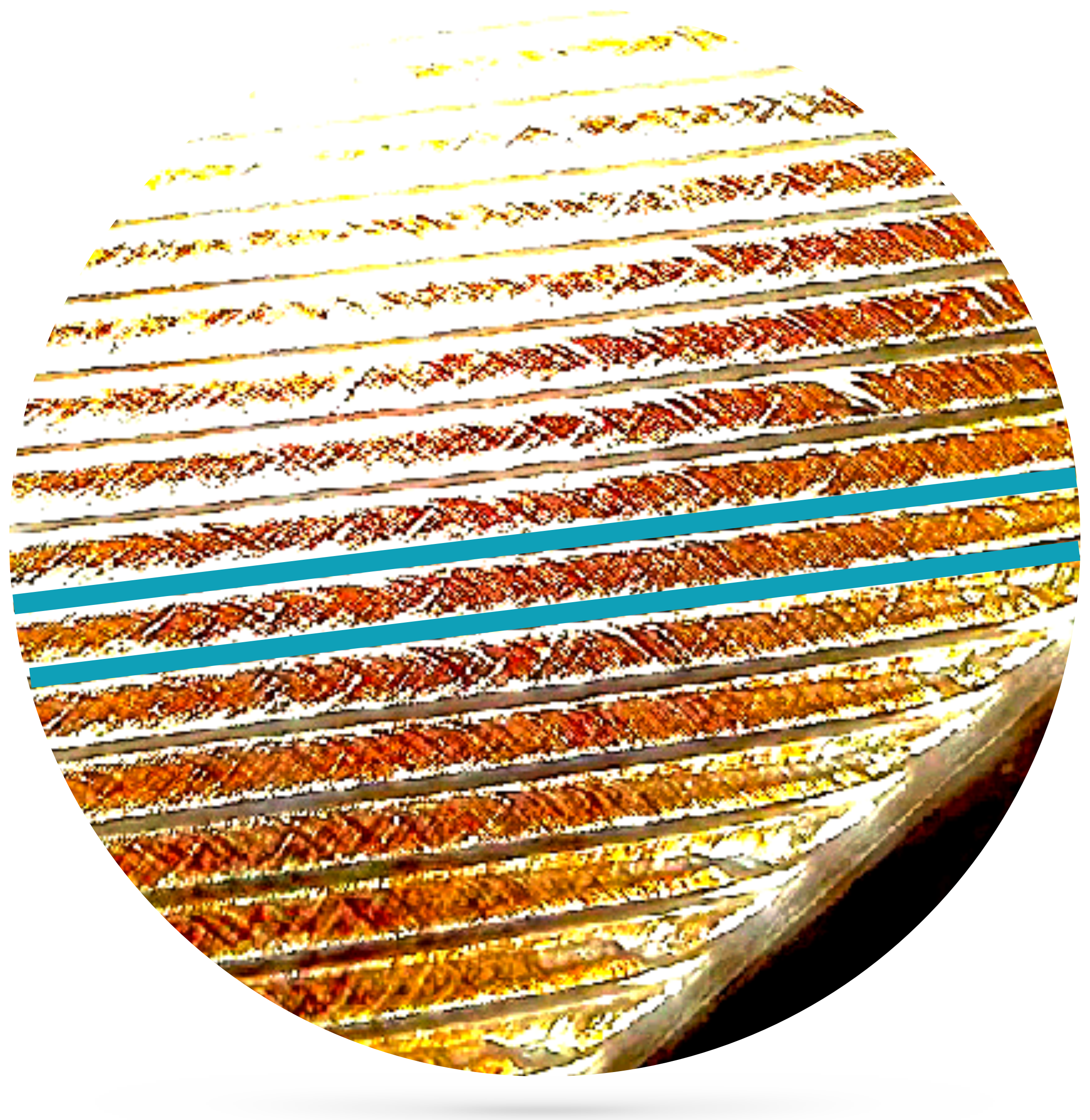
Bormashenko et. al. modeled the hydrophobicity of the feather **structure** by removing preening oil from the feather, and placing water droplets on the feather to measure contact angles. Droplets are supported by the air pockets trapped underneath the droplet through the systems of barbs and barbules.



Contact Angle

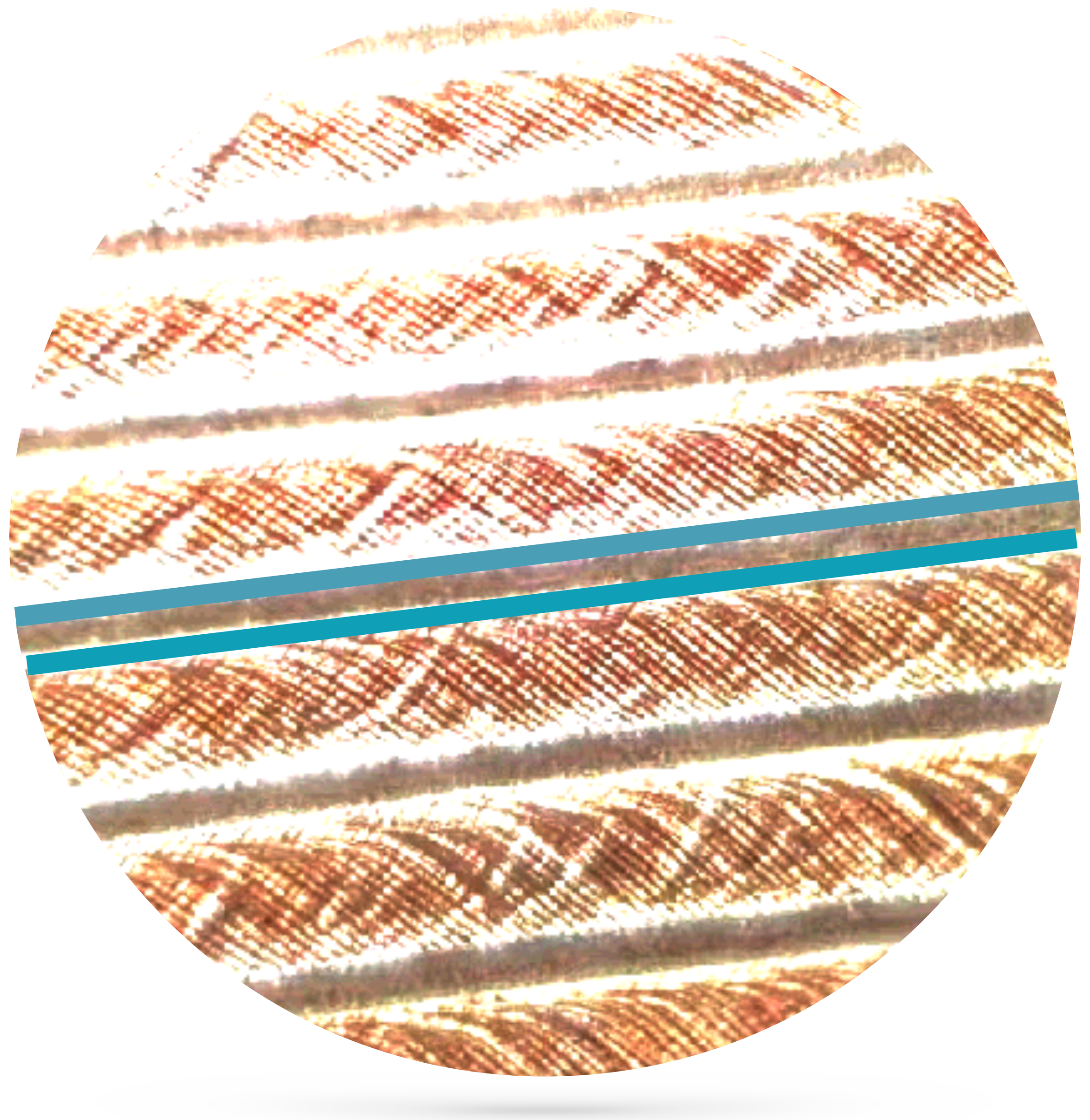
There exists a contact angle of the droplet interfacing with the feather, which is a measure of hydrophobicity. **Generally, the more obtuse the contact angle, the more hydrophobic the surface is.** The experimental contact angle found for the feather structure was approximately 120°.

FEATHER MEASUREMENTS



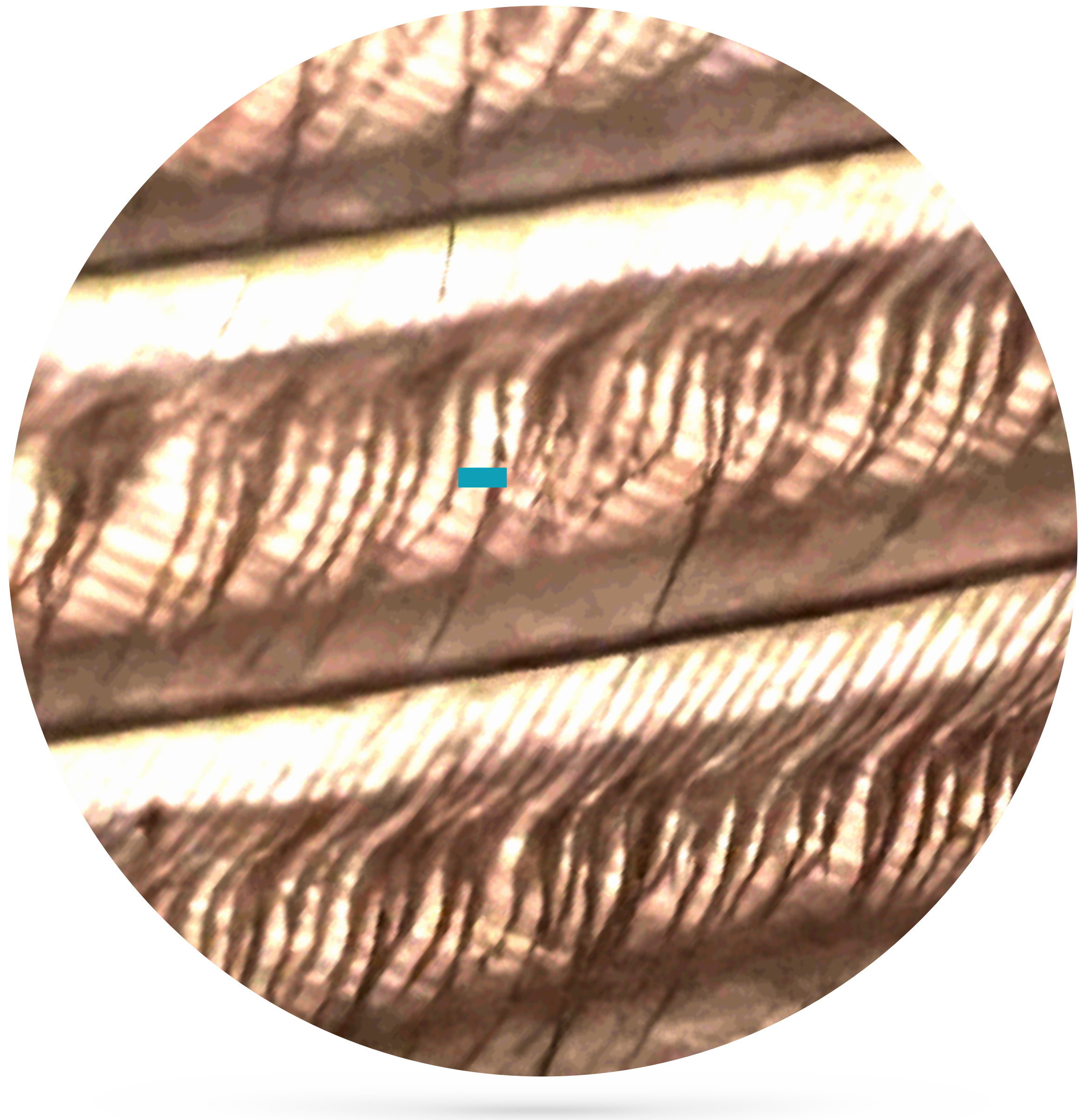
Super Magnification

With this magnification, you can see the barbs and their relative size to the spine of the feather. You can also take out the interlocking nature of the barbules. **The distance between the barbs is roughly 300μm-550μm.**



Insane Magnification

With this magnification, you can more clearly see the barbules and start to understand how fine these interlocking fibers are. At this distance, we can **measure the barbs at approximately 65μm in width.**

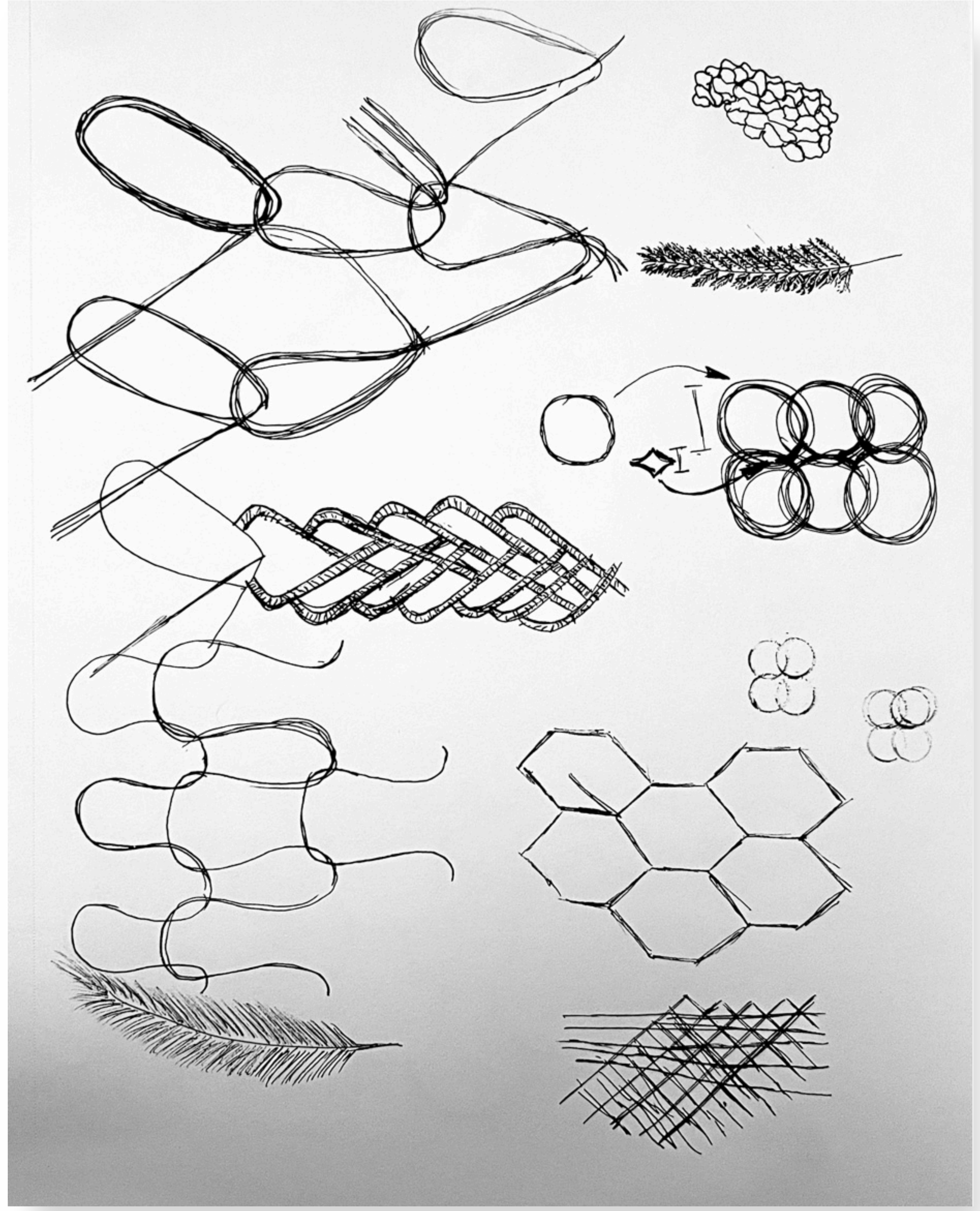


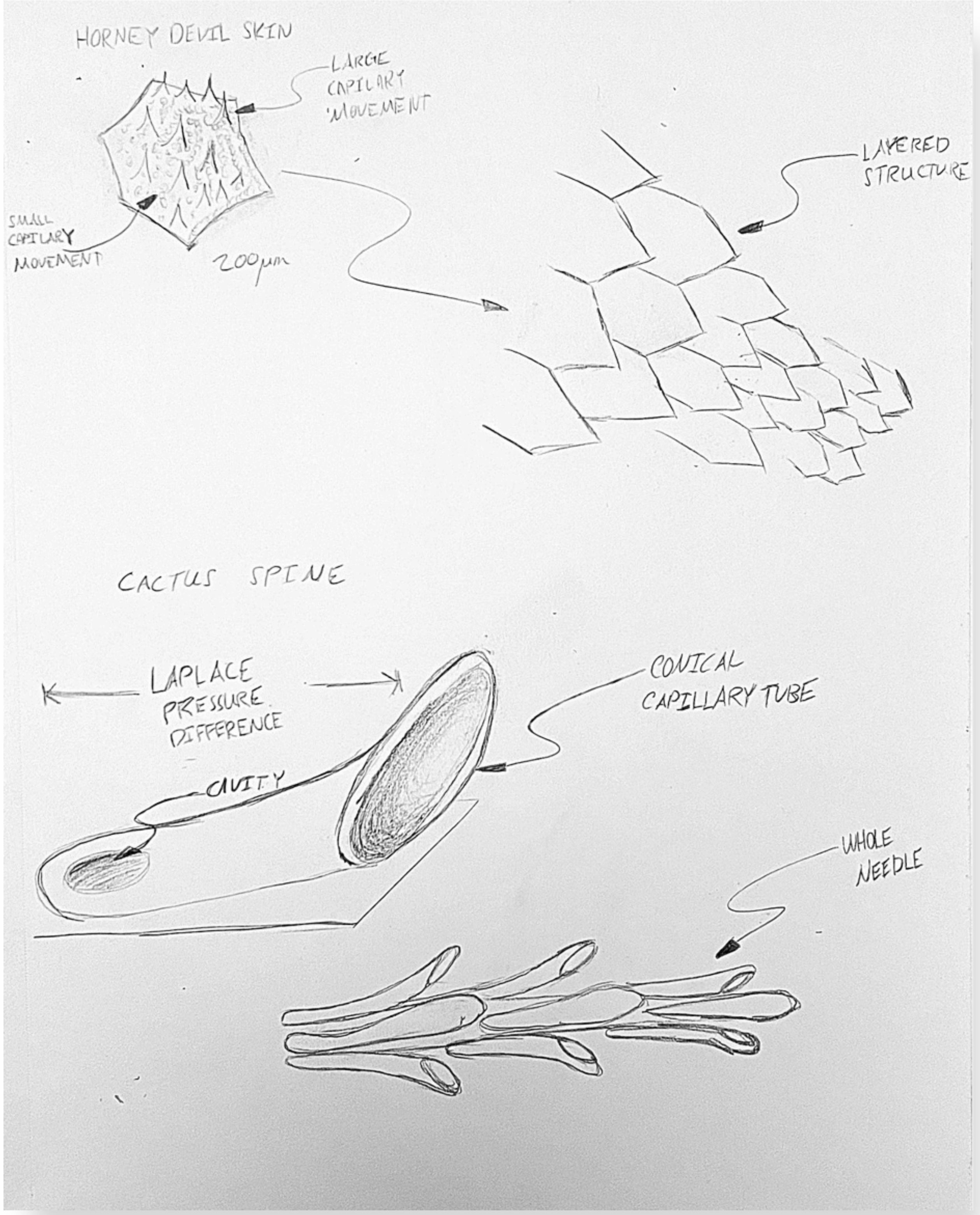
Ludicrous Magnification

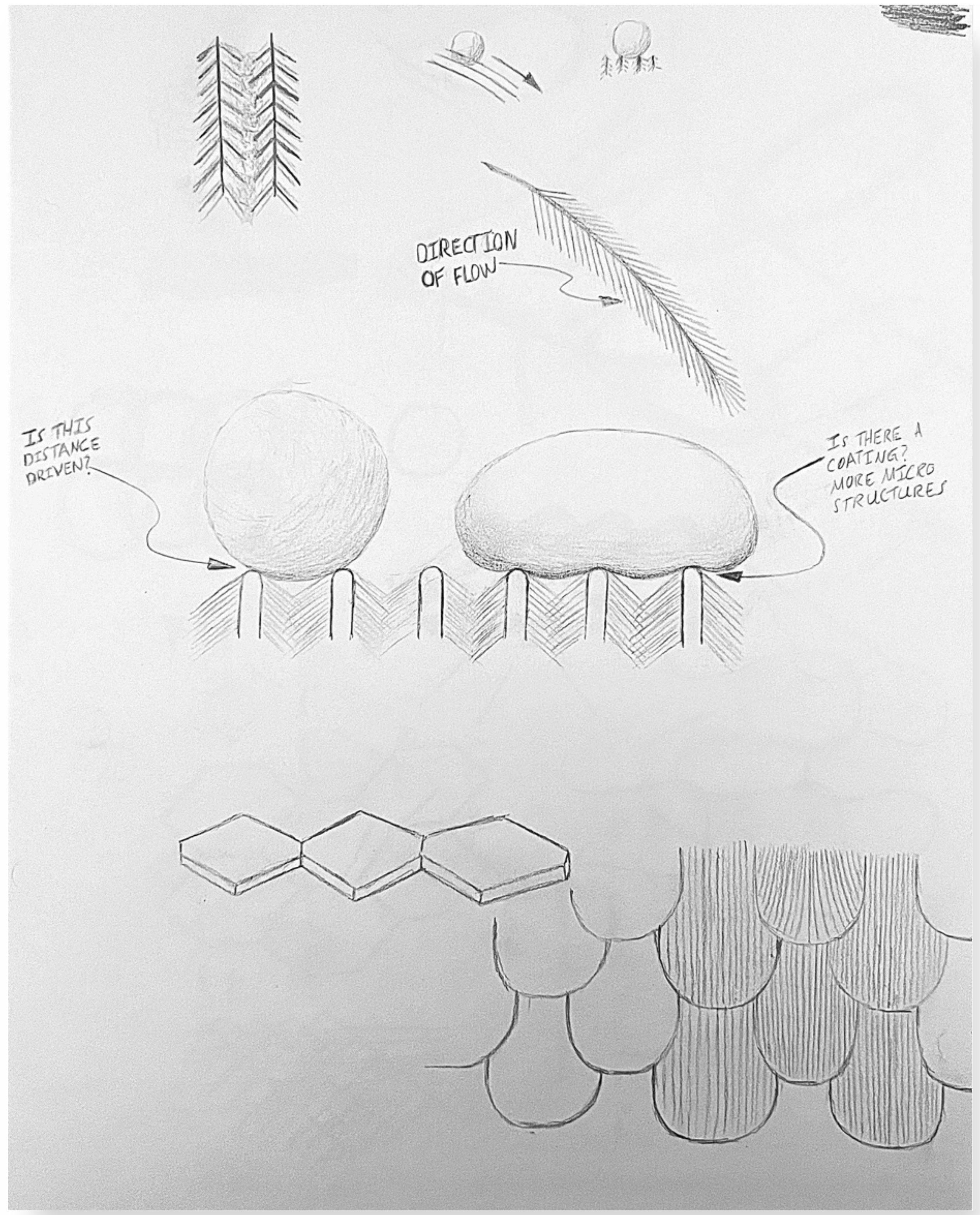
Finally, at ludicrous magnification, you can see the intricate nature of the barbules and how small they are relative to the barbs. The **distance between the barbules is roughly 10μm~15μm**, but their orientation is more varied than the barbs.

Ideation

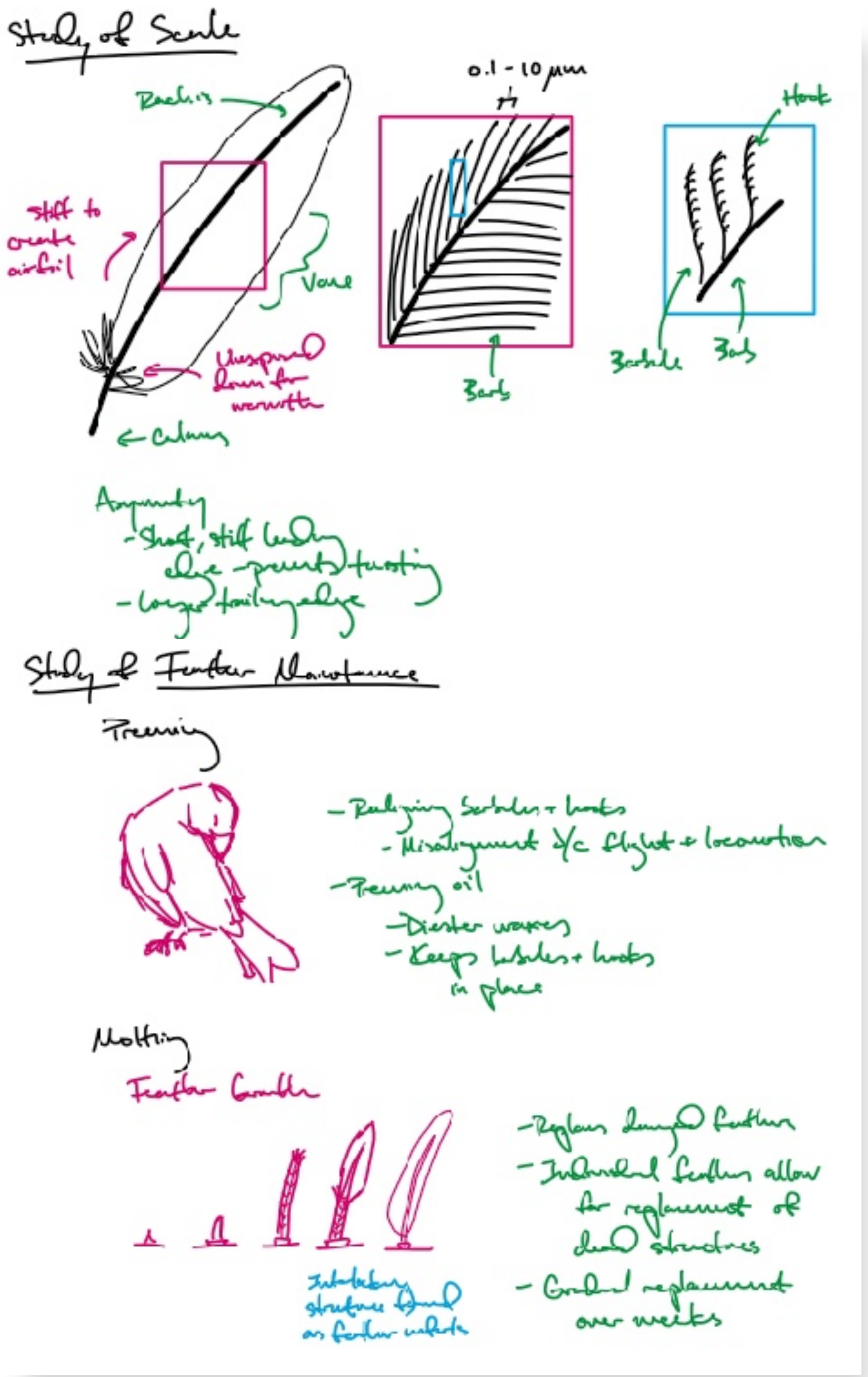
SKETCHING



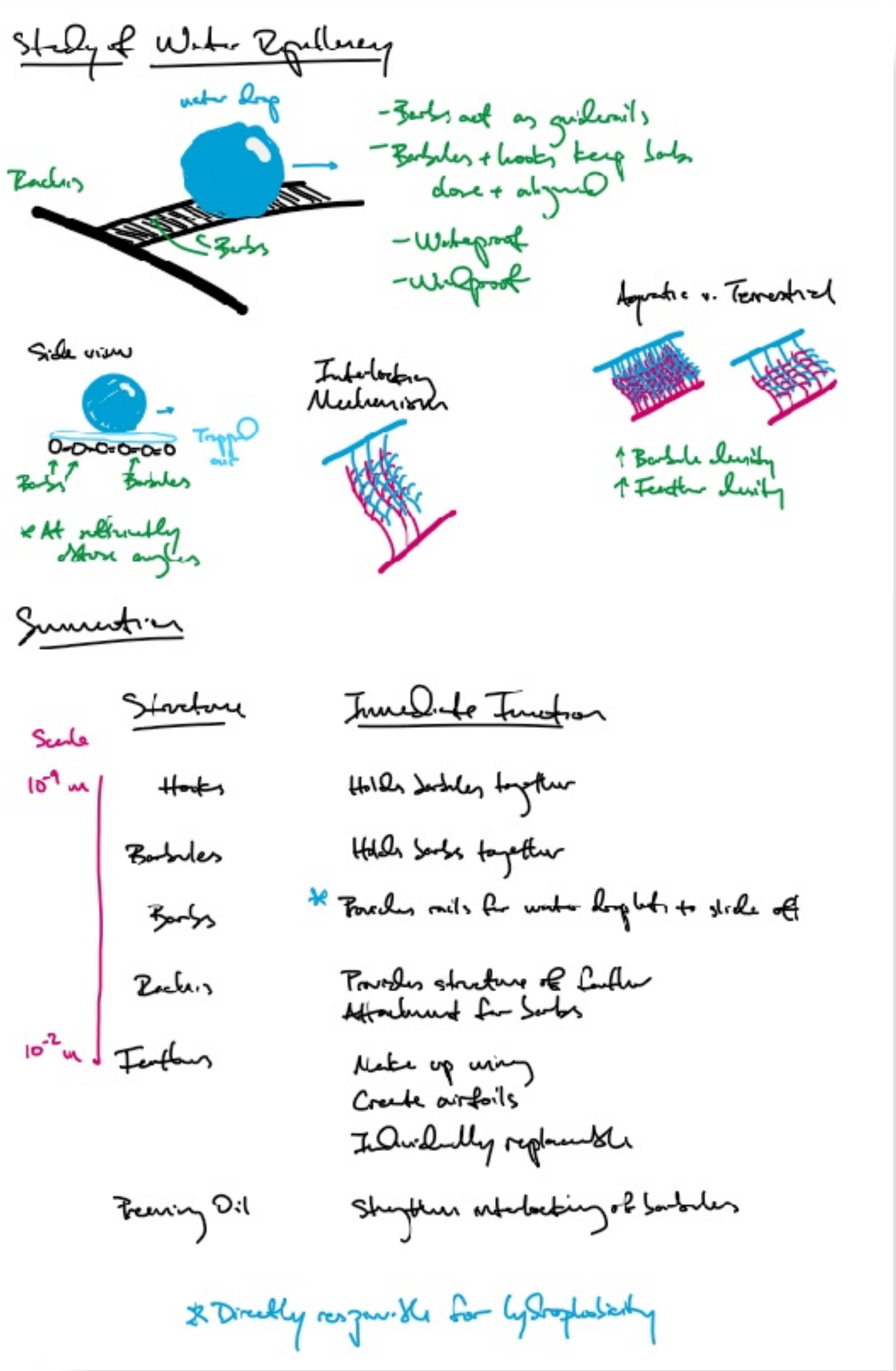

HORNEY DEVIL SKIN
LARGE CAPILARY MOVEMENT
SMALL CAPILARY MOVEMENT
200μm
LAYERED STRUCTURE
CACTUS SPINE
LAPLACE PRESSURE DIFFERENCE
CAVITY
CONICAL CAPILLARY TUBE
WHOLE NEEDLE


DIRECTION OF FLOW
IS THIS DISTANCE DRIVEN?
IS THERE A COATING? MORE MICRO STRUCTURES

SKETCHING



Study of Scale
Rachis
0.1 - 10 μm
Hook
stiff to create airfoil
Vane
Barb
Barbule
Calamus
Study of Feather Maintenance
Preening
-Preening oil
Molting
Feather Growth



Study of Water Repellency
water drop
Rachis
Barbs
-Waterproof
-Windproof
Aquatic v. Terrestrial
Side view
Barbules
Interlocking Mechanism
Summation
Structure
Immediate Function
Scale
Hooks
Holds barbules together
Barbules
Holds barbs together
Barbs
Rachis
Provides structure of feather
Feathers
Make up wing
Create airfoils
Individually replaceable
Preening Oil

Prototyping

RAPID PROTOTYPING

LASER ABLATION PROTOTYPE 1

Process

Hojin Seo created test plates from glass slides and Polydimethylsiloxane (PDMS), specifically SYLGARD 184 silicone elastomer from DOW Chemical, to give us something to ablate with a precise laser. This process involved spinning the material onto the glass plates so it coated them evenly.

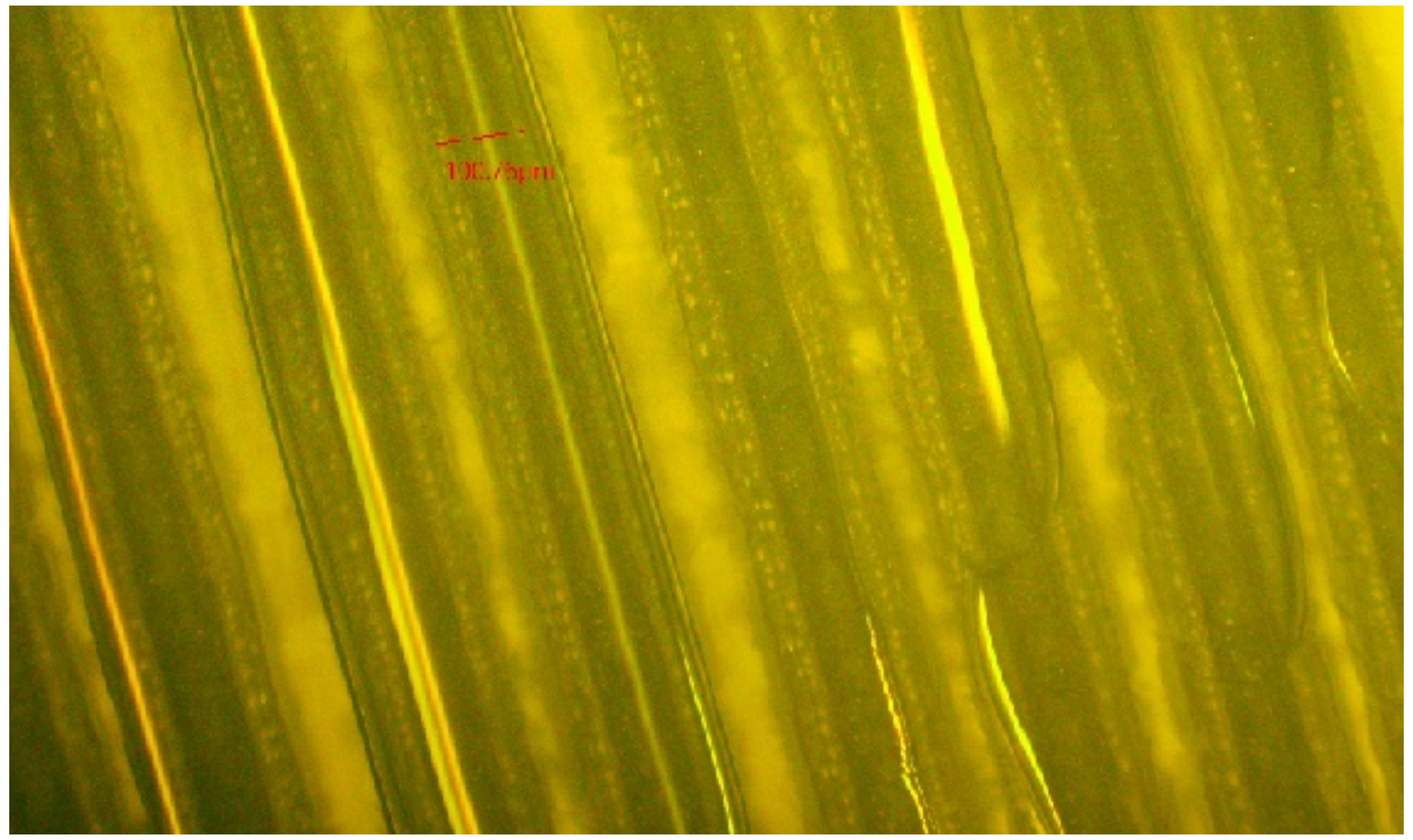
Next, we ablated the material in a pattern similar to the barbs of a feather and tested the results with water.

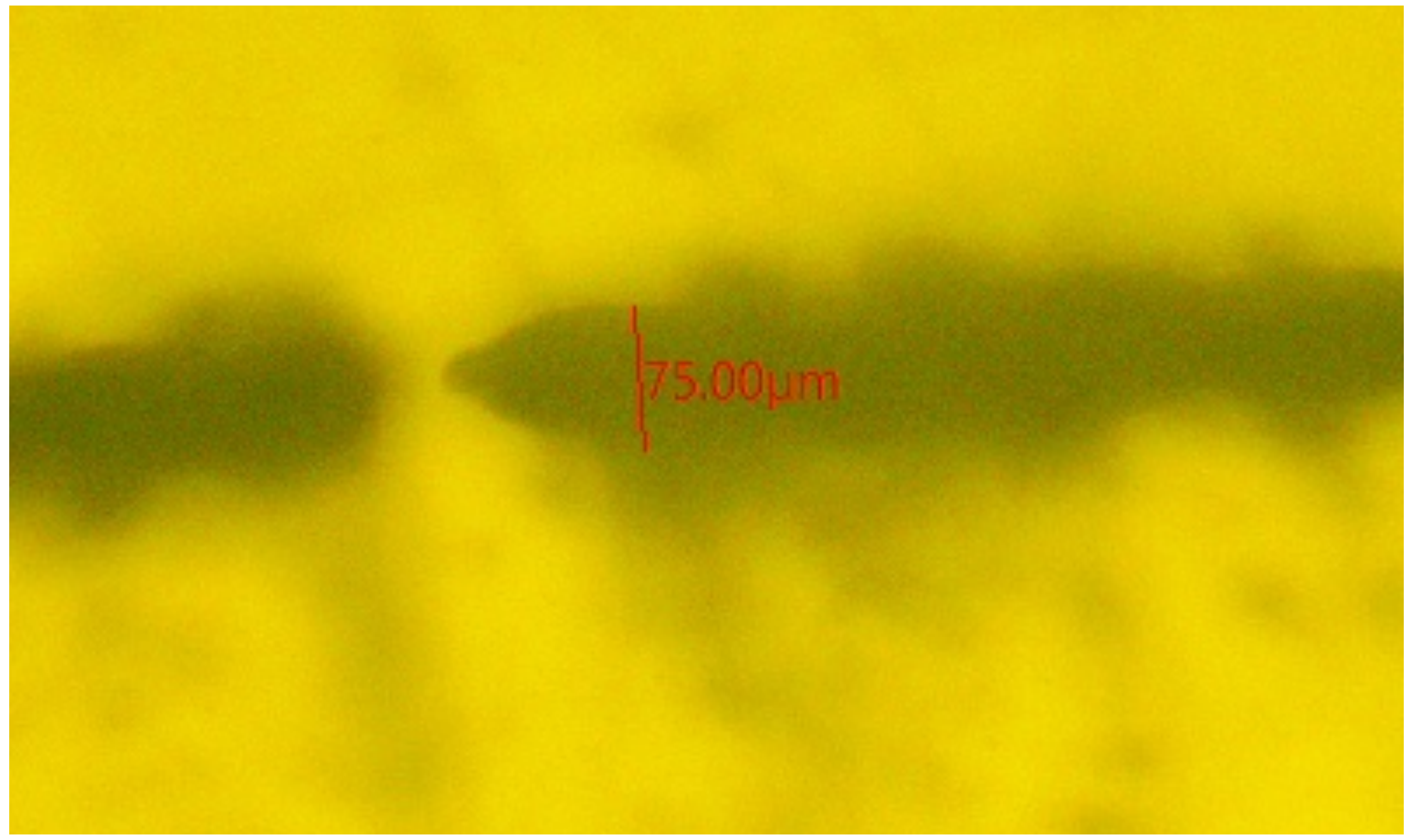
Learnings

- Understanding the Process
- Initial design feasibility
- Correct settings for power and speed

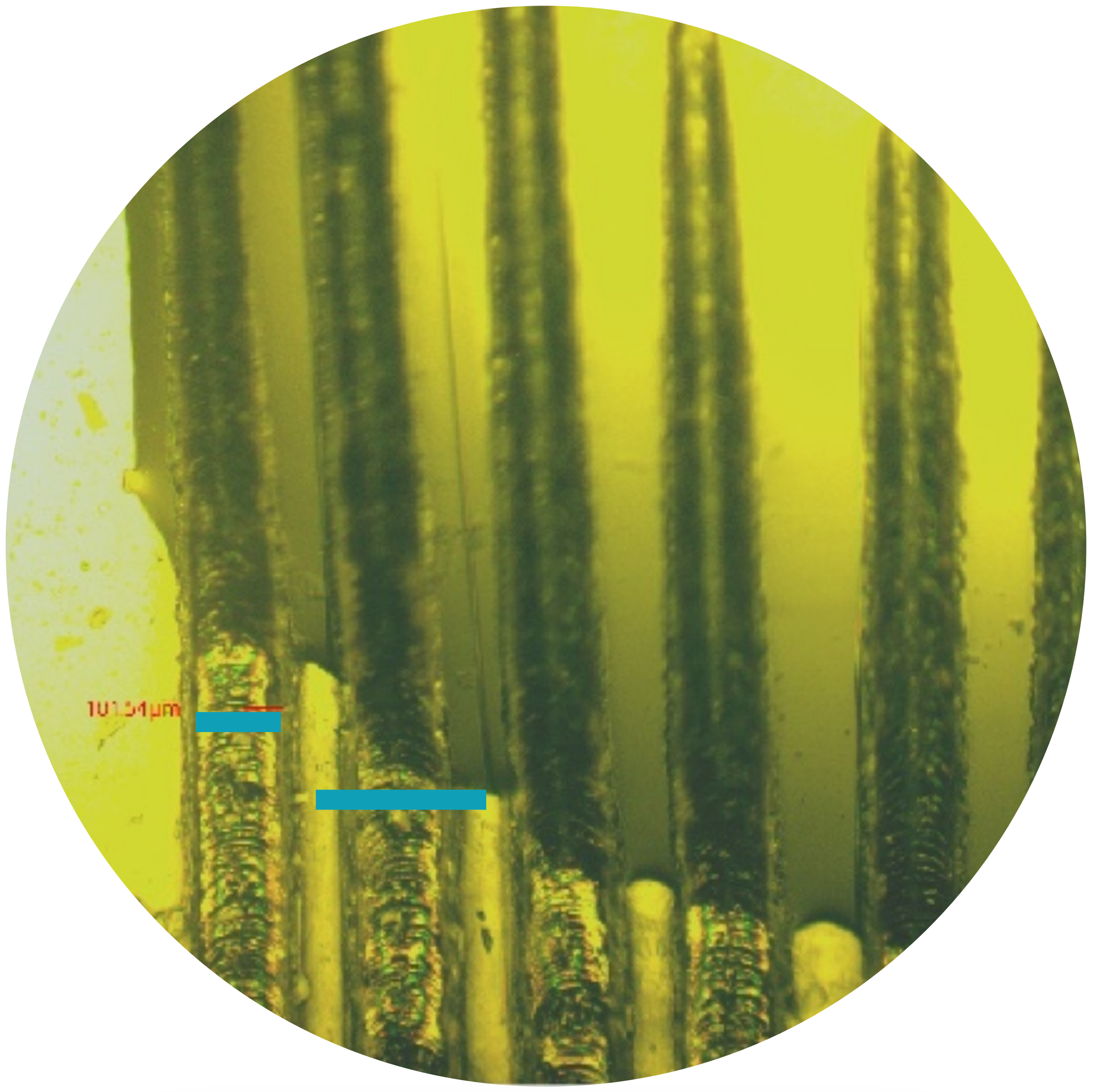
Challenges

- Fidelity did not match the feather
- Burning of the polymer
- Skipping of the polymer



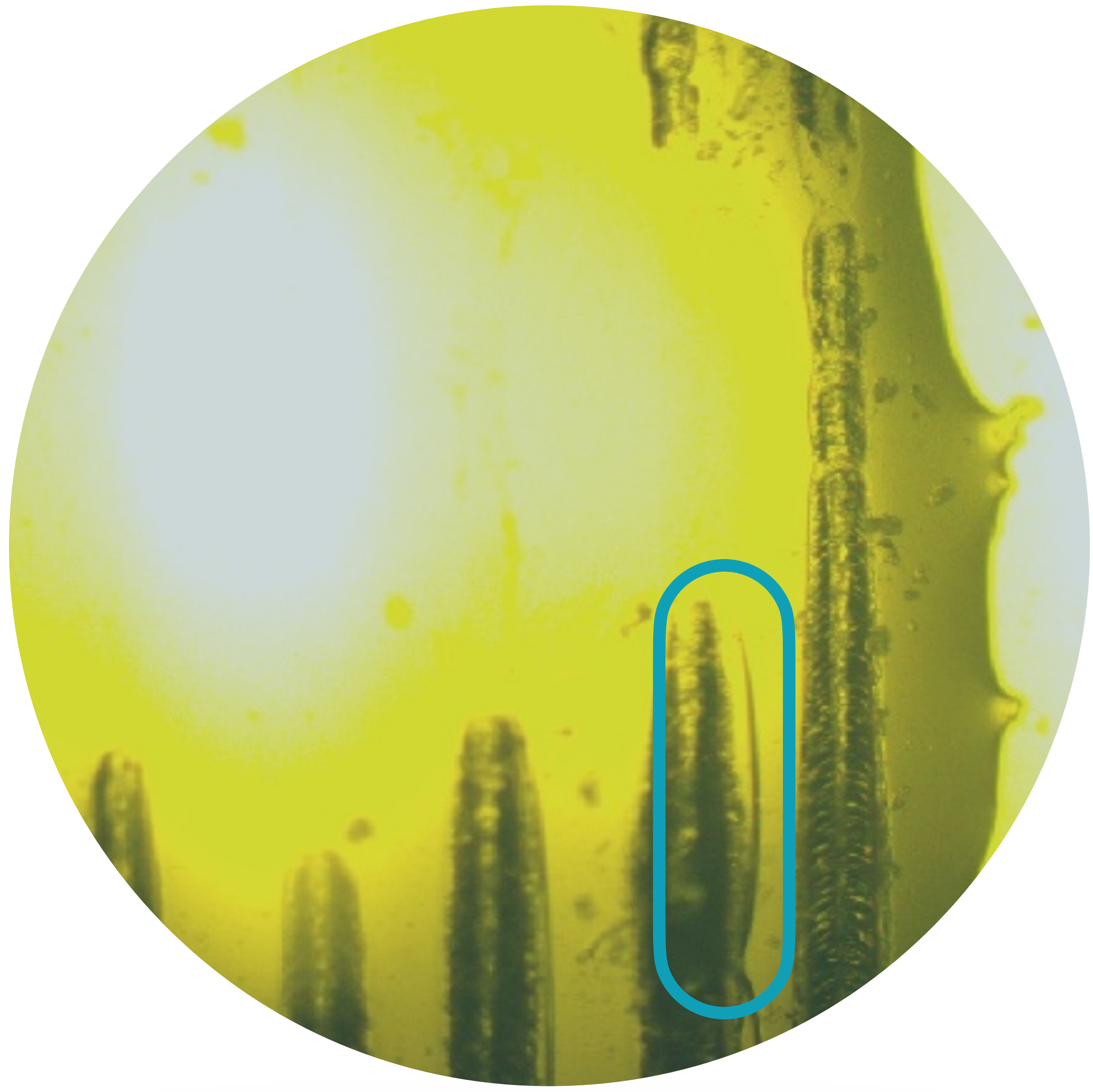


LASER ABLATION PROTOTYPE 1 — WATER



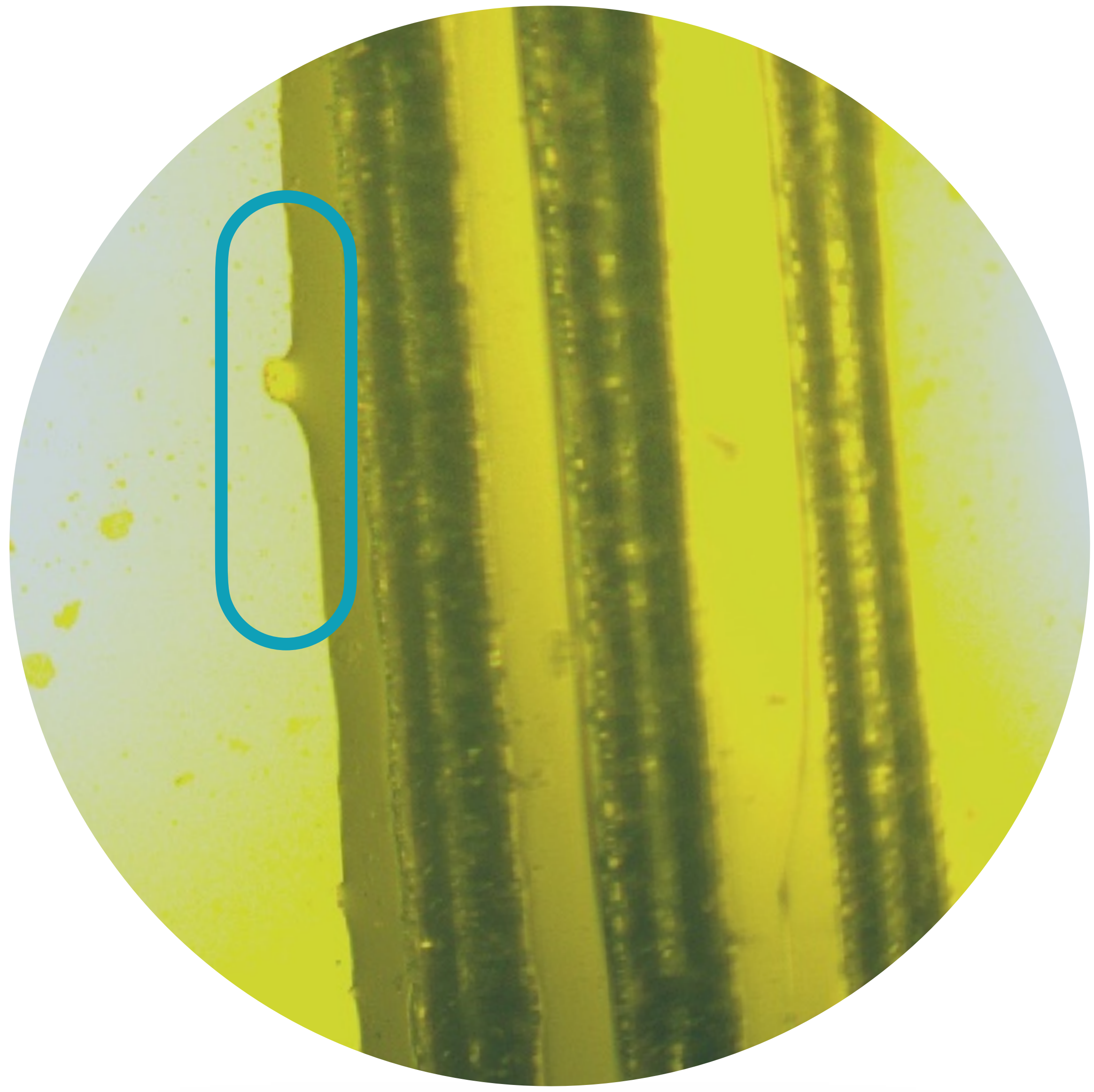
Tranches & Water

With this magnification, you can see the trenches (black) the laser made are larger than the barbs (yellow). **The trenches are about 101μm across while the distance between the barbs is roughly 200μm.**



Tiny Air Pocket?

When we look through the water droplet we see evidence of a possible air bubble forming at the edge of the trench and the barb. This is a promising sign.



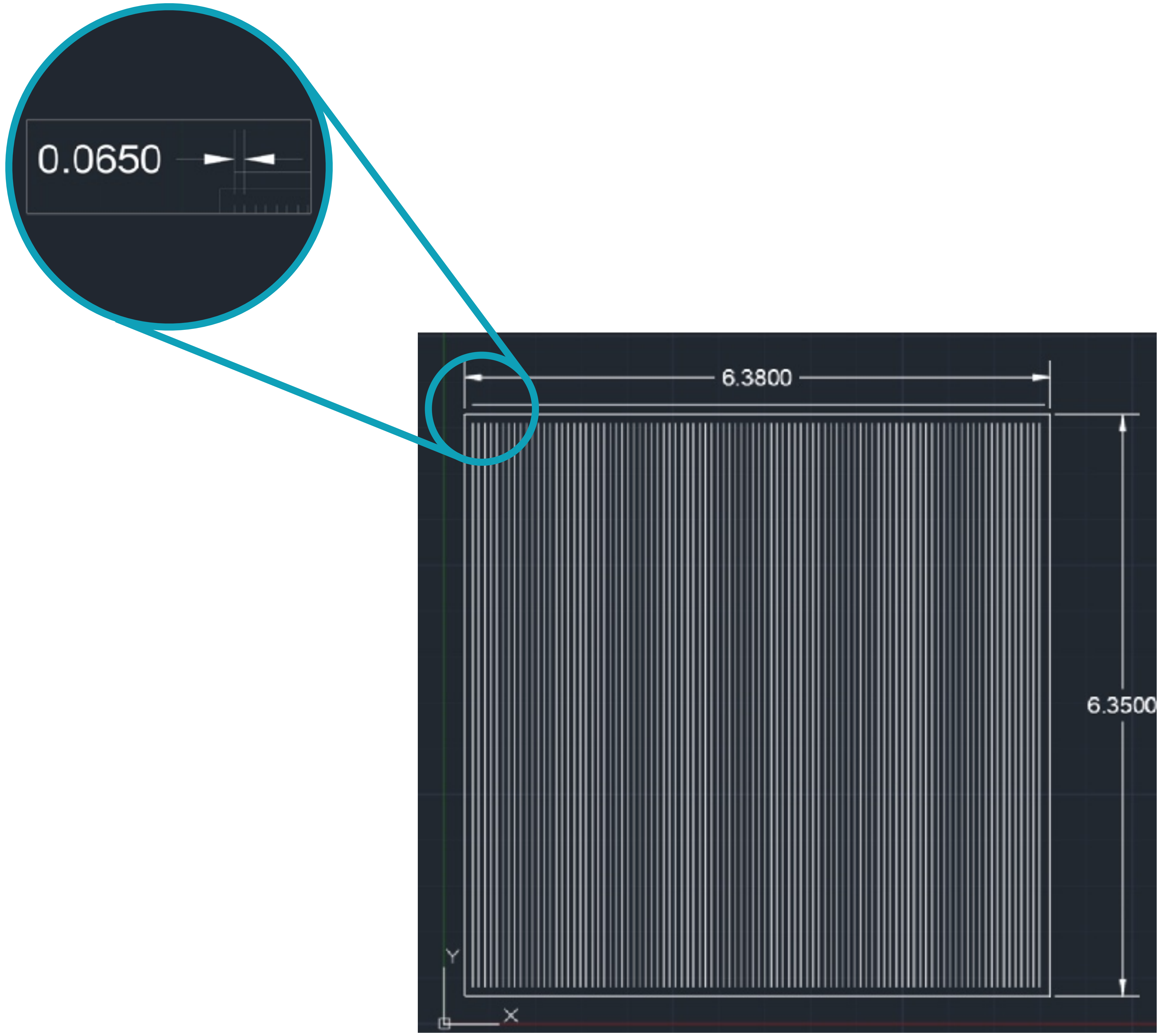
Water on SYLGARD 184

SYLGARD 184 (not radioactive) is a hydrophobic material but doesn't create strong surface tension with water. Can see the water pull out on the silicone here.

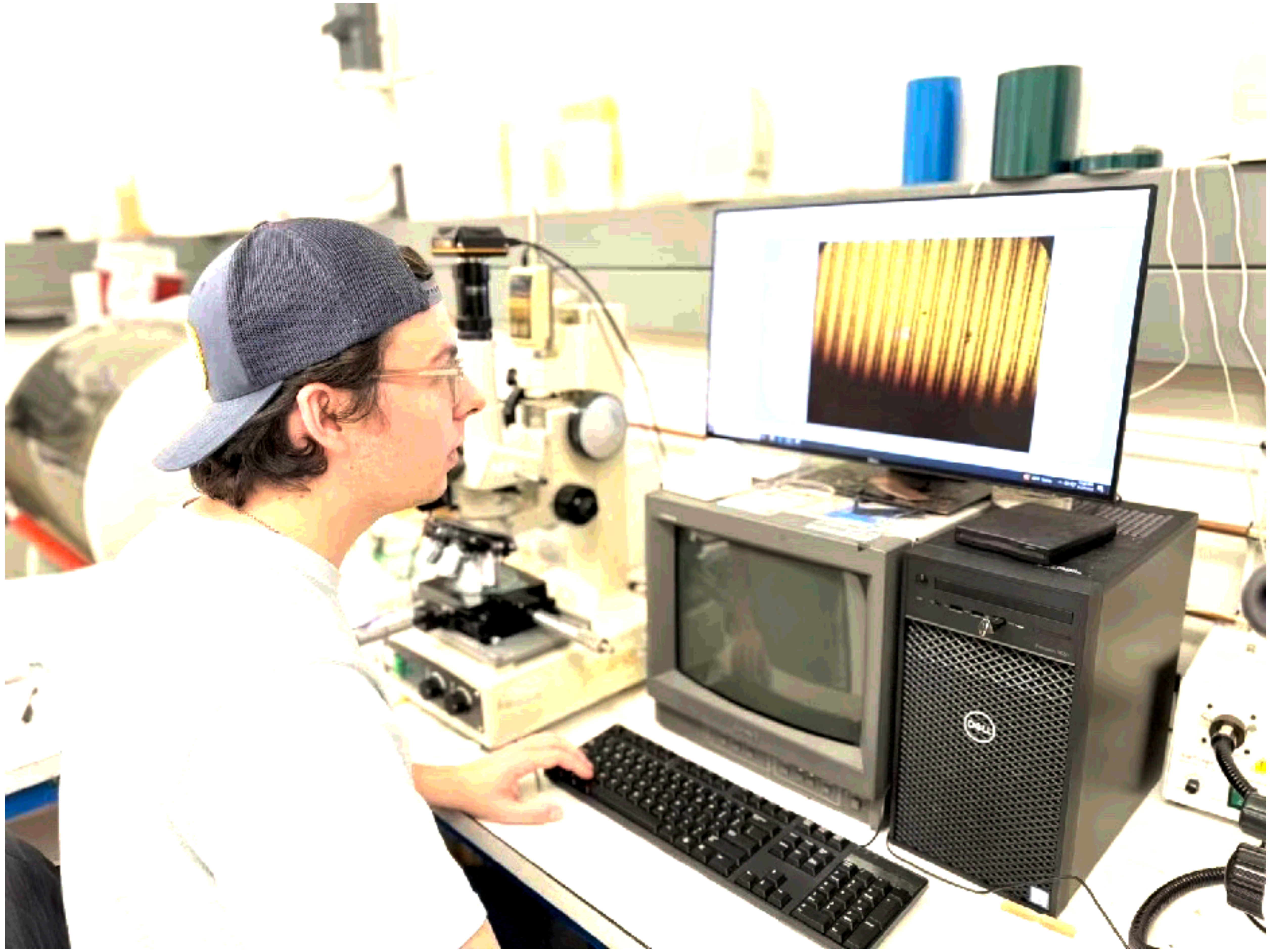
LASER ABLATION CAD

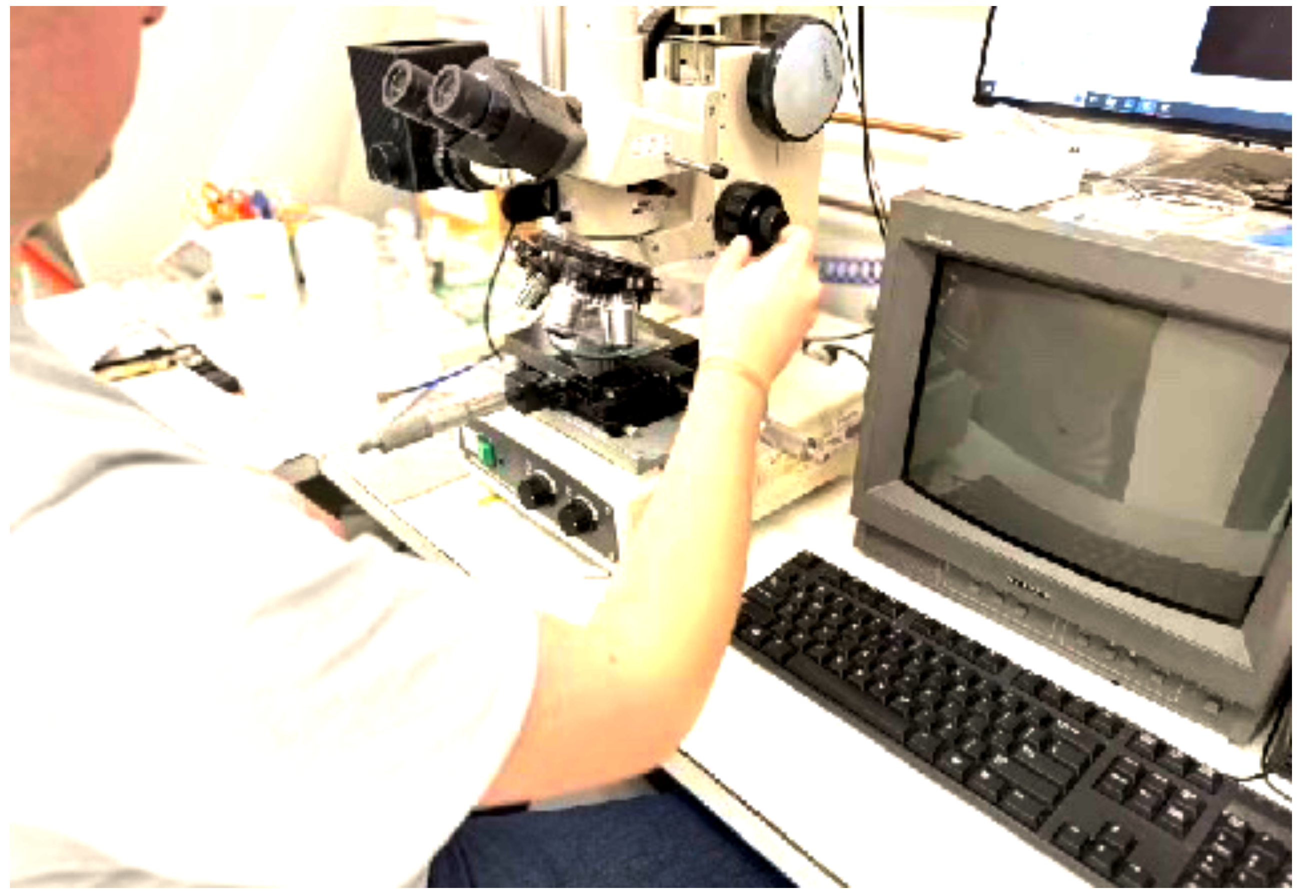
Adjustments

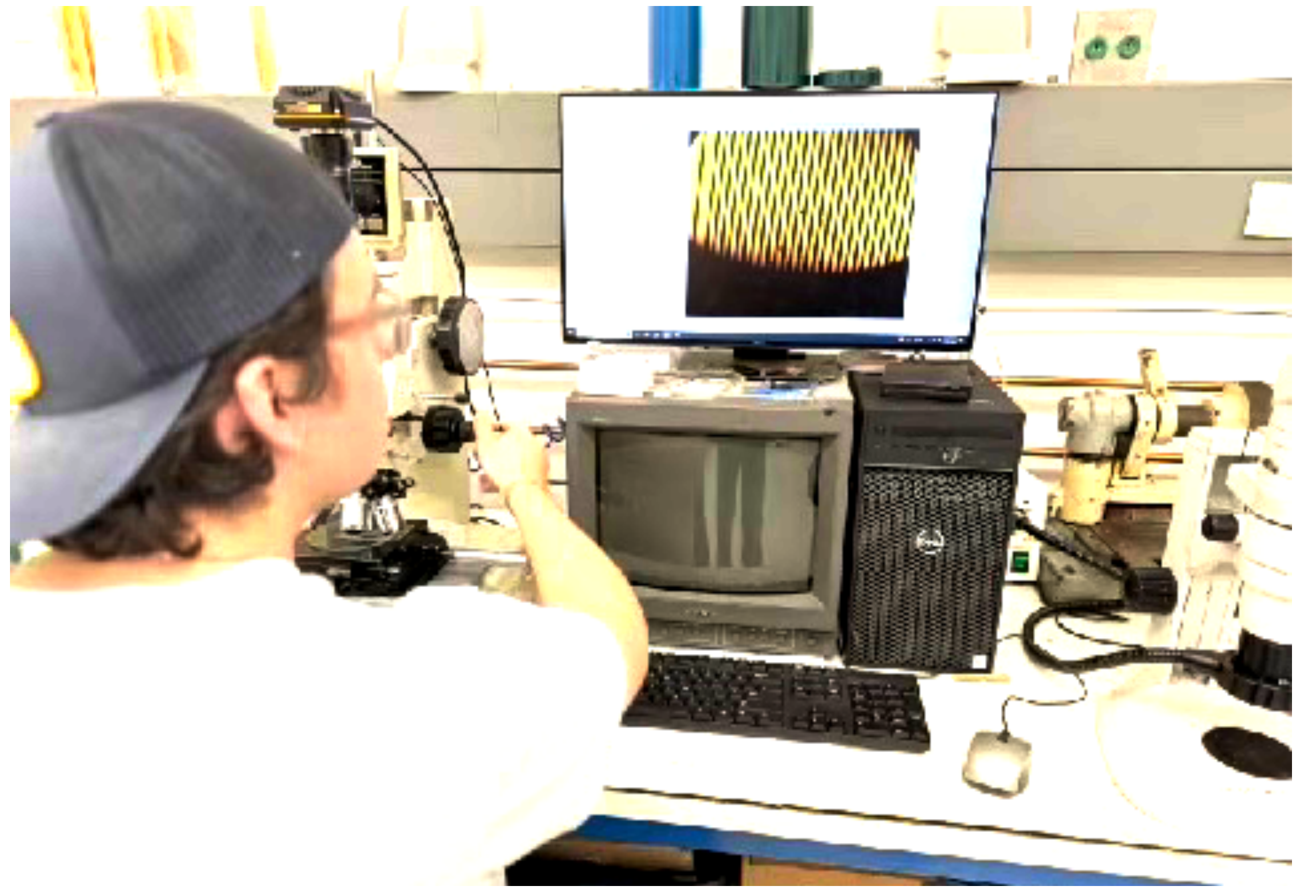
- Adjusted spacing to better model feather behavior
- Higher power, faster speed to avoids burning of polymer
- Lower detail to provide property without the risk of losing fidelity
- Easier to manufacture



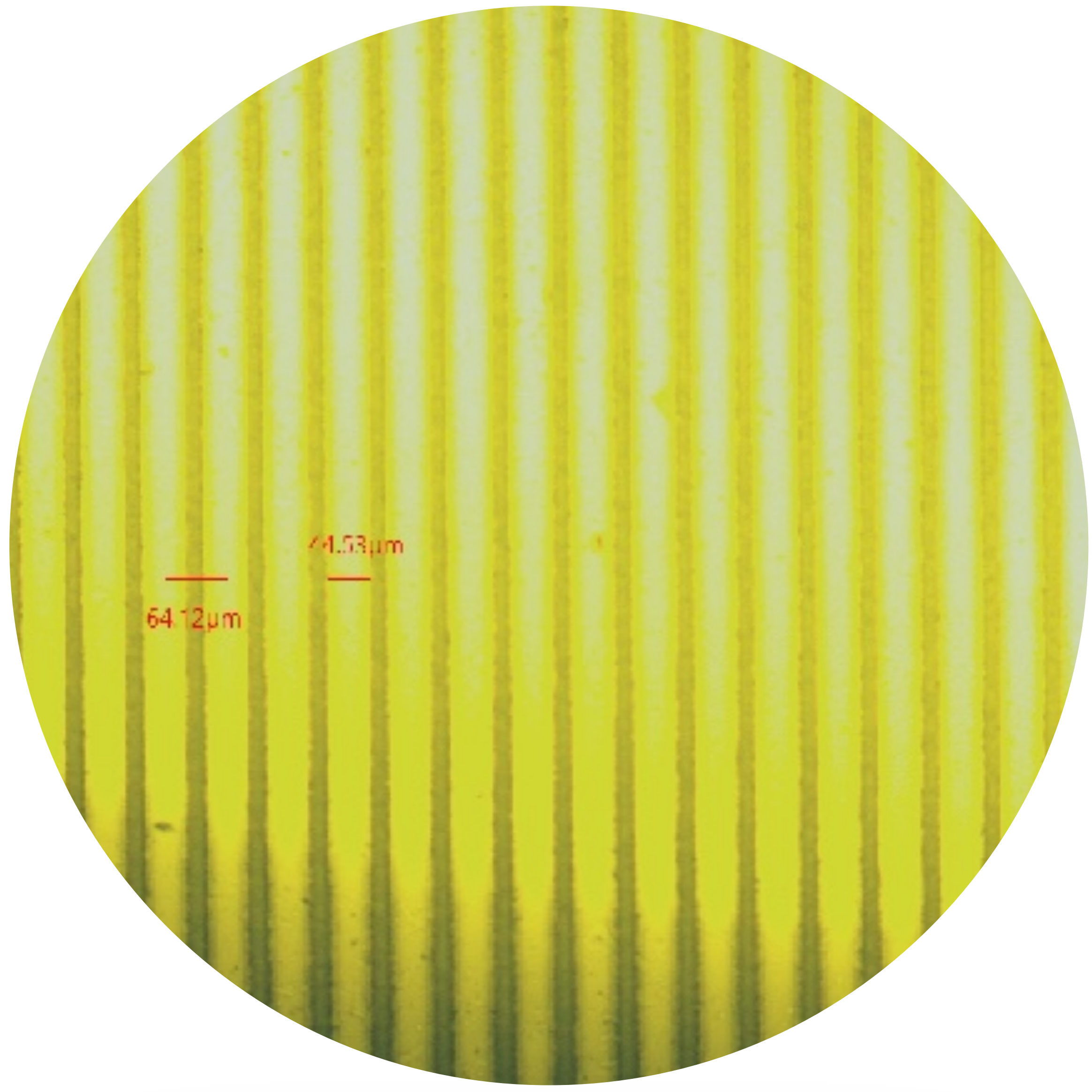
LASER ABLATION CAPTURING RESULTS



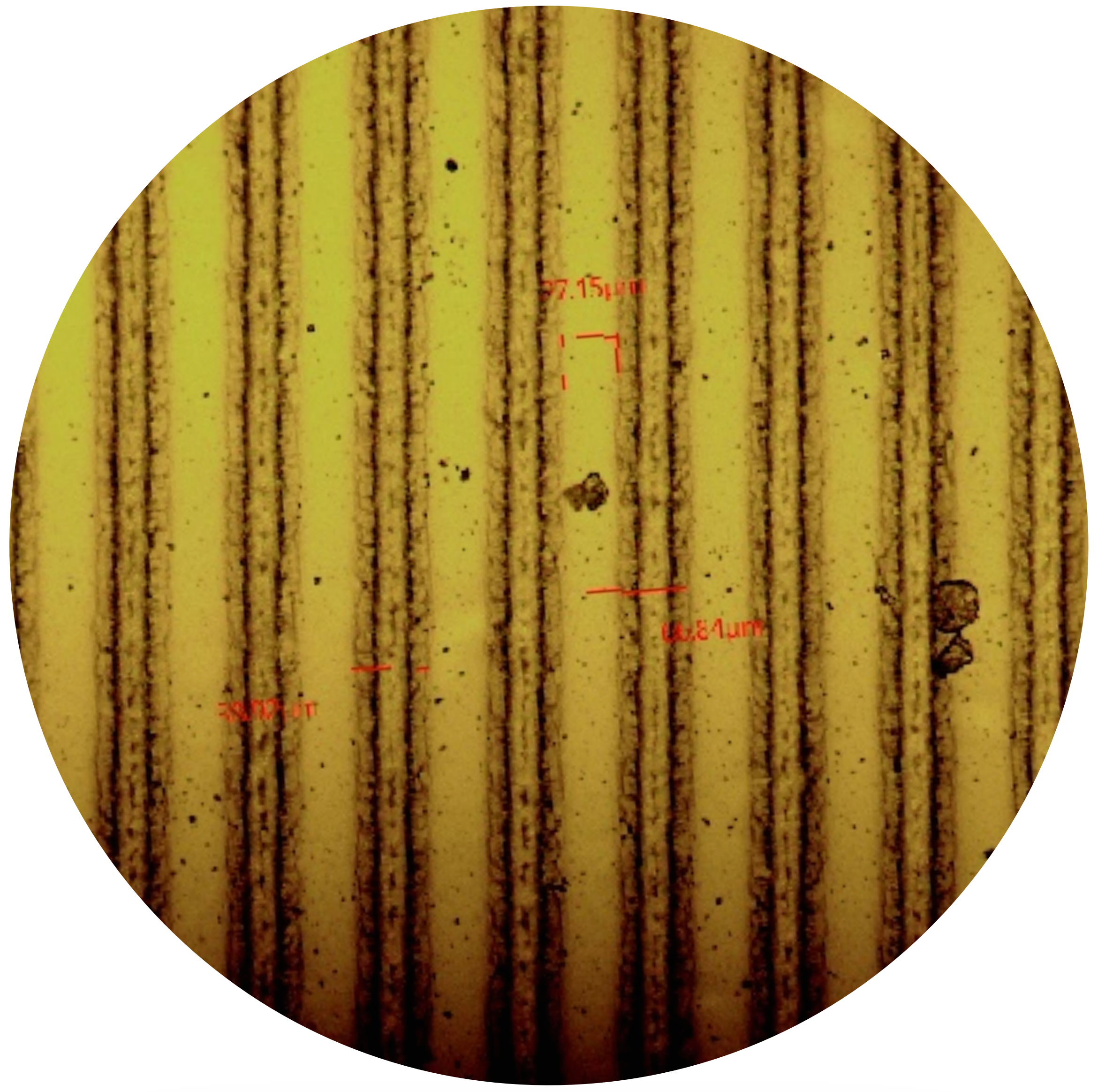




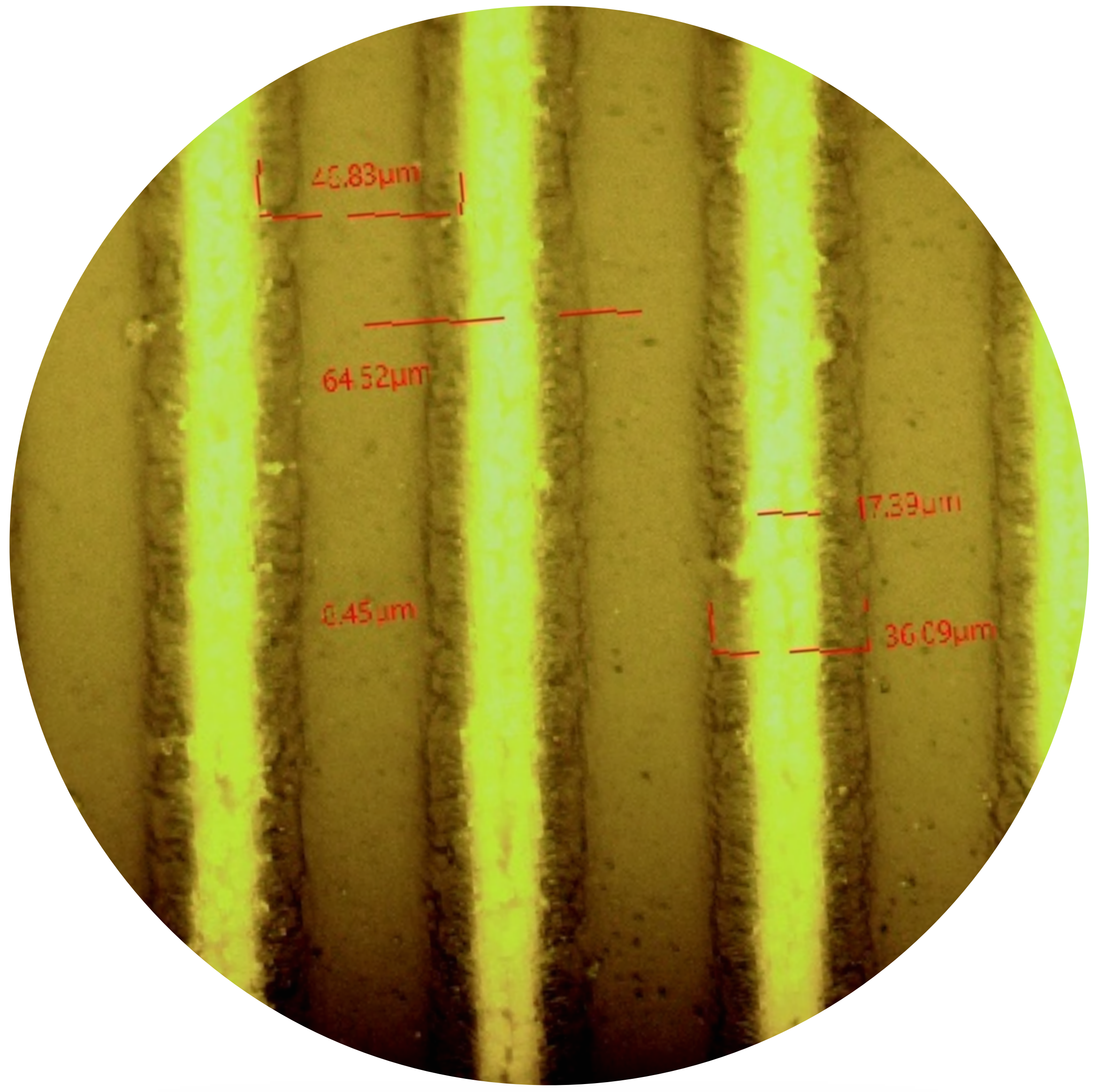
LASER ABLATION MEASURING RESULTS



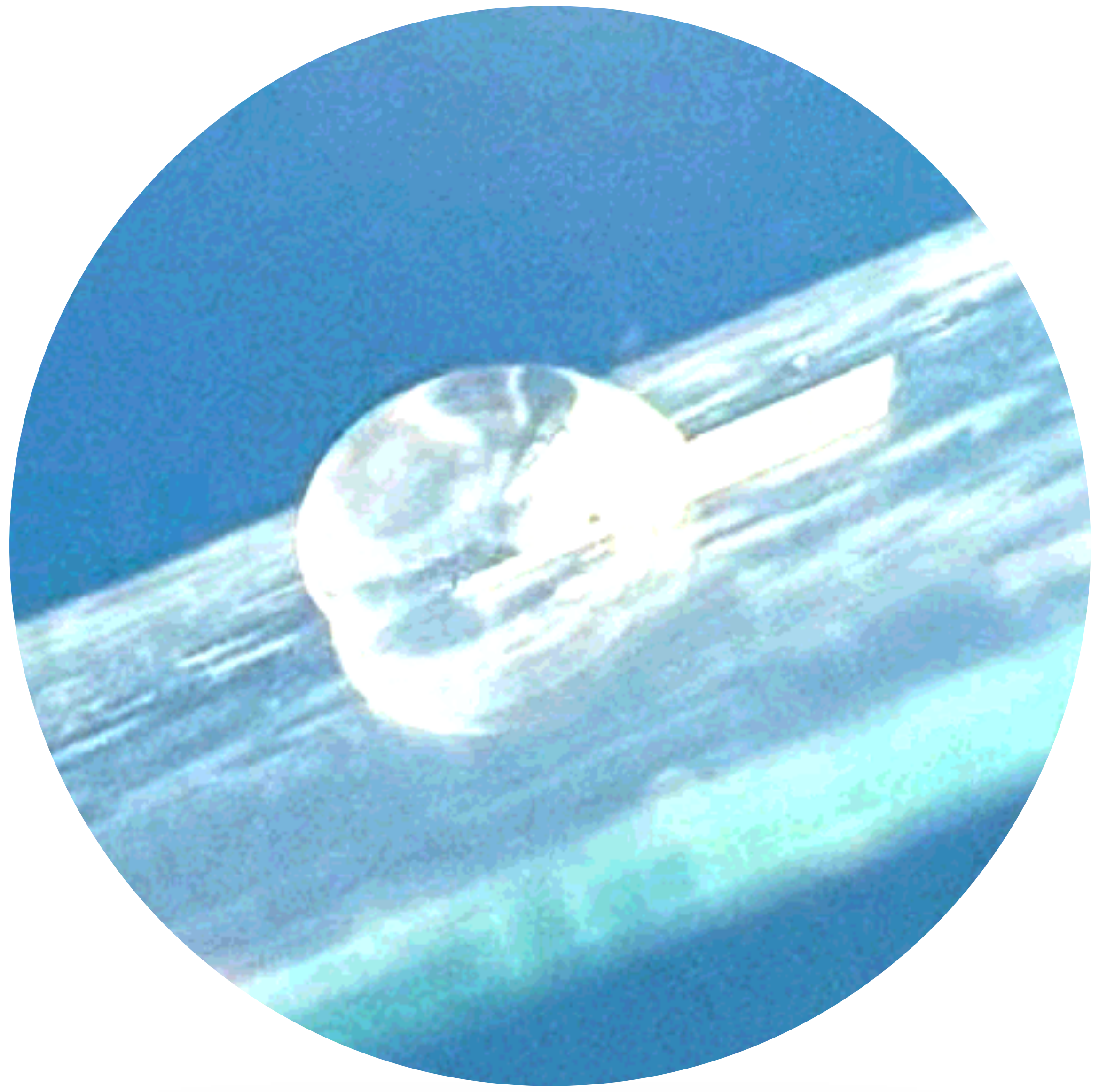
Super Magnification



Insane Magnification



Ludicrous Magnification



Tilting Untextured Surface

When we tilt the water droplet on the untextured surface, we can see the material has some amount of surface tension that creates a modest contact angle, as evidenced by the small bubble with the water droplet.

Tilting Textured Surface

When we tilt the water droplet on the textured material, we see evidence that the surface tension has increased by the extreme contact angle the water droplet creates with the textured surface.

Direct Comparison

When we compare the structured material to the unstructured material front to back, we can see further evidence that the surface tension is greater on the structured material, as evidenced by the contact angle.

MACRO VISUAL

Discussion

POTENTIAL APPLICATIONS

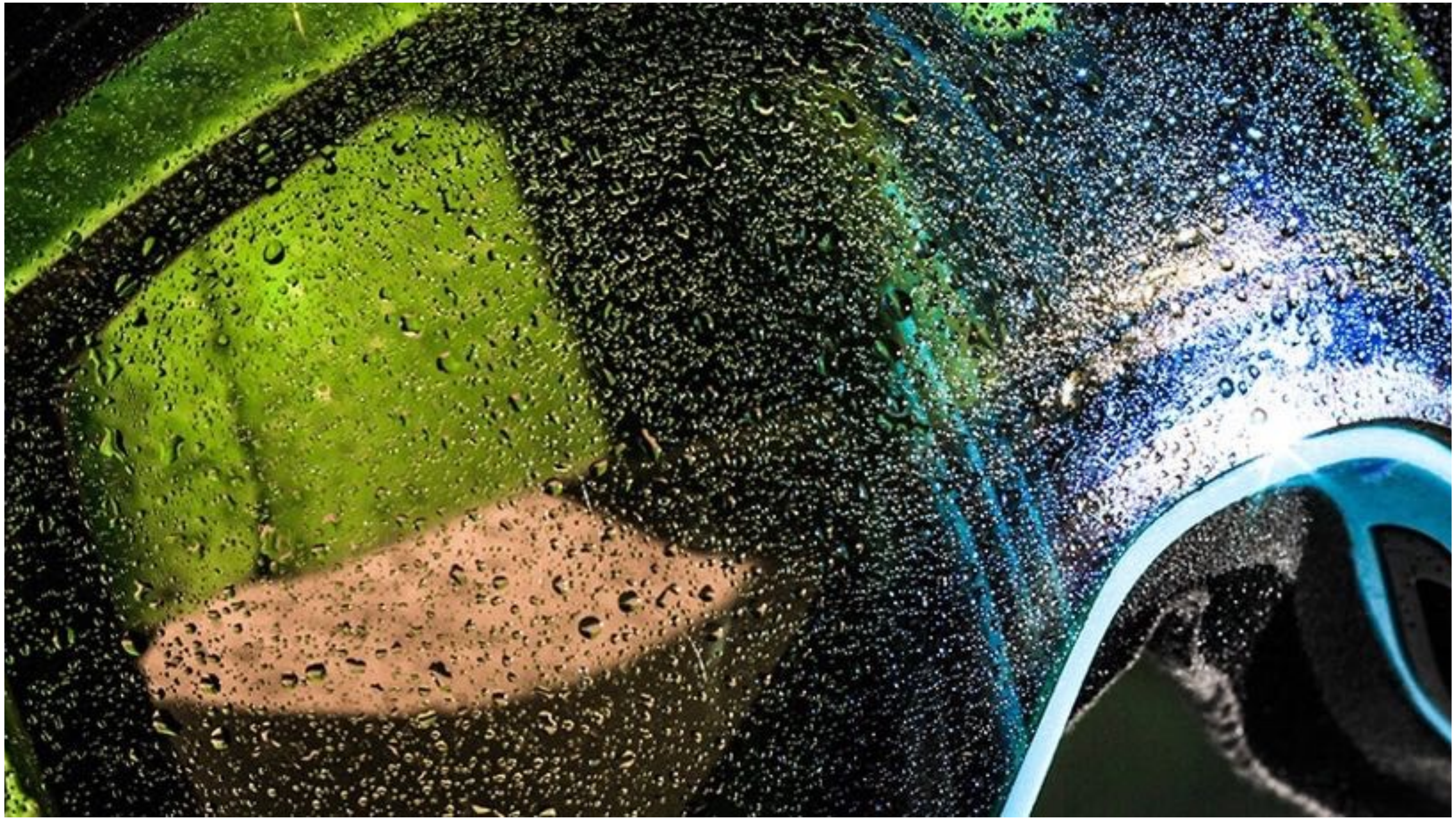
POTENTIAL APPLICATIONS

POTENTIAL APPLICATIONS

POTENTIAL APPLICATIONS

POTENTIAL APPLICATIONS

POTENTIAL APPLICATIONS



NEXT STEPS

Improving Hydrophobicity

Our prototype is meant to demonstrate the structure, scale, and uniformity of our ideal design.

Refining the spacing and material choice until sufficient water resistance is achieved.

Test with Different Liquids

Current DWR demands results with a variety of liquids and oils, from consumer applications to industrial applications. Effectiveness across multiple substances would help ensure adoption.

Replicate Results with Other Materials

To bring this finding to commercial applications, it's essential to replicate and even improve the results on fabrics, plastics, glass, fiberglass, and metal.

Consistent Biodegradation

One of our core product visions was to ensure biodegradability while providing a design whose lifetime was more than comparable to competitors.

Overview
Problem
Bio Exploration
Research
Ideation
Prototyping
Discussion
Q&A

BIO-INSPIRED DESIGN TAKEAWAYS

Evolution Optimizes

Nature has solutions for many of the problems we face.

Nature optimizes, but it does not perfect.

That said, it took the use of a 6–figure machine to create the structure of our organism.

Iteration Improves Results

Inspired Design takes a lot of iteration and ideation to achieve good results. Had we stopped at the first attempt we wouldn't have discovered we were on the right track.

Interdisciplinary Skills Are Key

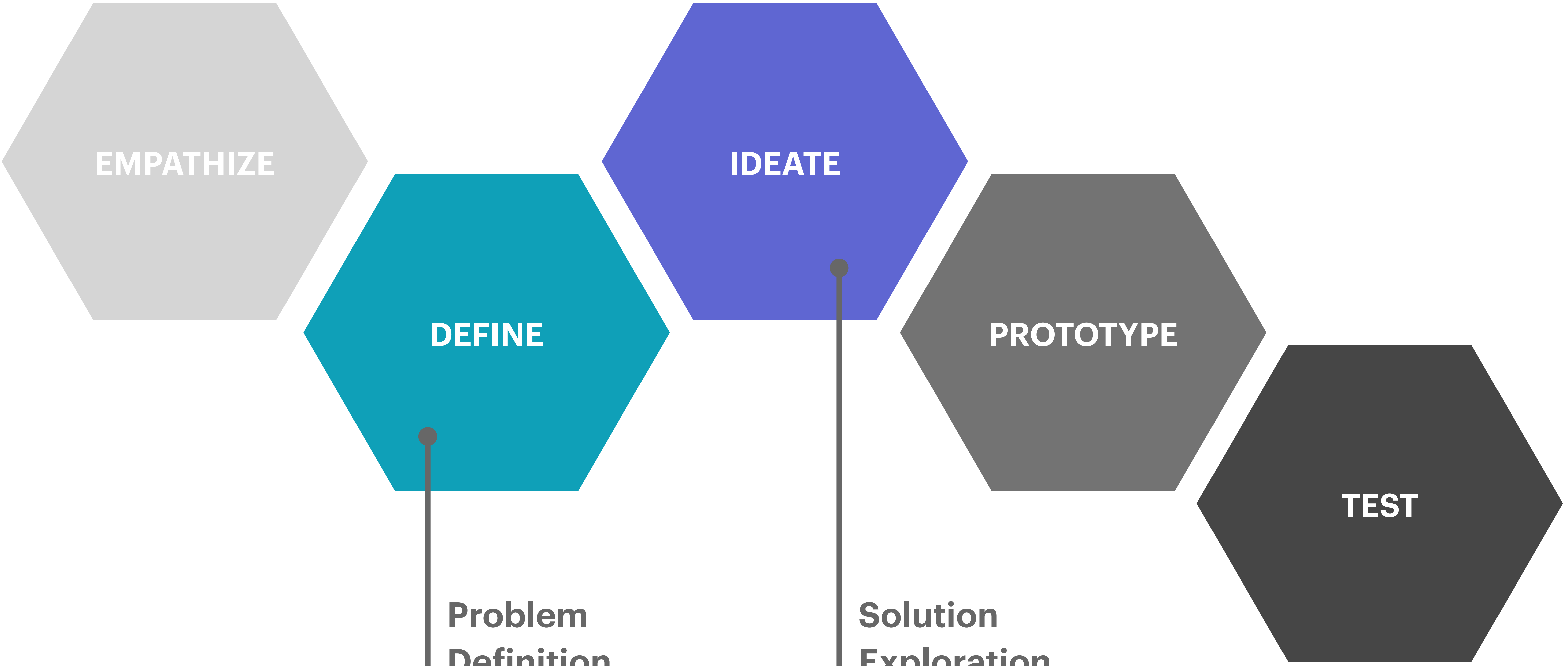
Effective prototyping would not have been possible without the help of newfound friends in the nano-tech labs!

Thanks Hojin Seo!

Find Multiple Organisms

Each organism may contain part of the functional solution for solving the complex problems we face. Also, organisms may solve the same problems in different ways that may be useful to understand for manufacturing flexibility.

BIO-INSPIRED DESIGN TAKEAWAYS



Problem Definition

Bio-inspired design can help define and explore the problem in different contexts based on the creature's adaptations.

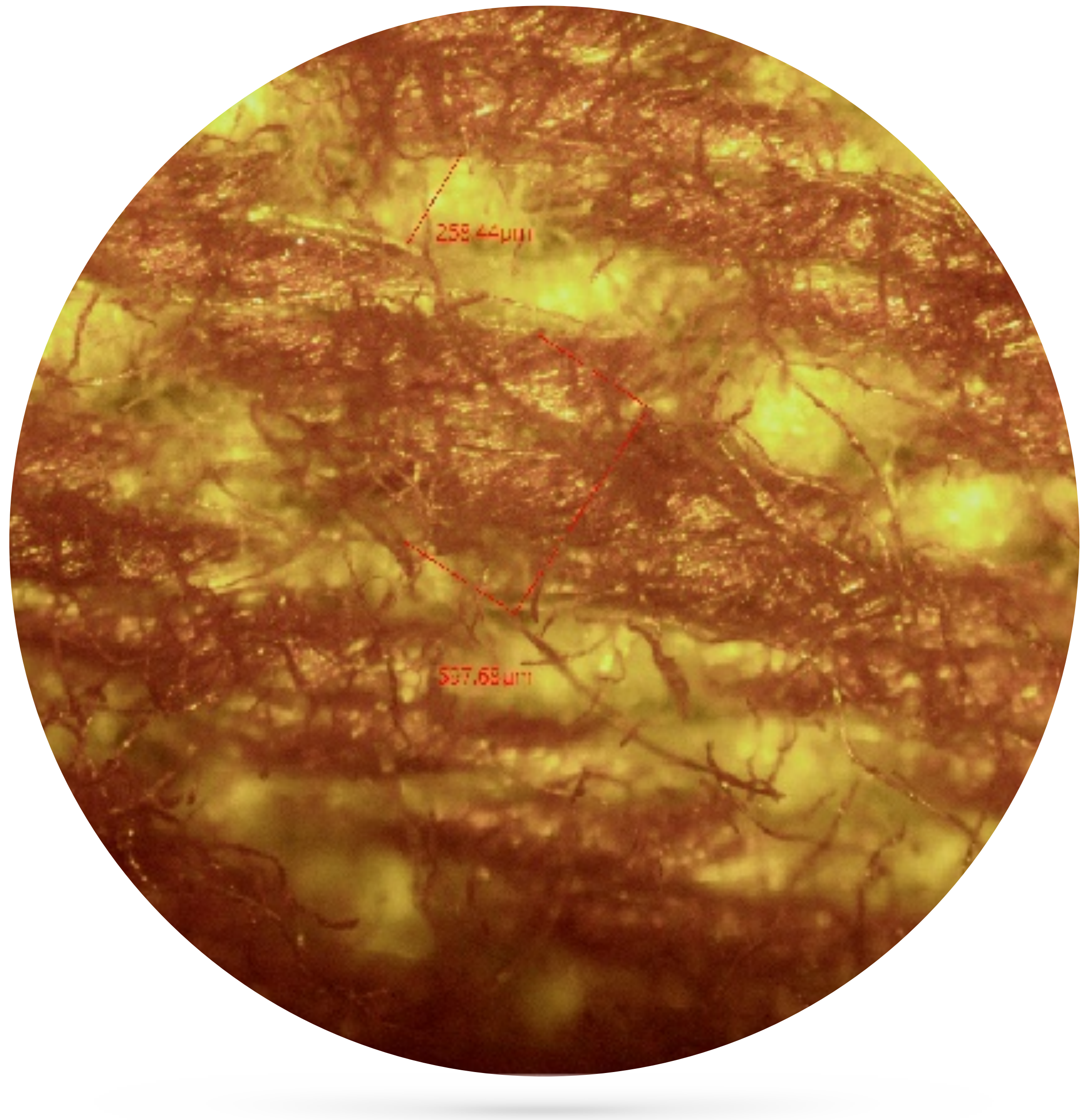
Solution Exploration

Nature has optimized for so many problems and outcomes. It's a great asset to help the ideation process to add solution sets to our more mechanical frame.

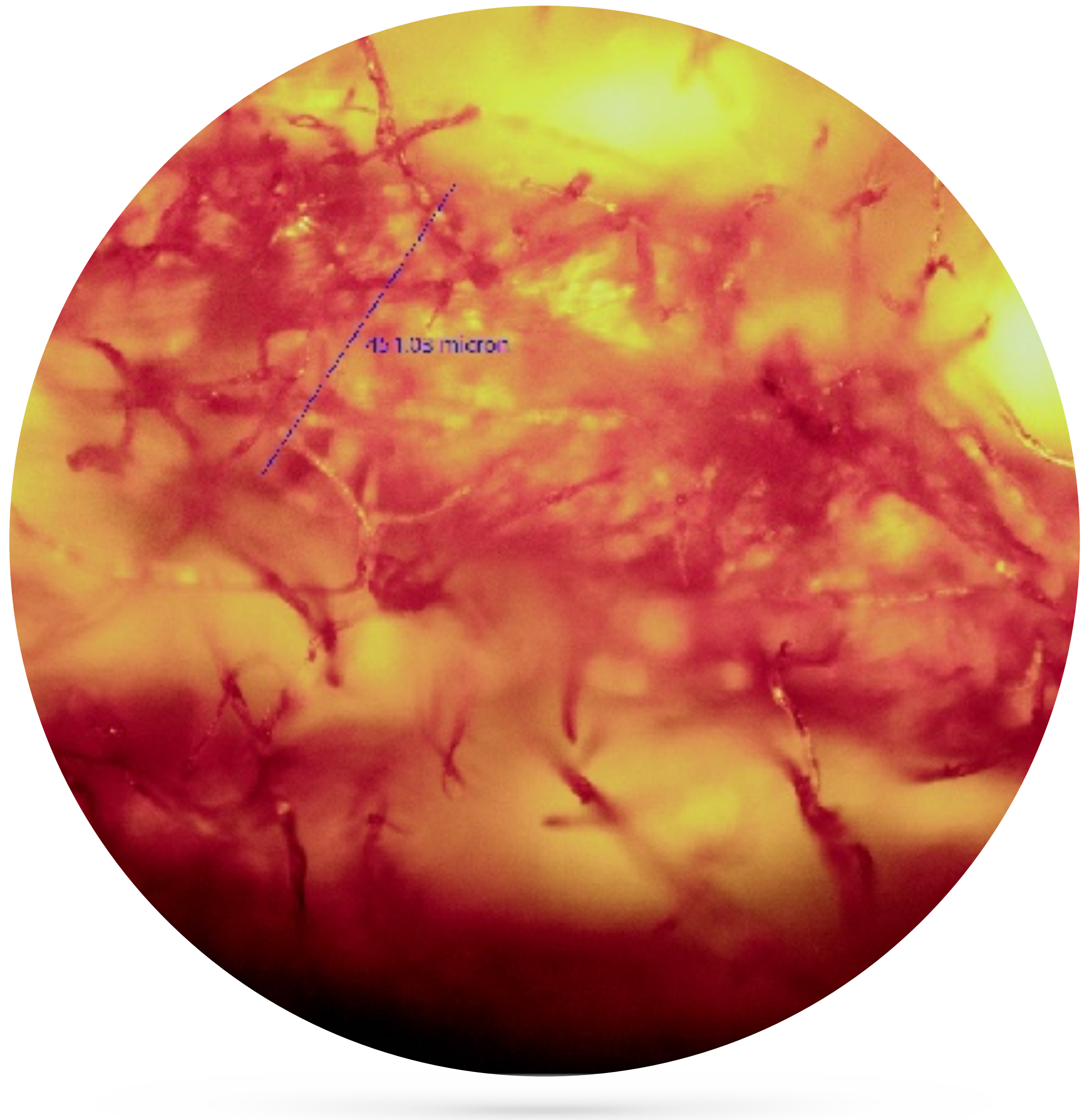
Questions?

Appendix

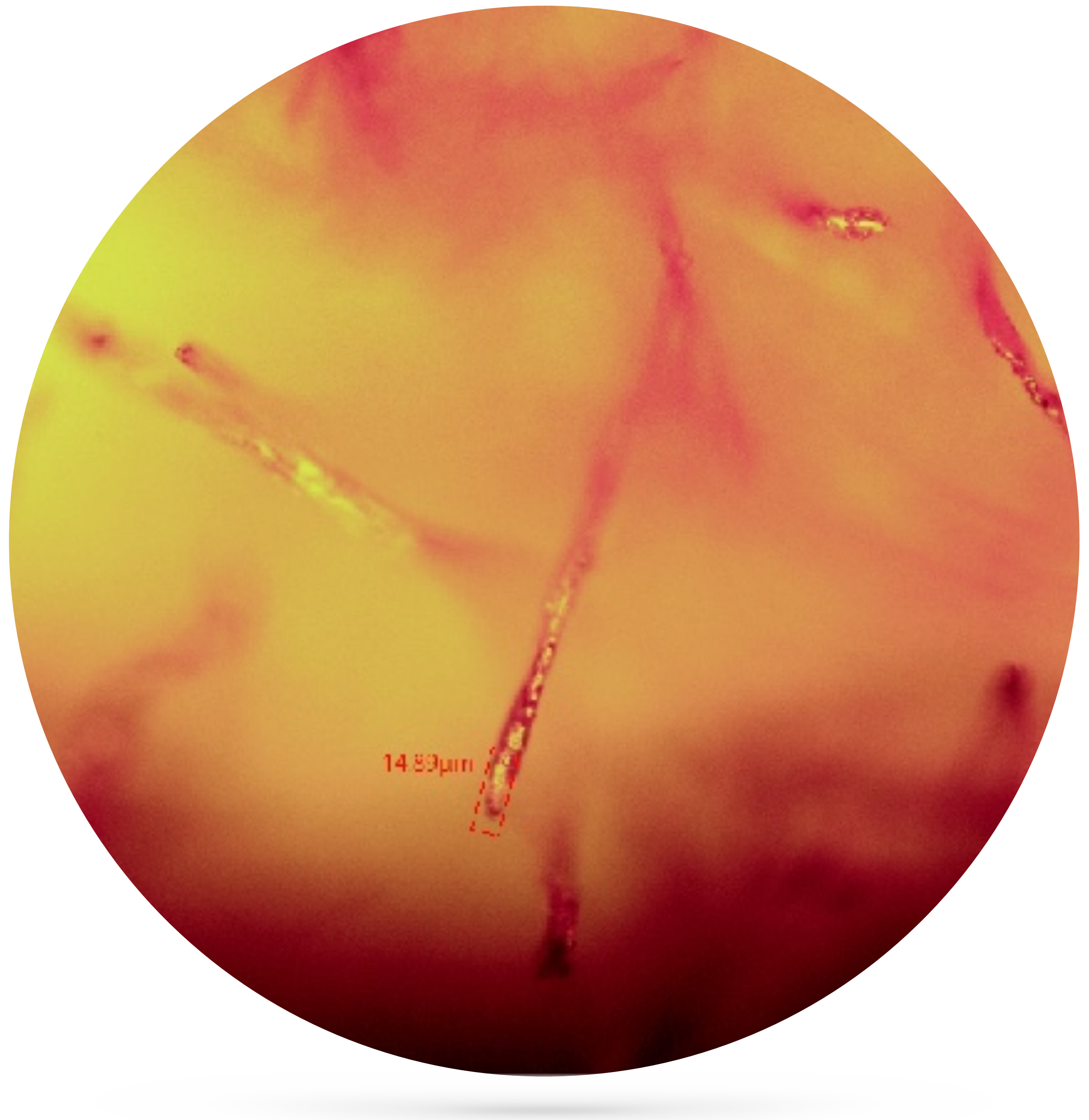
FABRICS — COTTON



Super Magnification



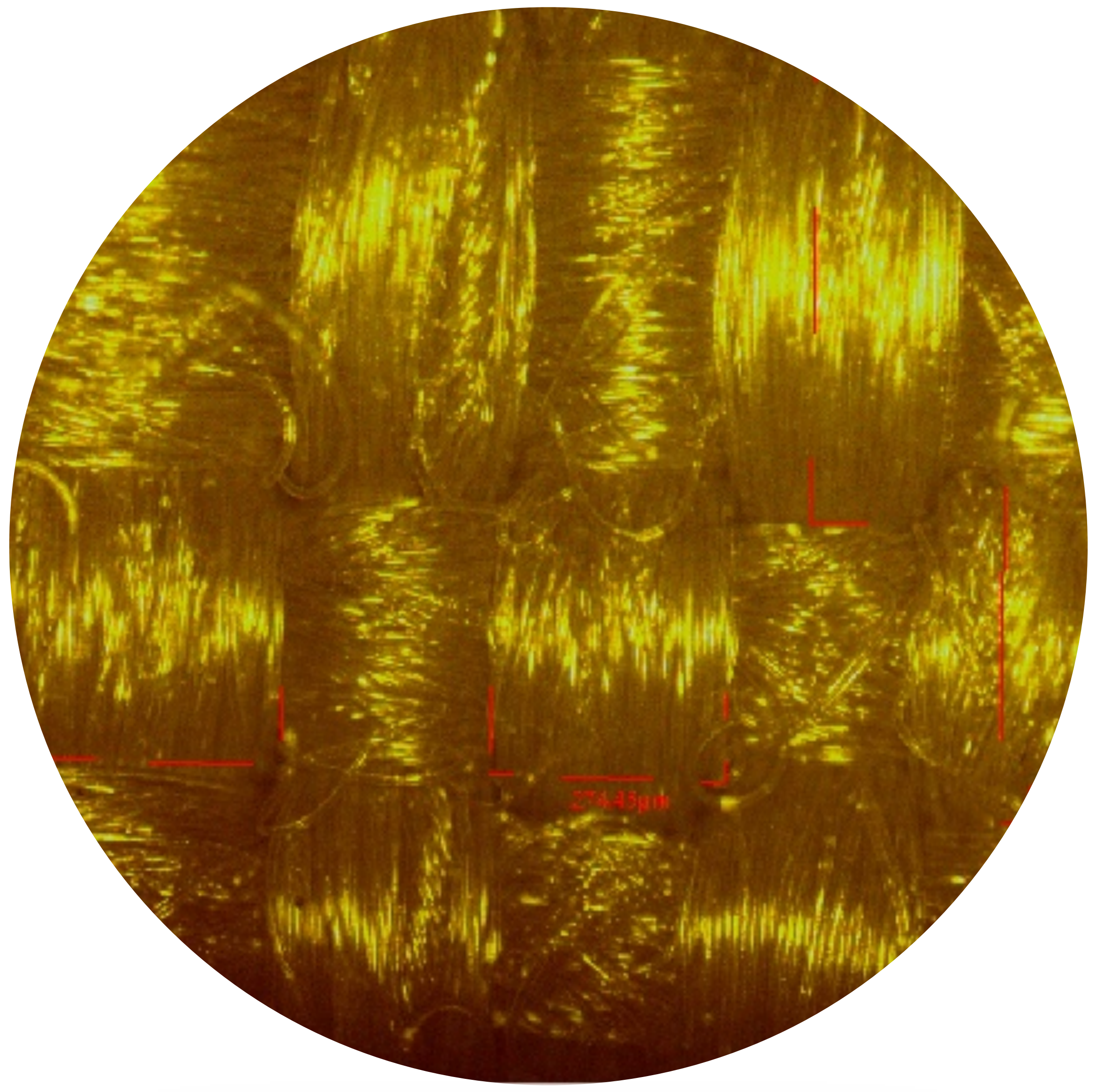
Insane Magnification



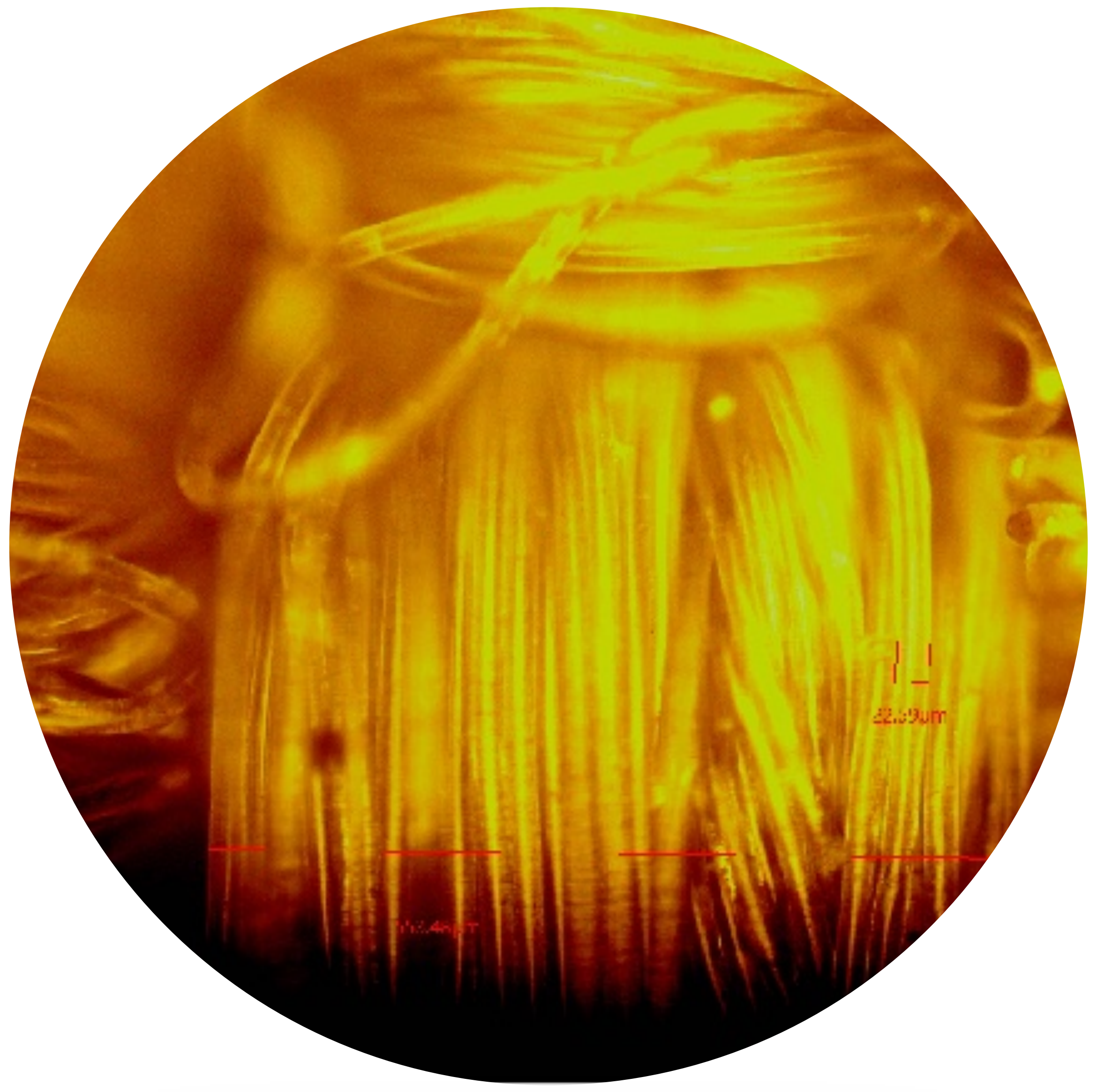
Ludicrous Magnification

Overview
Problem
Bio Exploration
Research
Ideation
Prototyping
Discussion
Q&A

FABRICS — HEAVY NYLON

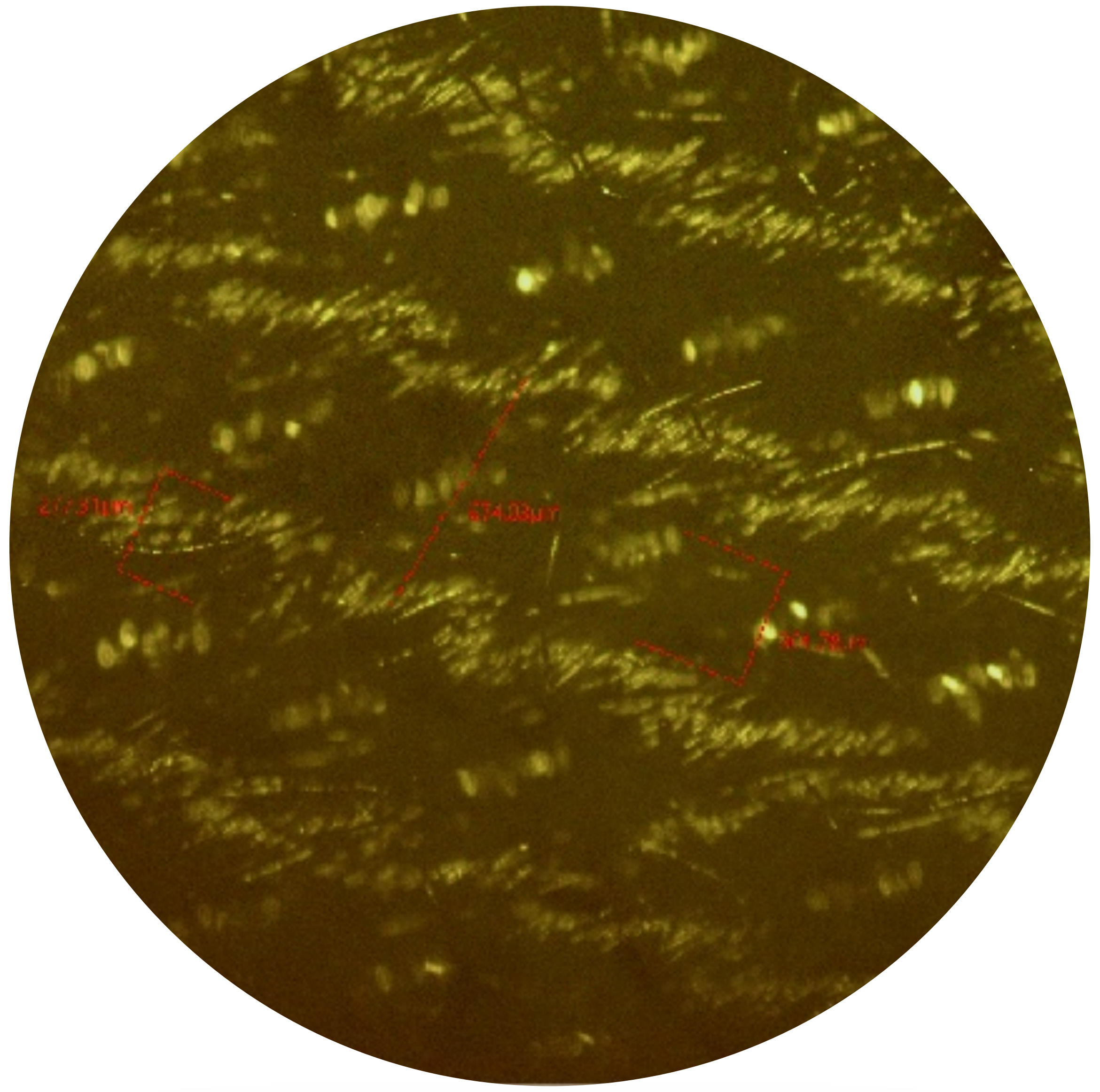


Super Magnification

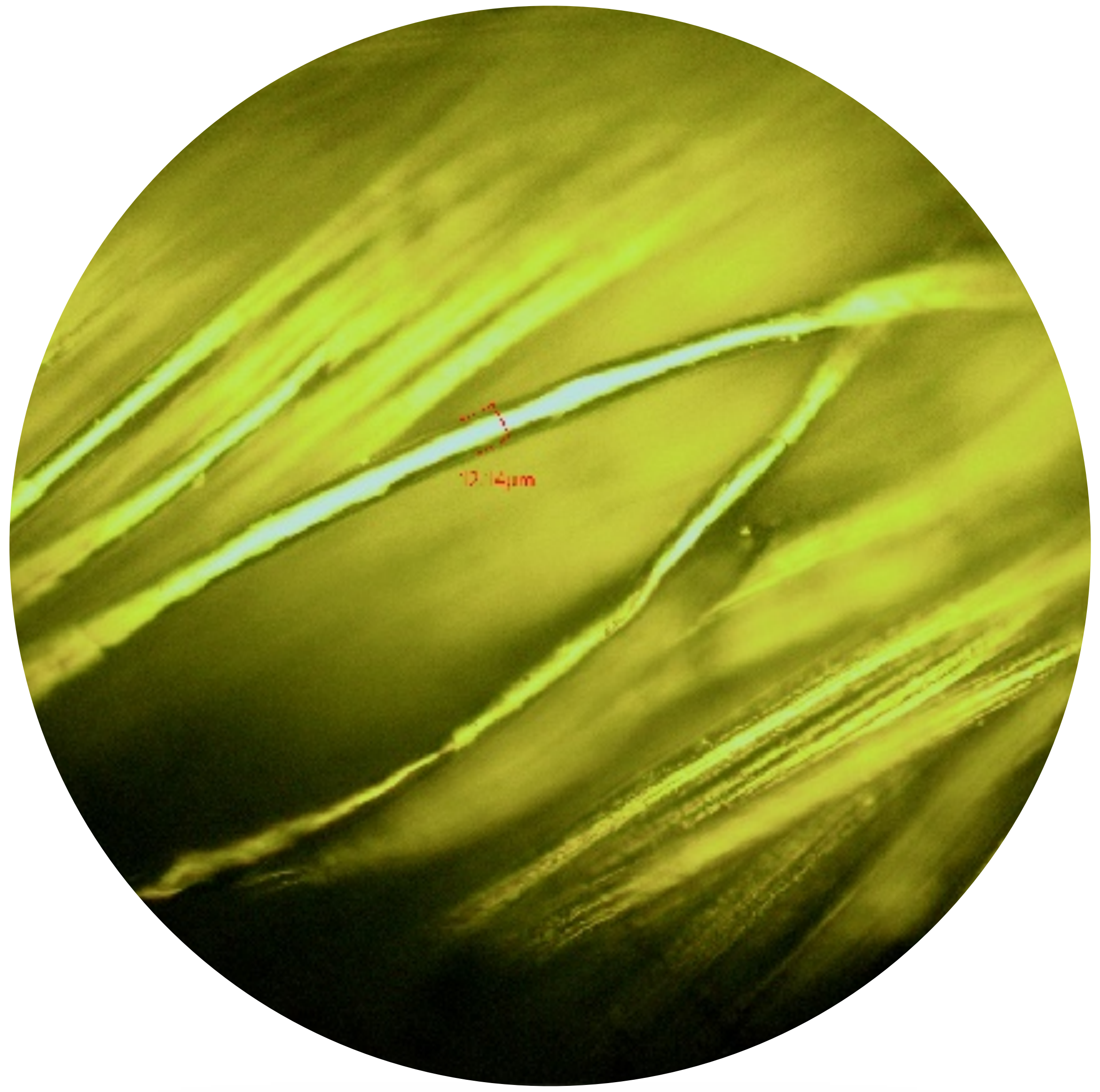


Insane Magnification

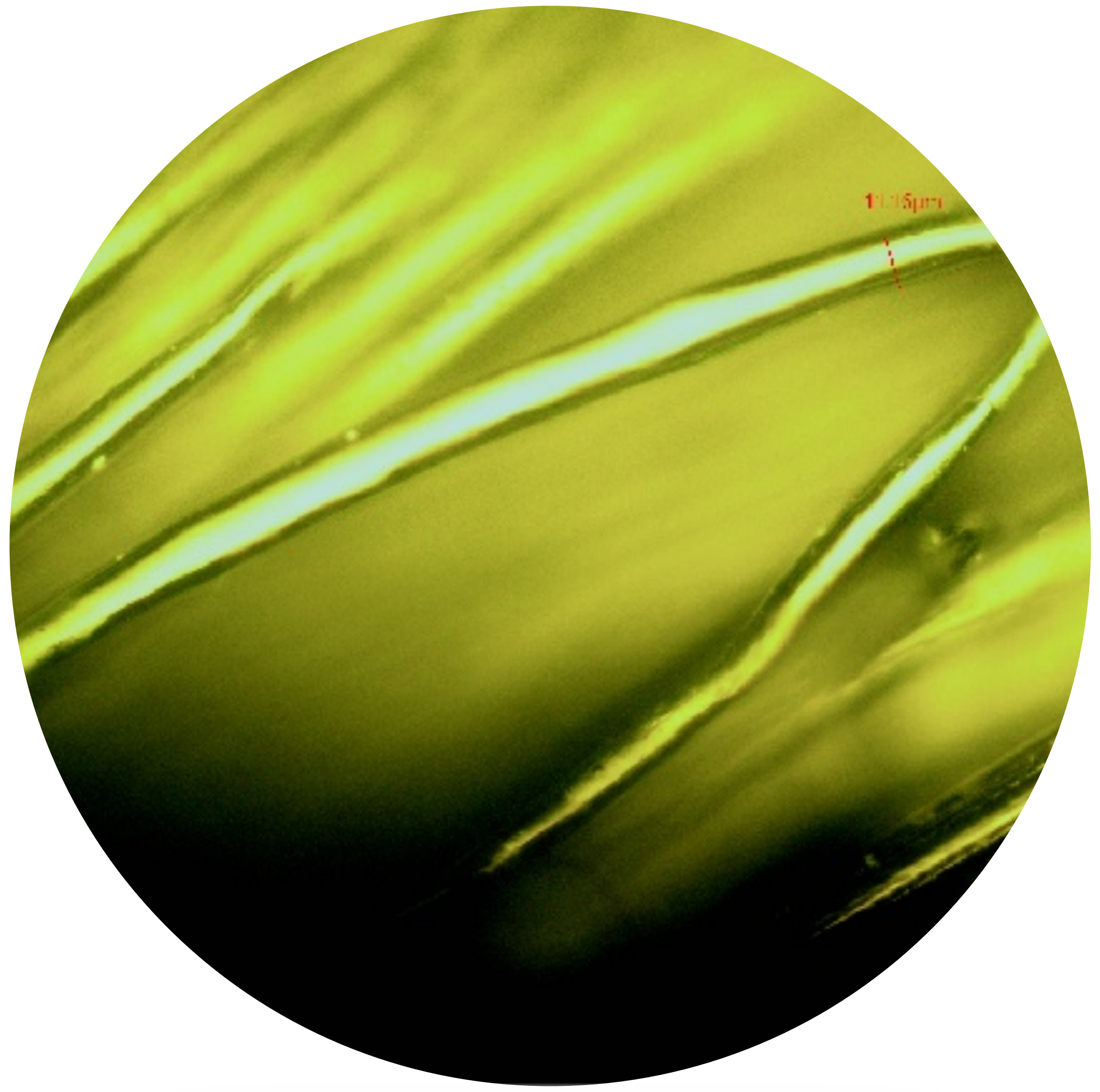
FABRICS — POLYESTER



Super Magnification

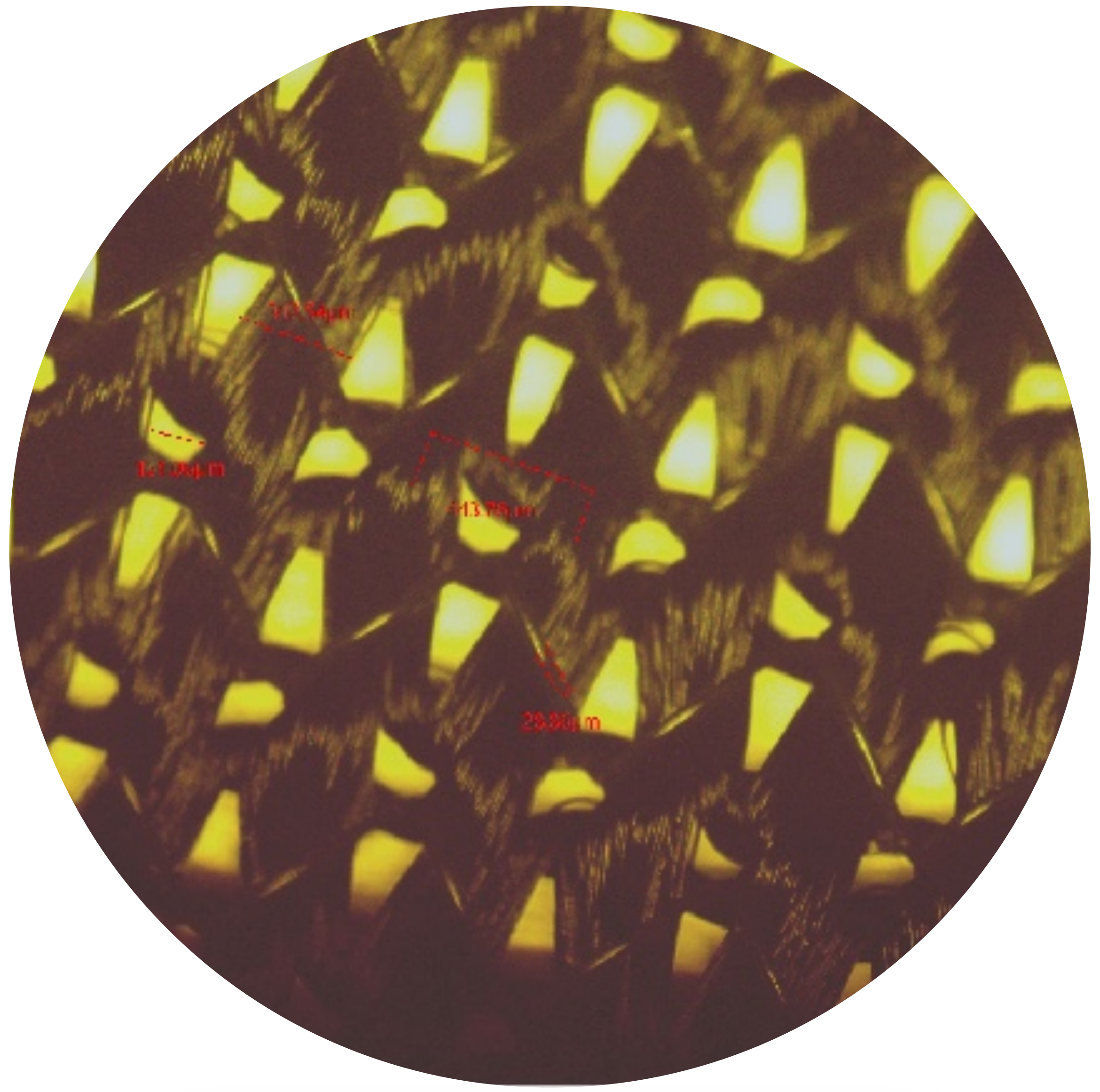


Insane Magnification



Ludicrous Magnification

FABRICS — SHEER NYLON OR POLYESTER



Super Magnification

Insane Magnification

CITATIONS

Armitage, James M., Urs Schenker, Martin Scheringer, Jonathan W. Martin, Matthew MacLeod, and Ian T. Cousins. "Modeling the Global Fate and Transport of Perfluorooctane Sulfonate (PFOS) and Precursor Compounds in Relation to Temporal Trends in Wildlife Exposure." *Environmental Science & Technology* 43, no. 24 (December 15, 2009): 9274–80. https://doi.org/10.1021/es901448p.

Buck, Robert C, James Franklin, Urs Berger, Jason M Conder, Ian T Cousins, Pim De Voogt, Allan Astrup Jensen, Kurunthachalam Kannan, Scott A Mabury, and Stefan Pj Van Leeuwen. "Perfluoroalkyl and Polyfluoroalkyl Substances in the Environment: Terminology, Classification, and Origins." *Integrated Environmental Assessment and Management* 7, no. 4 (October 2011): 513–41. https://doi.org/10.1002/ieam.258.

"EPA Finds Replacements for Toxic 'Teflon' Chemicals Toxic," November 15, 2018. https://www.nrdc.org/bio/anna-reade/epa-finds-replacements-toxic-teflon-chemicals-toxic.

Holmquist, H., S. Schellenberger, I. Van Der Veen, G.M. Peters, P.E.G. Leonards, and I.T. Cousins. "Properties, Performance and Associated Hazards of State-of-the-Art Durable Water Repellent (DWR) Chemistry for Textile Finishing." *Environment International* 91 (May 2016): 251–64. https://doi.org/10.1016/j.envint.2016.02.035.

Hori, Hisao, Yumiko Nagaoka, Ari Yamamoto, Taizo Sano, Nobuyoshi Yamashita, Sachi Taniyasu, Shuzo Kutsuna, Issey Osaka, and Ryuichi Arakawa. "Efficient Decomposition of Environmentally Persistent Perfluorooctanesulfonate and Related Fluorochemicals Using Zerovalent Iron in Subcritical Water." *Environmental Science & Technology* 40, no. 3 (February 1, 2006): 1049–54. https://doi.org/10.1021/es0517419.

Lindstrom, Andrew B., Mark J. Strynar, Amy D. Delinsky, Shoji F. Nakayama, Larry McMillan, E. Laurence Libelo, Michael Neill, and Lee Thomas. "Application of WWTP Biosolids and Resulting Perfluorinated Compound Contamination of Surface and Well Water in Decatur, Alabama, USA." *Environmental Science & Technology* 45, no. 19 (October 1, 2011): 8015–21. https://doi.org/10.1021/es1039425.

Löfstedt Gilljam, John, Juliana Leonel, Ian T. Cousins, and Jonathan P. Benskin. "Is Ongoing Sulfluramid Use in South America a Significant Source of Perfluorooctanesulfonate (PFOS)? Production Inventories, Environmental Fate, and Local Occurrence." *Environmental Science & Technology* 50, no. 2 (January 19, 2016): 653–59. https://doi.org/10.1021/acs.est.5b04544.

"Our DWR Problem - Patagonia Stories," March 6, 2015. https://www.patagonia.com/stories/our-dwr-problem/story-17791.html.

Paul, Alexander G., Kevin C. Jones, and Andrew J. Sweetman. "A First Global Production, Emission, And Environmental Inventory For Perfluorooctane Sulfonate." Environmental Science & Technology 43, no. 2 (January 15, 2009): 386–92. https://doi.org/10.1021/es802216n.

Bormashenko, E., Bormashenko, Y., Stein, T., Whyman, G., & Bormashenko, E. (2007). Why do pigeon feathers repel water? Hydrophobicity of pennae, Cassie–Baxter wetting hypothesis and Cassie–Wenzel capillarity-induced wetting transition. Journal of Colloid and Interface Science, 311(1), 212–216. https://doi.org/10.1016/j.jcis.2007.02.049

CITATIONS

"PFAS and Gore's Structural Firefighting Products | GORE-TEX Professional." Accessed September 27, 2023. https://www.goretexprofessional.com/about-us/research-and-insights/pfas-gore-firefighting-products.

"PFAS Replacement Compounds." Accessed September 27, 2023. https://www.bvna.com/insight/pfas-replacement-compounds.

Prevedouros, Konstantinos, Ian T. Cousins, Robert C. Buck, and Stephen H. Korzeniowski. "Sources, Fate and Transport of Perfluorocarboxylates." Environmental Science & Technology 40, no. 1 (January 1, 2006): 32–44. https://doi.org/10.1021/es0512475.

Sun, Mei, Elisa Arevalo, Mark Strynar, Andrew Lindstrom, Michael Richardson, Ben Kearns, Adam Pickett, Chris Smith, and Detlef R. U. Knappe. "Legacy and Emerging Perfluoroalkyl Substances Are Important Drinking Water Contaminants in the Cape Fear River Watershed of North Carolina." Environmental Science & Technology Letters 3, no. 12 (December 13, 2016): 415–19. https://doi.org/10.1021/acs.estlett.6b00398.

Vierke, Lena, Claudia Staude, Annegret Biegel-Engler, Wiebke Drost, and Christoph Schulte. "Perfluorooctanoic Acid (PFOA) — Main Concerns and Regulatory Developments in Europe from an Environmental Point of View." Environmental Sciences Europe 24, no. 1 (December 2012): 16. https://doi.org/10.1186/2190-4715-24-16.

Wang, Xiaoping, Crispin Halsall, Garry Codling, Zhiyong Xie, Baiqing Xu, Zhen Zhao, Yonggang Xue, Ralf Ebinghaus, and Kevin C. Jones. "Accumulation of Perfluoroalkyl Compounds in Tibetan Mountain Snow: Temporal Patterns from 1980 to 2010." Environmental Science & Technology 48, no. 1 (January 7, 2014): 173–81. https://doi.org/10.1021/es4044775.

Wang, Zhanyun, Ian T. Cousins, Martin Scheringer, Robert C. Buck, and Konrad Hungerbühler. "Global Emission Inventories for C4–C14 Perfluoroalkyl Carboxylic Acid (PFCA) Homologues from 1951 to 2030, Part I: Production and Emissions from Quantifiable Sources." Environment International 70 (September 2014): 62–75. https://doi.org/10.1016/j.envint.2014.04.013.

Wang, Zhanyun, Ian T. Cousins, Martin Scheringer, and Konrad Hungerbuehler. "Hazard Assessment of Fluorinated Alternatives to Long-Chain Perfluoroalkyl Acids (PFAAs) and Their Precursors: Status Quo, Ongoing Challenges and Possible Solutions." Environment International 75 (February 2015): 172–79. https://doi.org/10.1016/j.envint.2014.11.013.

Wang, Zhanyun, Ian T. Cousins, Martin Scheringer, and Konrad Hungerbühler. "Fluorinated Alternatives to Long-Chain Perfluoroalkyl Carboxylic Acids (PFCAs), Perfluoroalkane Sulfonic Acids (PFSAs) and Their Potential Precursors." Environment International 60 (October 2013): 242–48. https://doi.org/10.1016/j.envint.2013.08.021.

Herzke, Dorte, Elisabeth Olsson, and Stefan Posner. "Perfluoroalkyl and Polyfluoroalkyl Substances (PFASs) in Consumer Products in Norway – A Pilot Study." *Chemosphere* 88, no. 8 (August 2012): 980–87. https://doi.org/10.1016/j.chemosphere.2012.03.035.