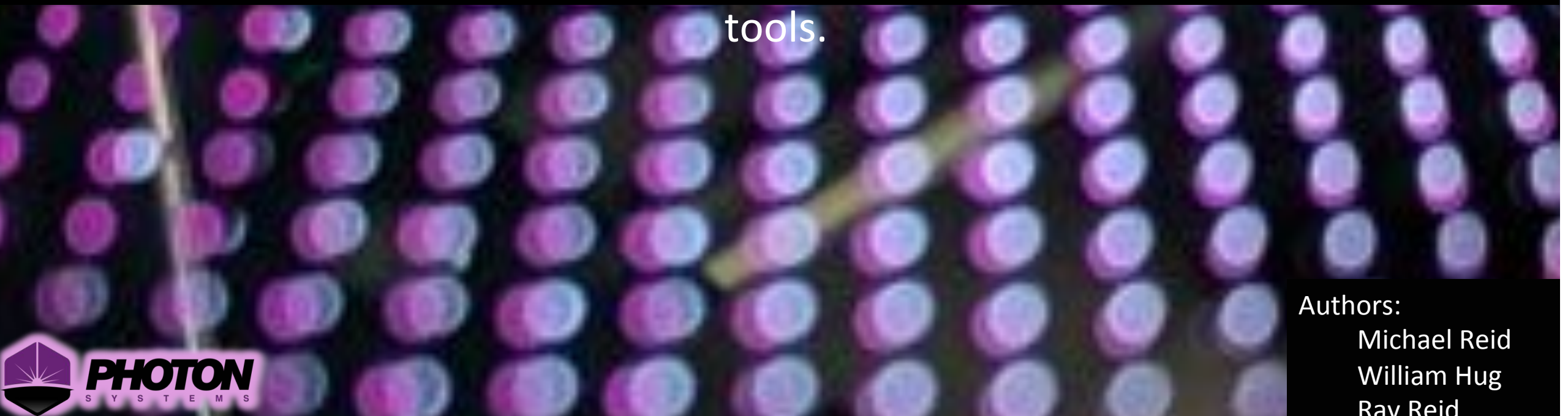
IFPAC Conference - Feb 14, 2018

ChemCal, a surface cleaning validation tool for depositing pre-determined chemical concentrations, used in the calibration of surface cleaning validation tools.



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PHOTON SYSTEMS

Are you at the right talk???

- Surface Chemical Deposition:
- Feature size, resolution of the deposits and negative space.
- Chemistry of deposition and ring formation.
- Solvent morphologies: alcohols, water, acetonitrile, acetates
- Solvent viscosities.
- Interleave/overlay of multiple chemicals.
- Drying patterns.
- Unusual substrates: *i.e.* EPDM, TEFLON, screens, mesh and curved surfaces.

We will be discussing the ChemCal – a surface chemical printer.

ChemCal – a surface chemical depositor.

Why?

Rapid surface cleaning validation (RCV) holds the promise of reduced reliance on swabbing and HPLC, yielding immediate cleaning feedback.

As companies use on-surface chemical detectors for quantifying residues the need to calibrate these devices with homogenous chemical deposition techniques becomes paramount.

Applications:

Calibration/validation of new rapid cleaning validation tools *i.e* TraC.

Creation of new swabbing protocols.

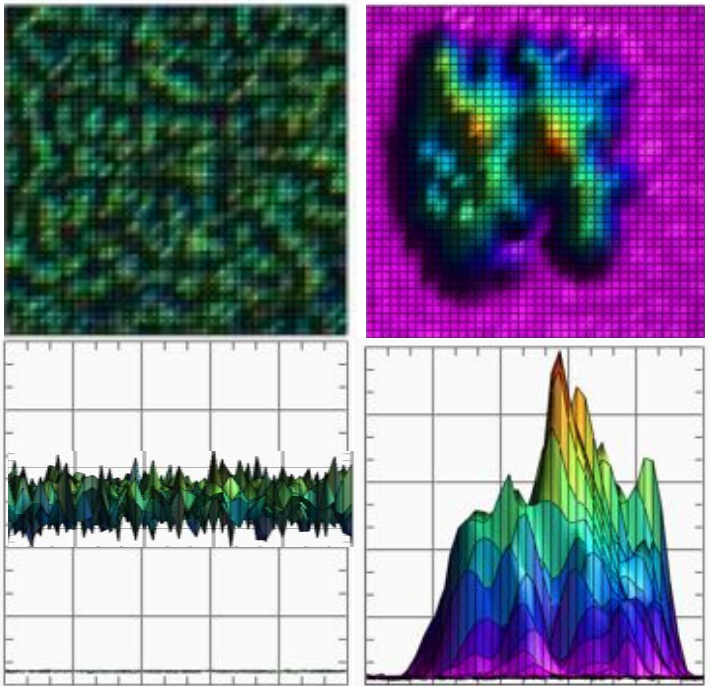
Training new swabbing personnel.

Printing known amounts of thin layer API for drug delivery.

In-Situ hotspot detection training.

Research on thin layer API chemistry such as sublimation, oxidative damage, photo-stability etc.

ChemCal: Status Of Deposition Methods



Spin Coating
Inkjet Printing
Spray Coating
Ultrasonic Piezo Printing

Speed

Uniformity

ChemCal
Printer

Manual Deposition

Known Quantity

ChemCal: Overview

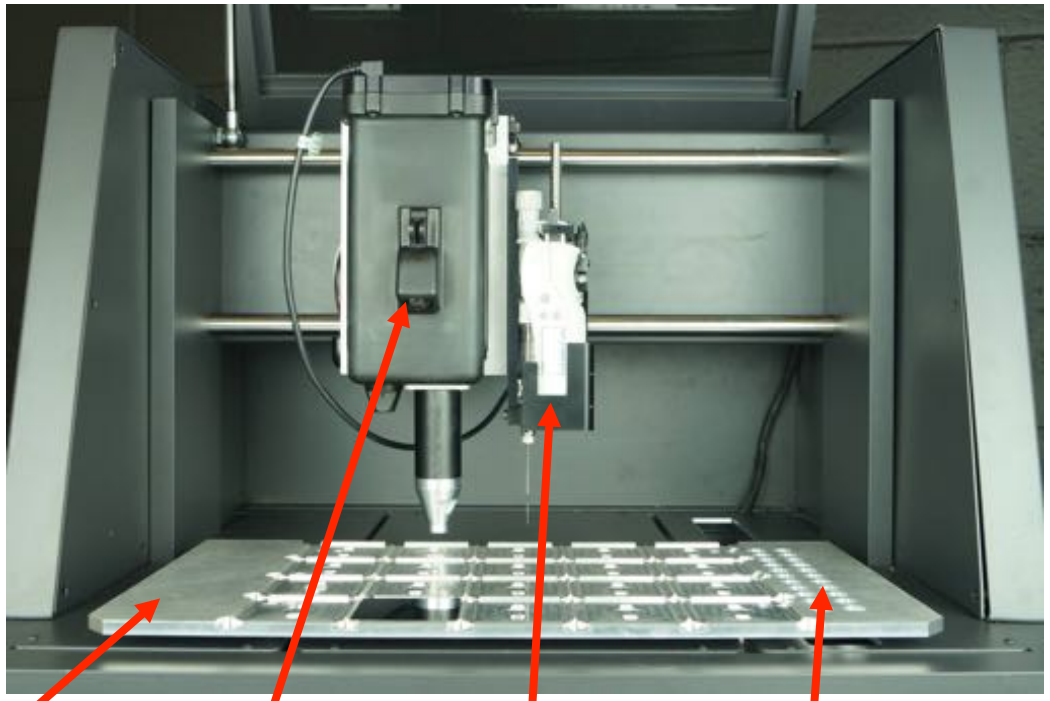
Creates coupons with an *a priori* known concentrations of many different chemicals, including APIs, detergents, excipients, etc. on Pharma-type surfaces for the purpose of performing calibration of hand-held TraC sensors for rapid cleaning validation.

Operational Scenario:

1. Load APIs in Micro-centrifuge rack.
2. Load coupons onto tray.
3. Press Start.
4. The system outputs a full calibration curve in under 4 hours. (Print and scan 16 coupons.)

How does it work?

A NIST traceable syringe acquires sample. Then, the syringe dispenses known mass per unit area onto a single coupon in an array format. .. Repeat for each coupon.



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Surface Deposition Vocabulary

Drop – a sessile liquid on a surface

Deposit – a dry sample after a drop has desiccated.

Beam – the area of a light source mapped onto a surface.

I will try not to use the words spot or mark or sample (ambiguity).

Areal concentration (microgram/cm^2).

Volumetric concentration (microgram/microliter).

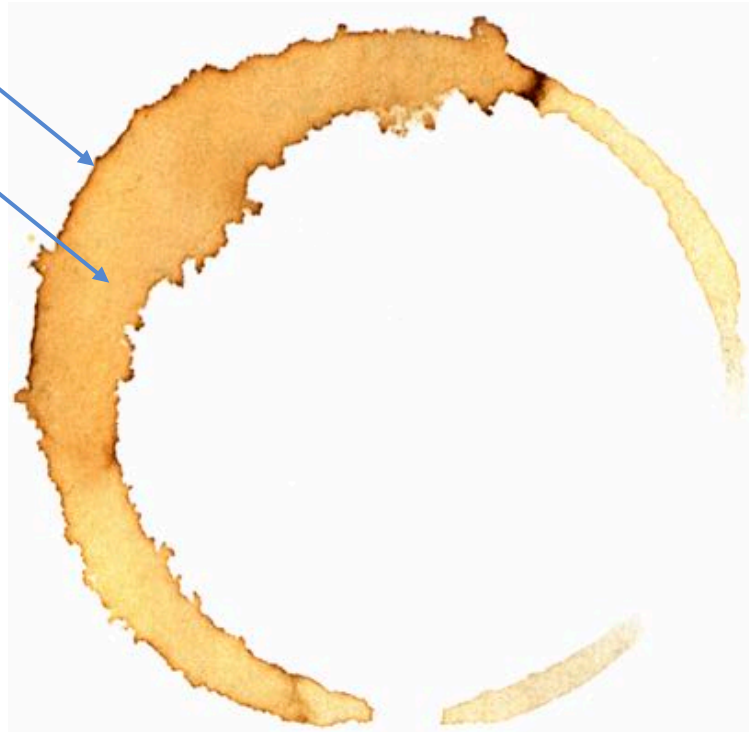
Coffee Ring Drying Pattern

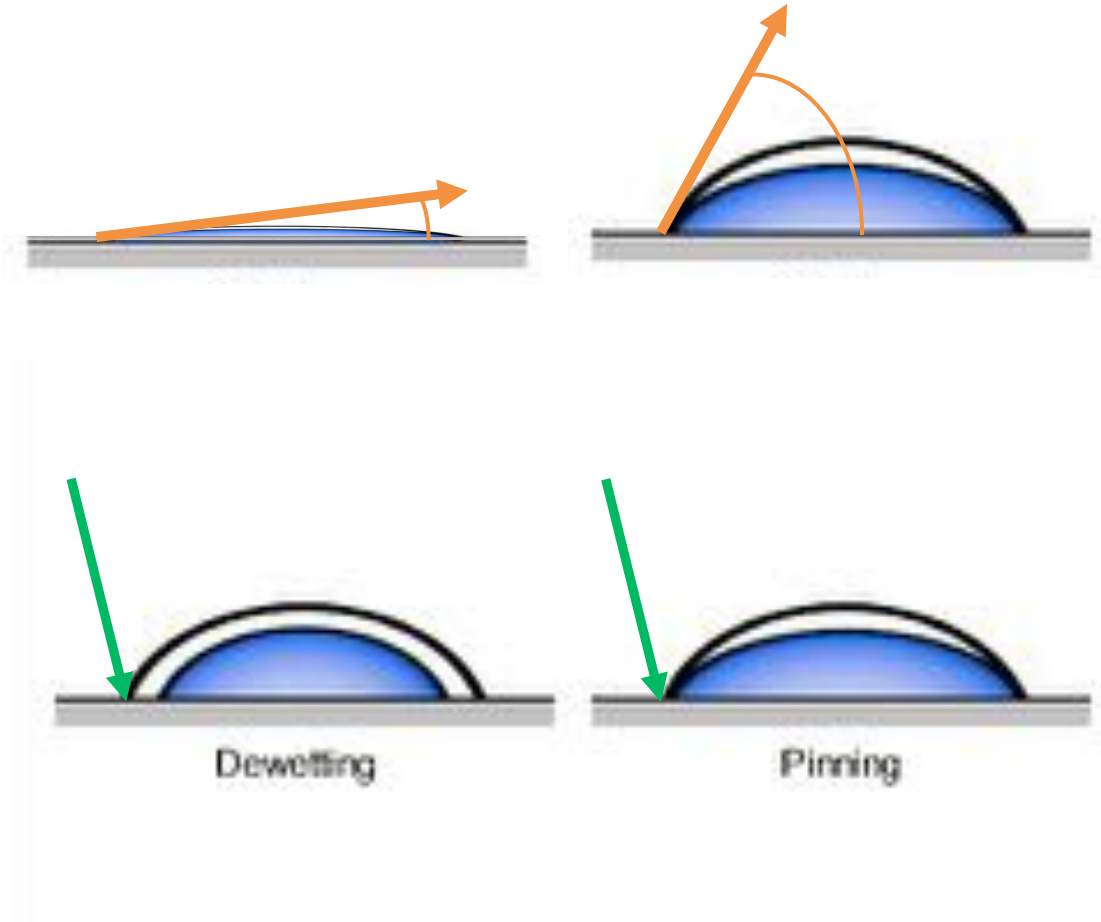
Three Requirements for Coffee Ring Formation:

1. Solvent meets the surface at a non zero contact angle (Orange Arrow).
2. Contact line is pinned at it's initial position (Green Arrow).
3. The solvent evaporates (slowly).

Darker Perimeter

Lighter Center





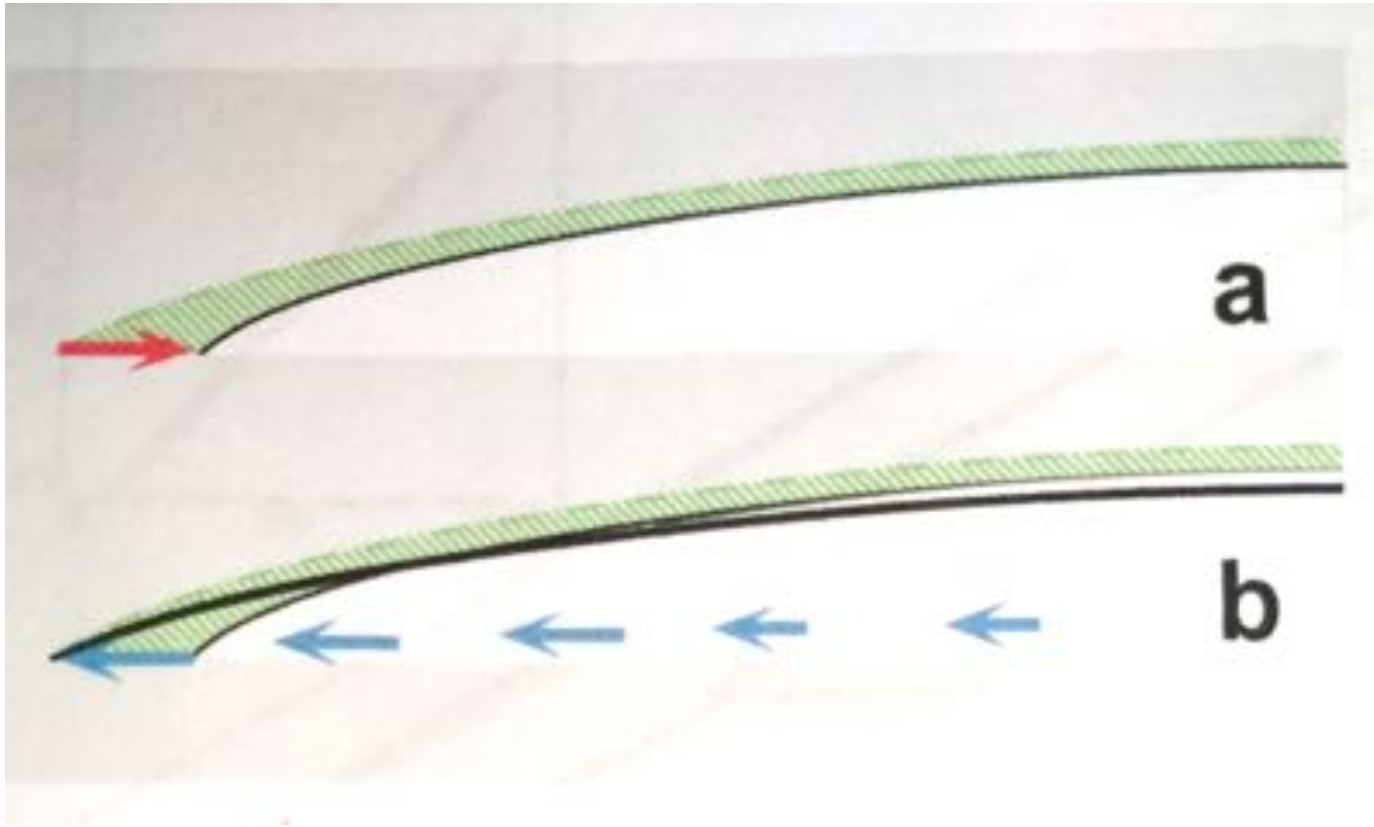
Details of how a coffee ring stain forms.

Assume an even evaporation as a function of surface area:

To maintain the geometry (i.e. pinned outer border) the droplet interior must flow (blue arrow) from the thick center area to the outer thin area to replenish the solvent lost to evaporation (green).

This results in a net compensating flow of solvent from the center to the periphery, the net outward solvent flow carries with it solute and/or suspended particles.

This results in a solutes ring mass that is disproportionately large in aerial distribution.



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Deegan, Robert D.; Bakajin, Olgica; Dupont, Todd F.; Huber, Greb; Nagel, Sidney R.; Iwitten, Thomas A. (1997). "Capillary flow as the cause of ring stains from dried liquid drops". Nature. 389 (6653): 827–829.

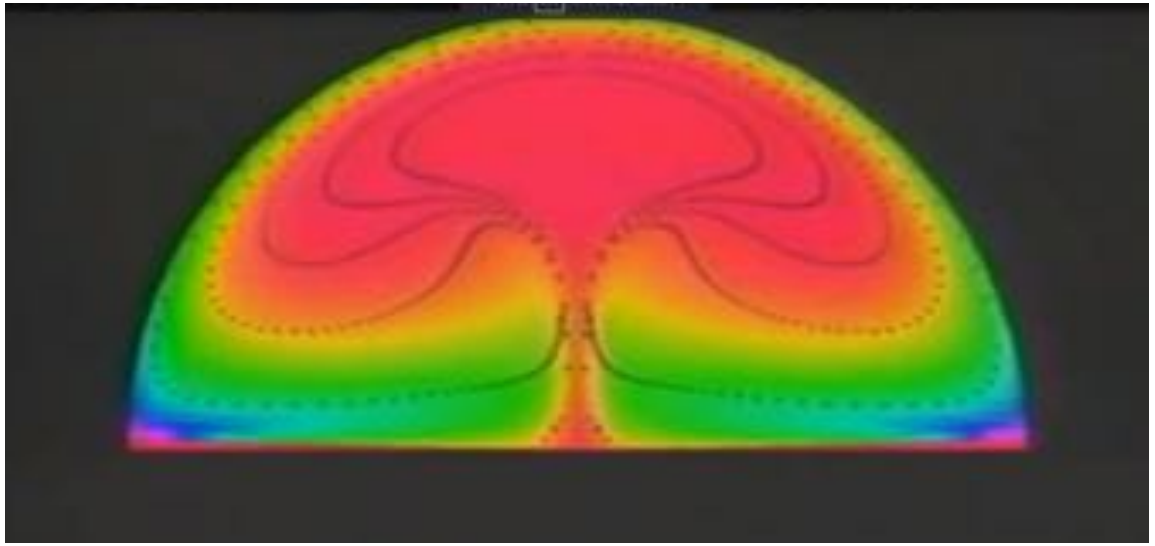
Other Factors influencing drying morphologies.

Irregular Solute Accumulation:

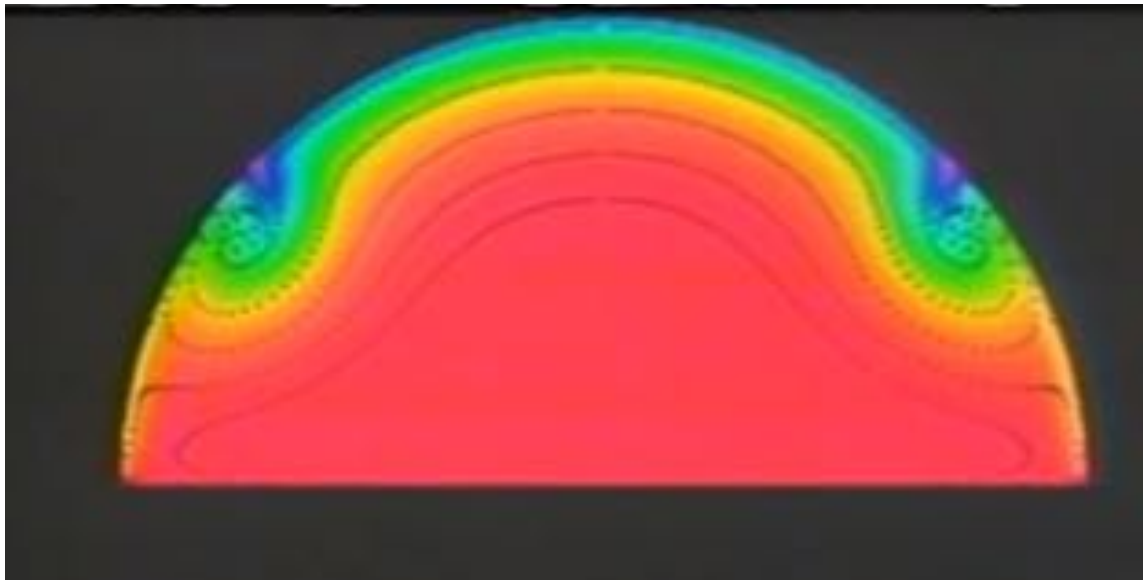
- Gravitational Buoyancy Force.
- Circulating surface tension gradient driven flow.

Rough Morphology Causes:

- Evaporative gradients.
- Shape of solute.
- Solvent drying rate.
- Applied Voltage.



Gravitational Buoyancy Force.



Circulating surface tension gradient driven flow.

Images: Thermocapillary convection in liquid droplets. NASA STI Program. J. C. Duh, Sverdrup Technology, Inc, NASA Lewis Research Center.

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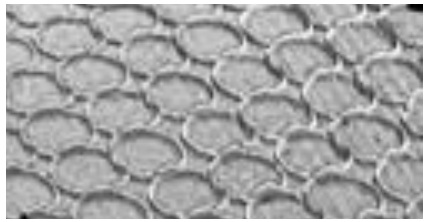
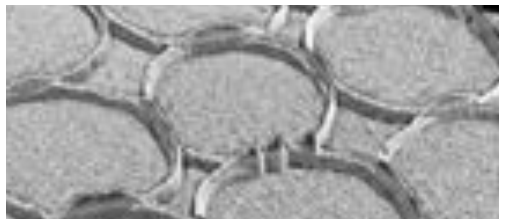
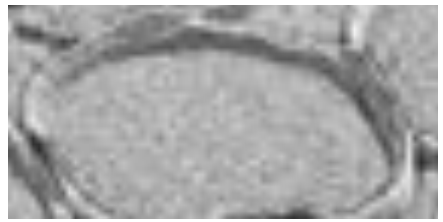
Why do we require deposits with small radii to increase homogeneity?

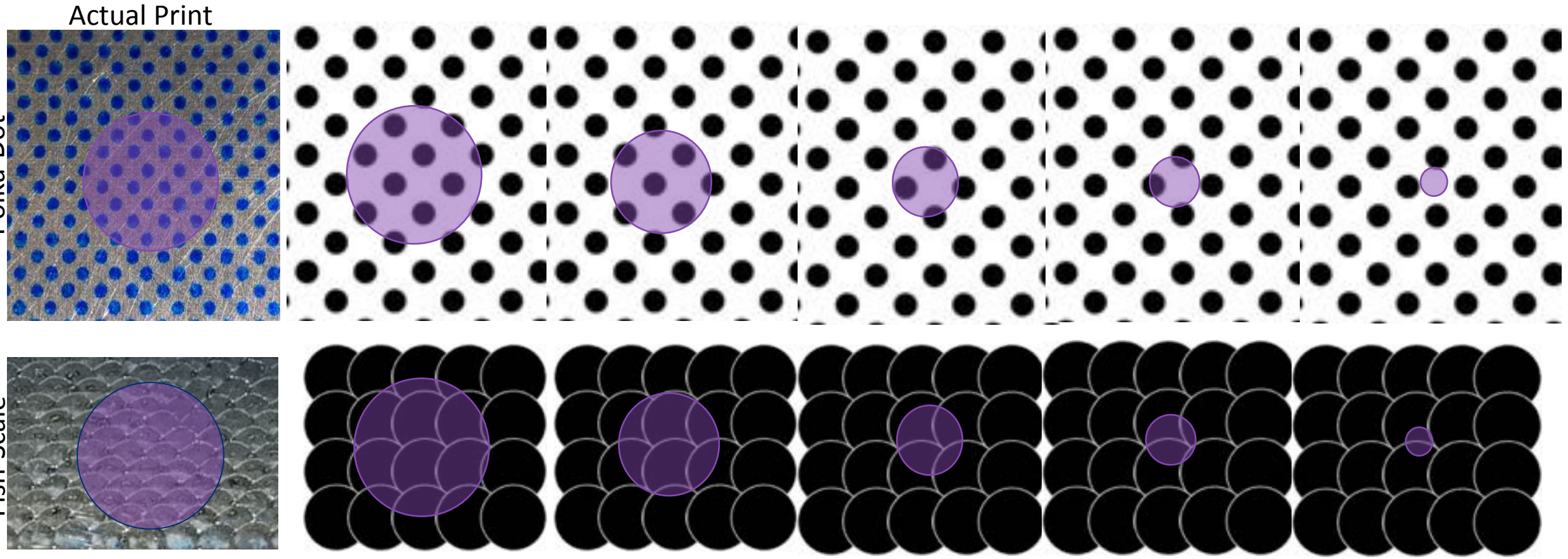
Variation of solutes mass distribution across an individual deposit is large.

Generally this is countered by intra-deposit inconsistencies as volume decreases (Difficulties in keeping small drops consistent).

	Homogenous			Non-Homogenous
Micrograph				
Cross section				

Issues with large deposits:
Optical penetration of detectors.
Swabbing removal issues.
Chemical modeling issues of reactions: sublimation, photo-oxidation, autoxidation, or stainless steel mediated catalysis.

Quantity of droplets in Detector path



Fish Scale:
Pinned contact line.
Rapid dry rate.
Low contact angle
High surface adhesion

Polka Dot:
De-wetting
Slow dry rate
High contact angle
Low surface adhesion

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We will consider three areas of surface chemical deposition:

1. Print quality
   NIST traceability,
   intra/ inter sample reproducibility
   a priori knowledge of deposited areal concentration.

2. Chemistry limitations:
   solvent compatibility,
   solvent viscosity limitations,
   interleave/overlay of multiple chemicals and drying patterns.

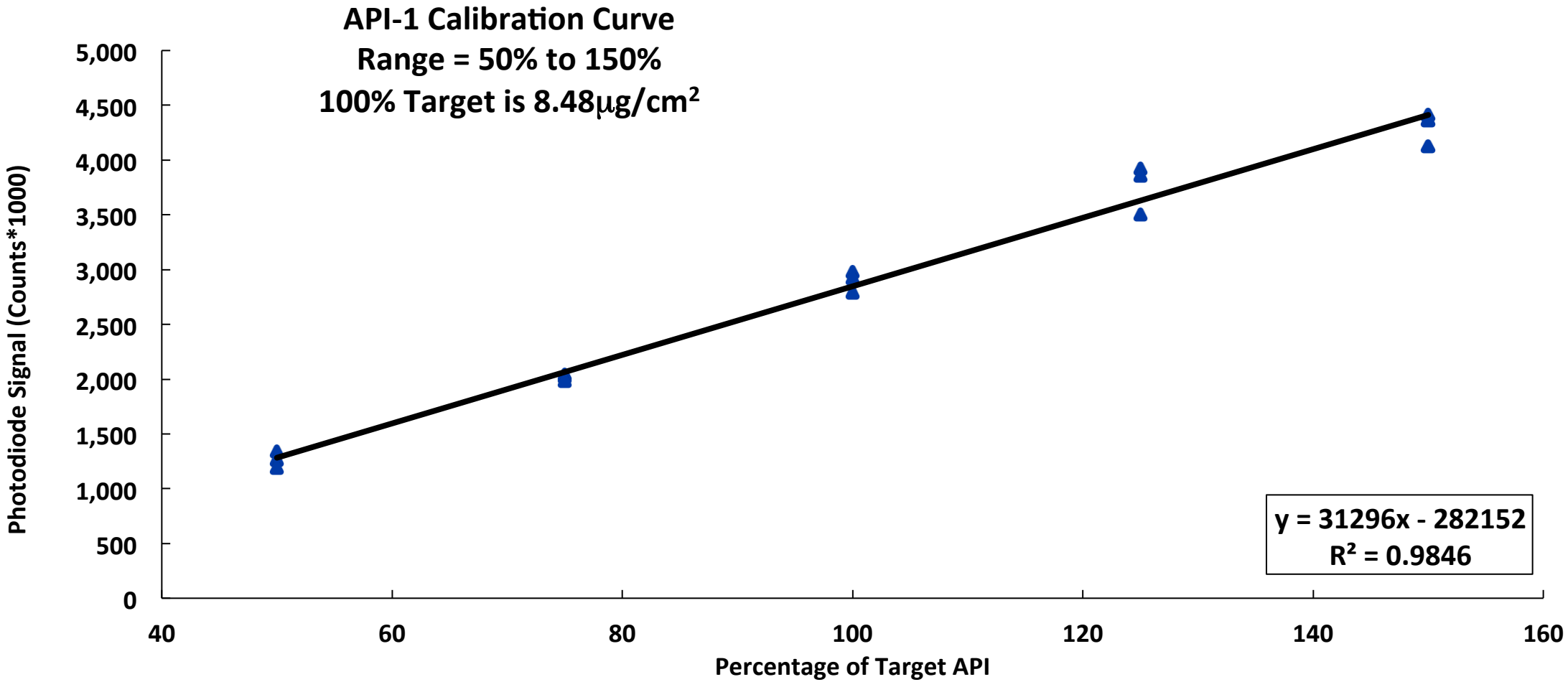
3. Substrate compatibility.
   Unusual substrates: *i.e.* Stainless Steel, EPDM, TEFLON, screens, mesh and curved surfaces.

Print quality

NIST traceability.

Intra & inter sample reproducibility.

A priori knowledge of deposited concentration.



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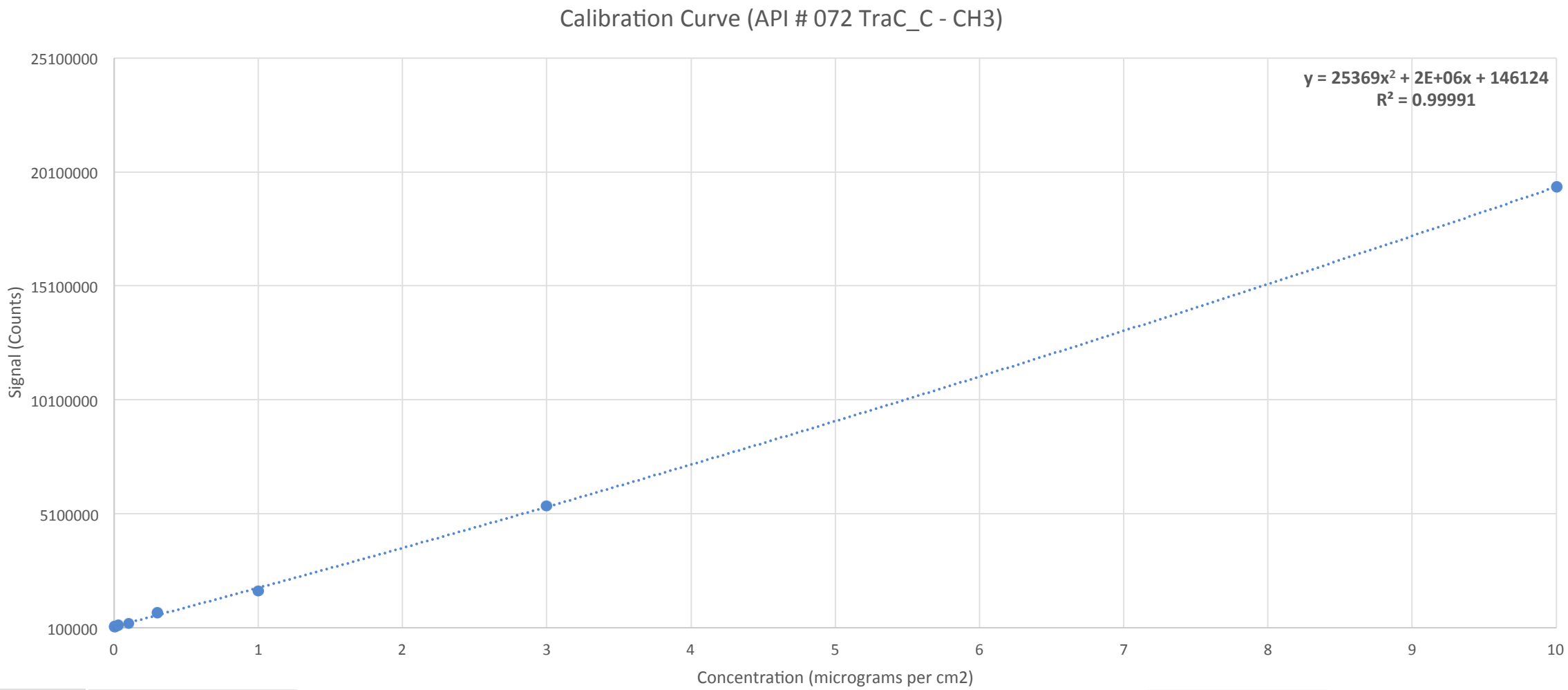
Concentration Orders of Magnitude (30ng/cm2 to 10 micrograms/cm2),



20	40	80	160	320	640	1,280	2,560	5,120	10,240

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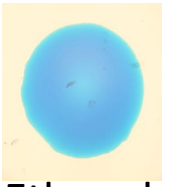
Solvent compatibility

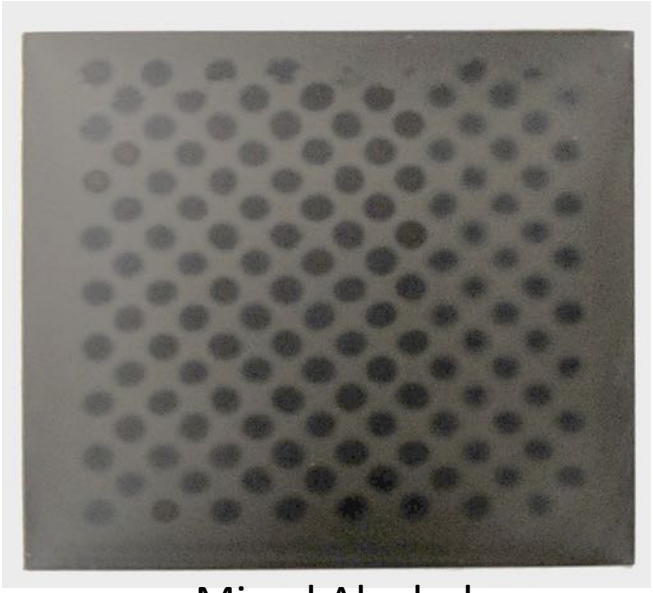
- Drying patterns.
- Empty ring
- Homogenous ring
- Small Spot

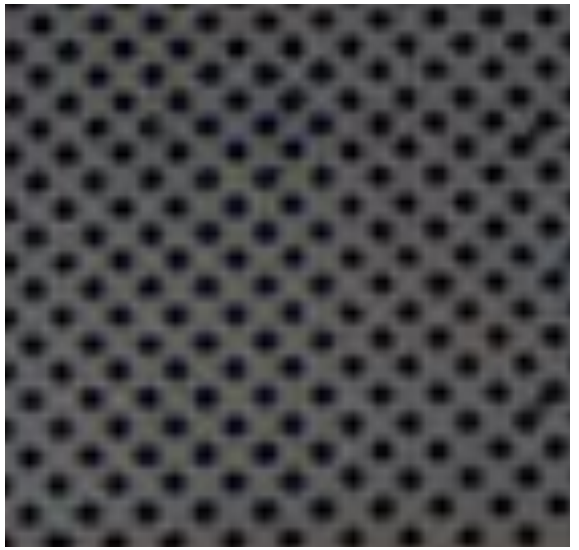
Acetonitrile

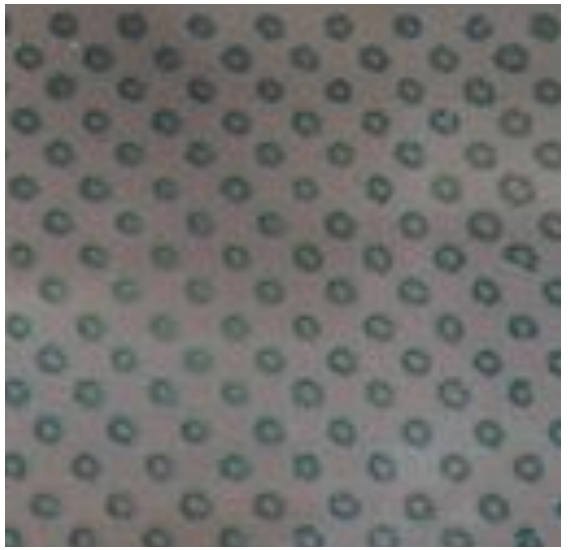


Ethanol

Ethanol Water Mix



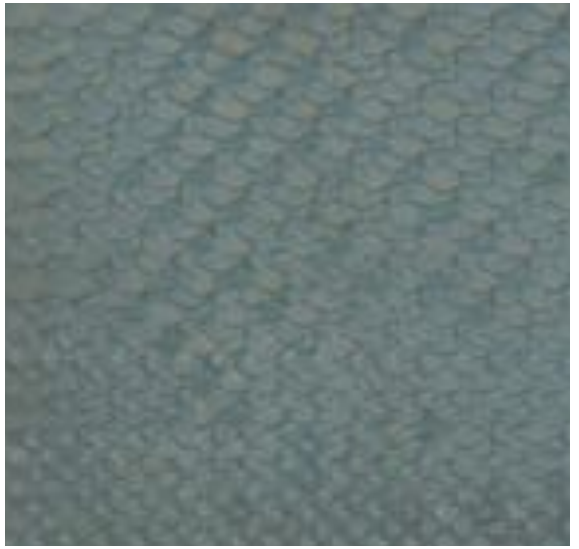




Mixed Alcohol

Ethyl Acetate

Methanol



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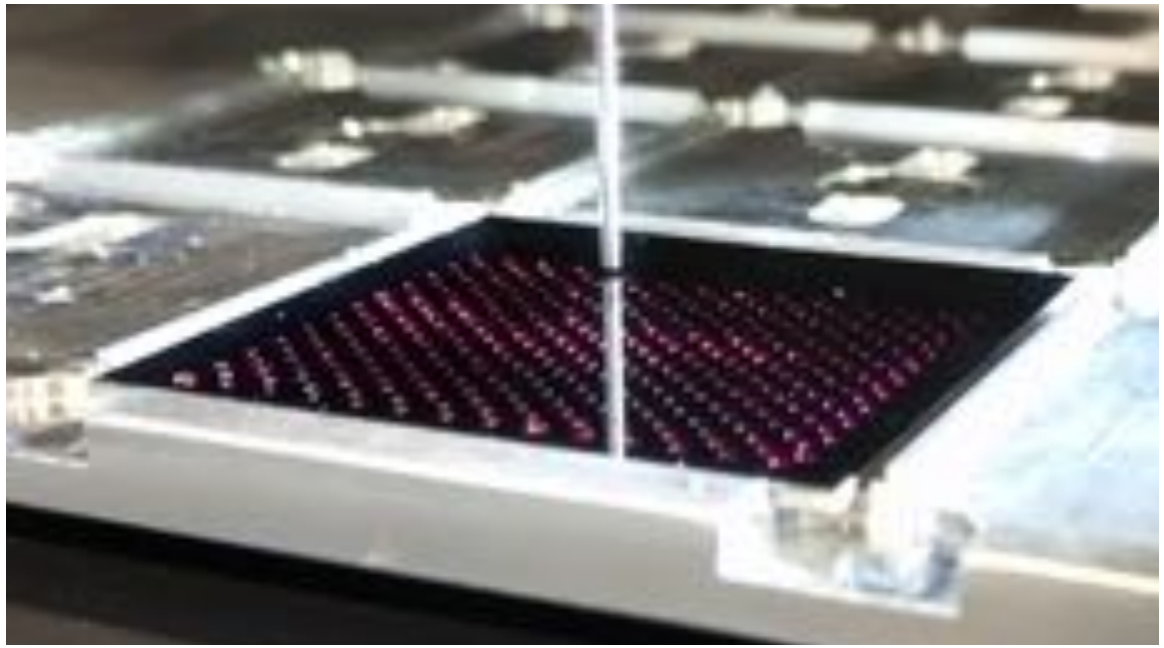
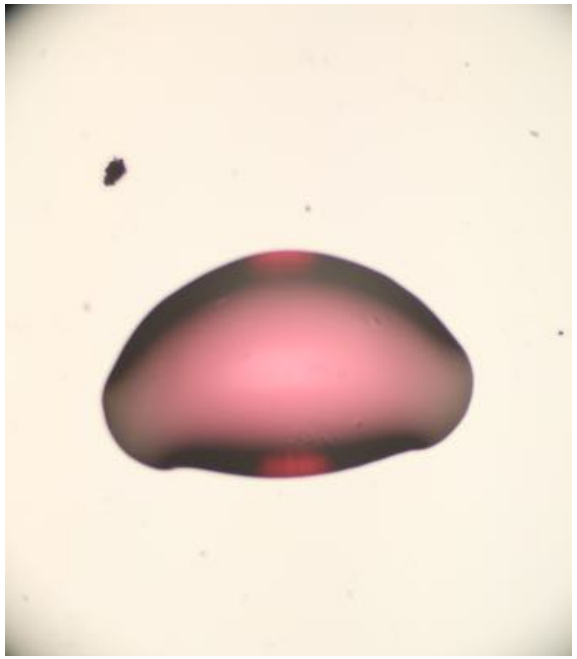
2. Chemistry limitations

- Solvent viscosities

Glycerol Stock Solution with Red Ink.

Water	0.00089	Pa*s
Ethanol	0.00109	Pa*s
Glycerol	0.95	Pa*s





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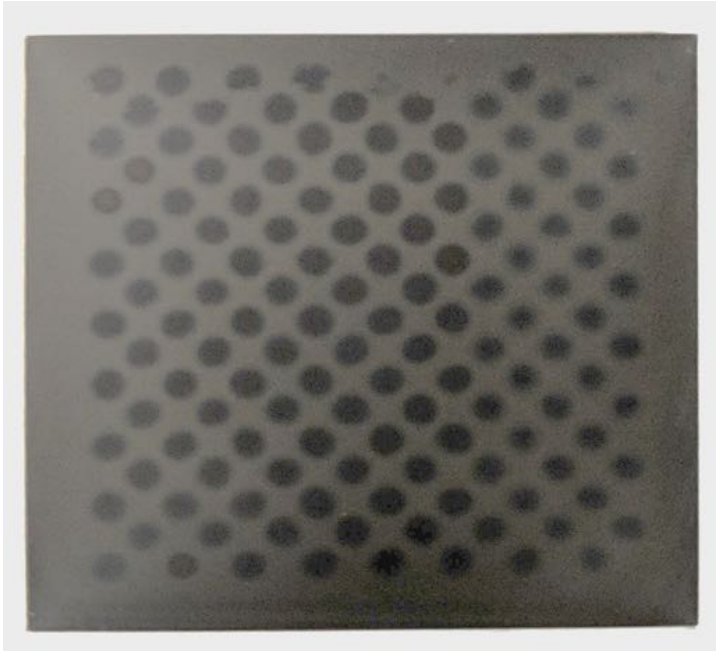
3. Substrate compatibility

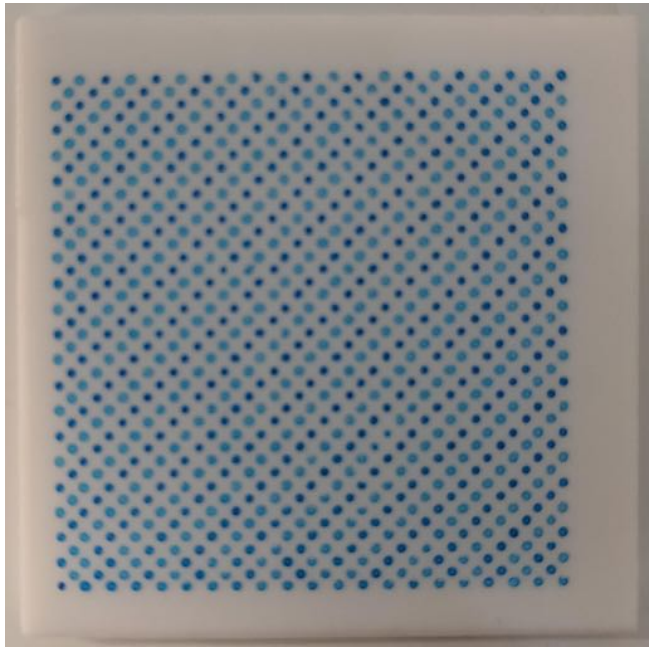
Considerations: Interplay between the surface tension of the deposit and adhesion to the substrate.

Cleanliness determines pinned perimeter for solvents that have receding perimeter.

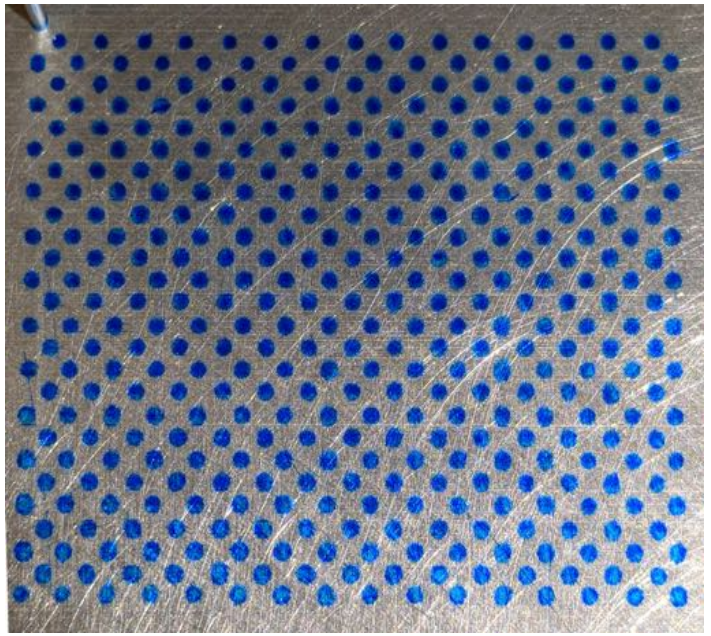
Successful Printed Materials:
Stainless Steel (304, 316, [#8,#7,#4])
Teflon
Aluminum
EPDM
Paper
Quartz
Polycarbonate
PVC
Acrylic
Many more..



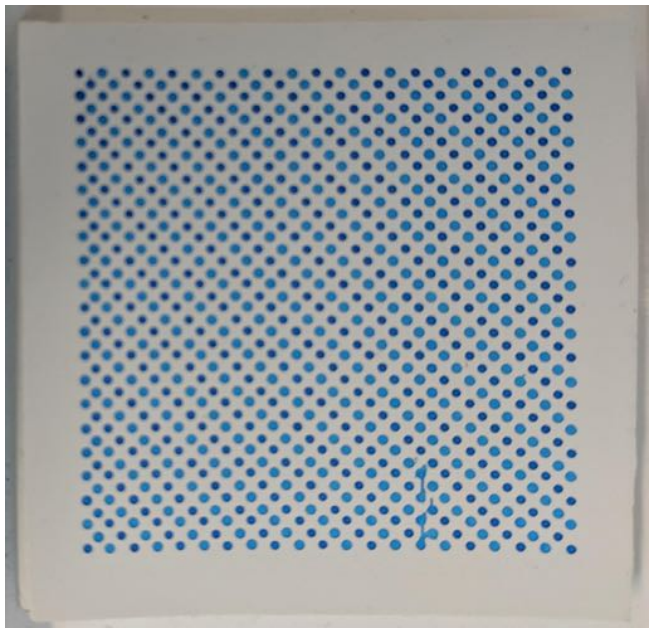
Stainless 316 #8



Teflon



Aluminum



EPDM

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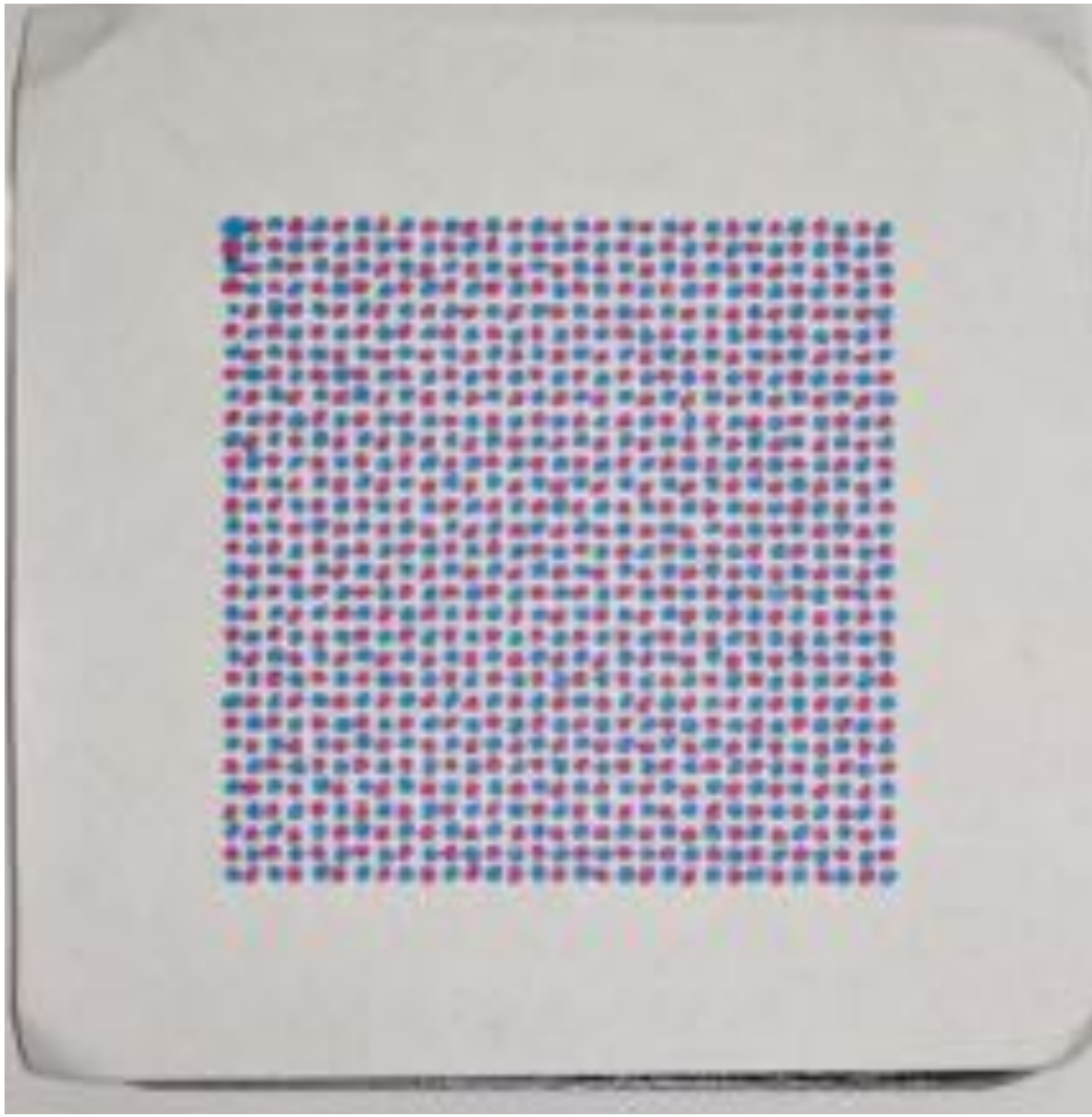
2. Chemistry limitations

Second, the chemical interactions deal with:

- Interleave/overlay of multiple chemicals

Some chemicals interact like sodium hydroxide and APIs. Yet users want to combine them without touching. Press the interleave option and enter the well numbers.

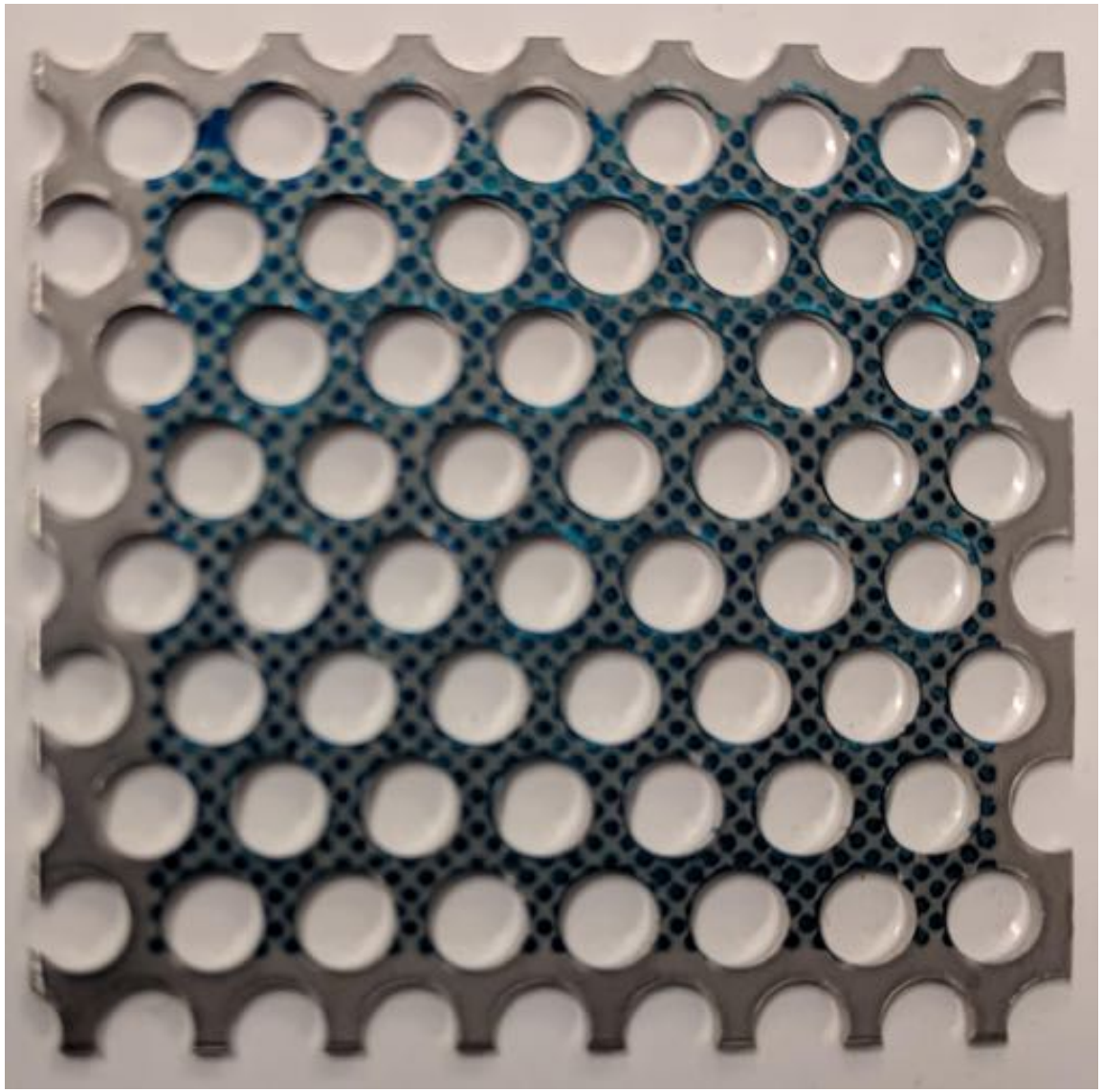


Screens & mesh. (50% Stainless steel mesh shown here)

Whole coupon	Fractional coupon
100%	46%

Deposit a known amount and test your facilities
Swabbers!

Or if you are attempting to spin coat, try a screen/mesh.



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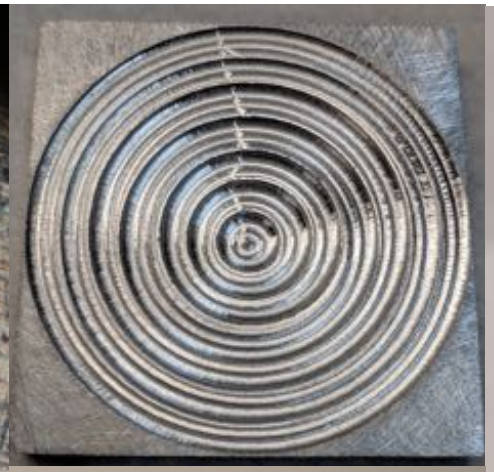
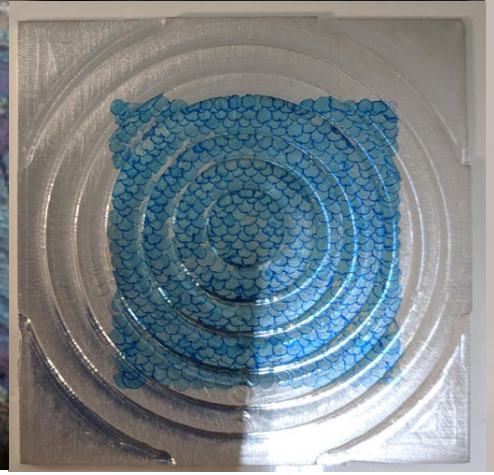
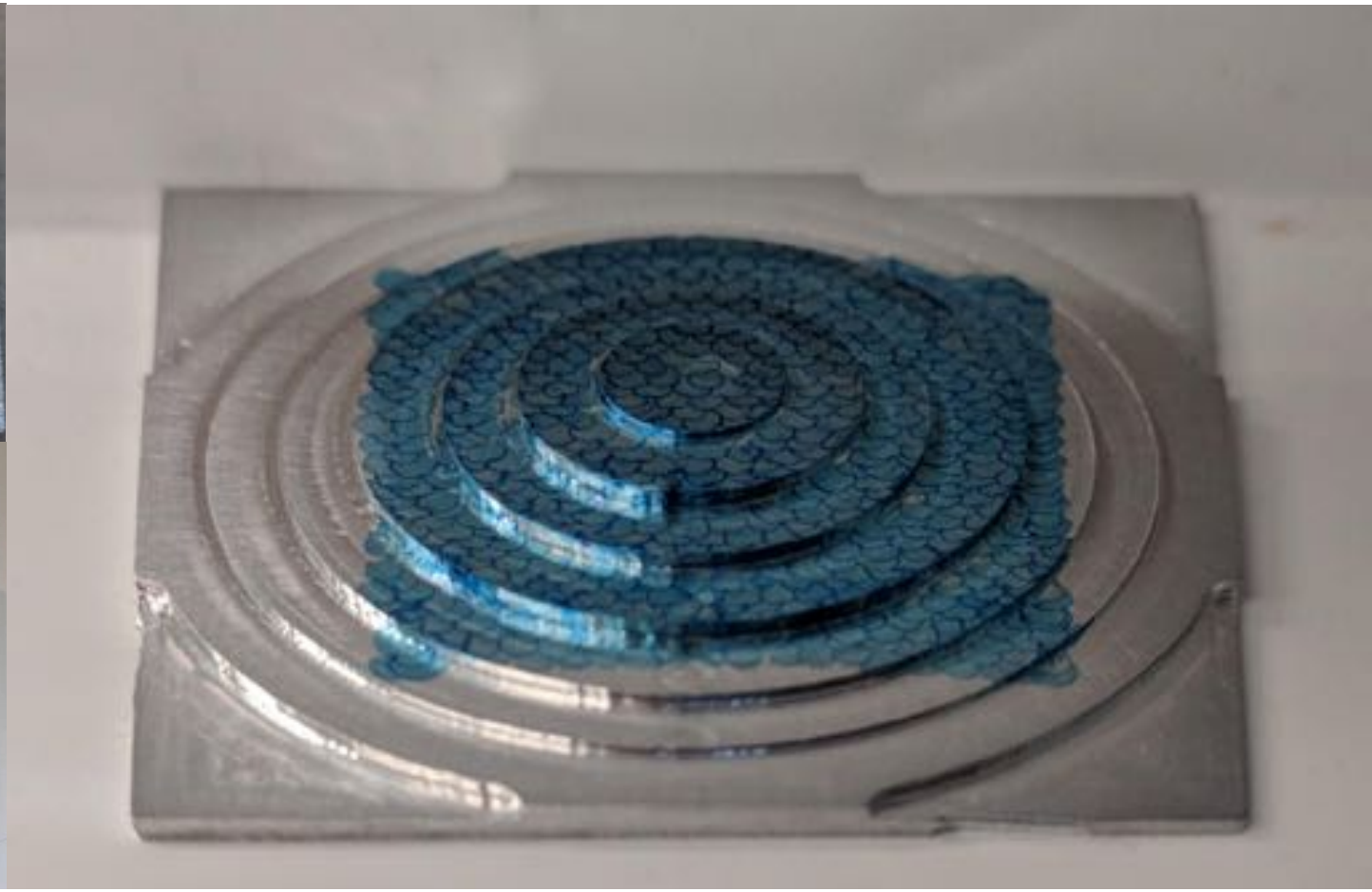
Substrate compatibility deals with topographically challenged substrates: *i.e* Curved surfaces.







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Conclusion:

In conclusion, we have given you the chemical groundwork to debug your deposition problems and/or enhance your current surface deposition methodologies.

I hope we have made a compelling case that if you are fumbling with spin coating, spray coating, or manual deposition contact us and we can give some help with your deposition instrumentation or rapid cleaning tools needs.

Micrographs