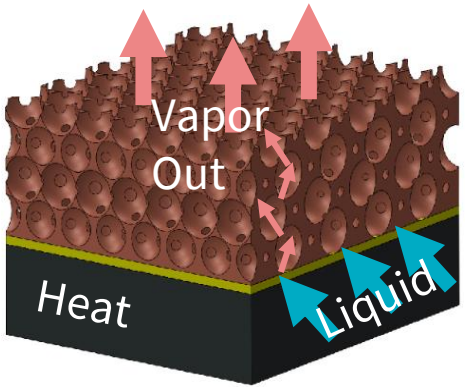
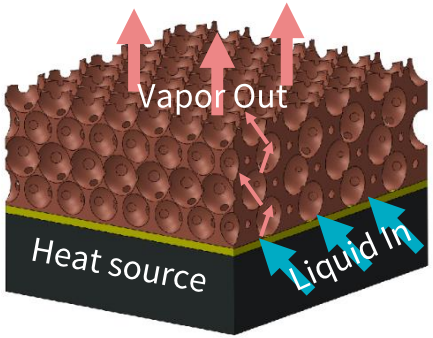
3D, porous, electroplated metallic structures using two-photon lithography templates



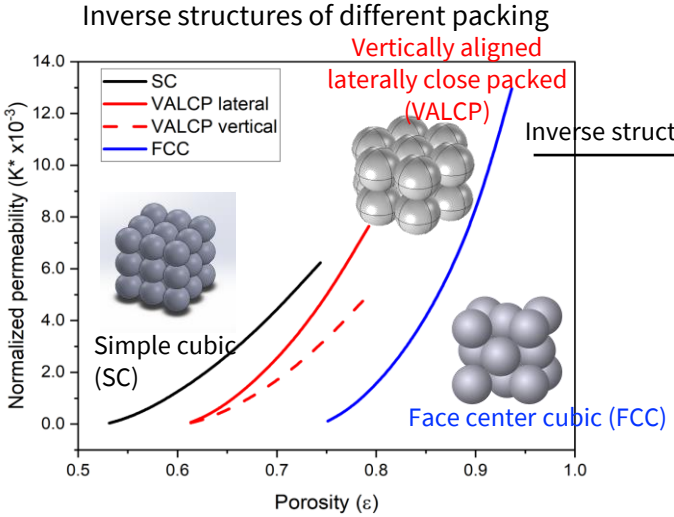
Fall Quarter Report

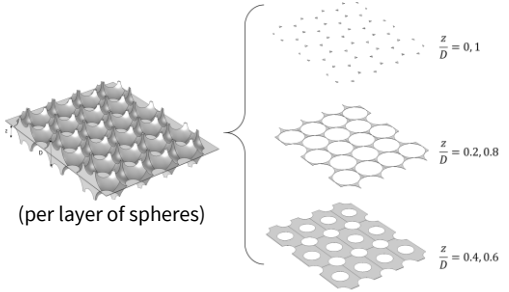
Qianying Wu and Alisha Piazza
Mentors: Swaroop Kommera and Tony Ricco

Exploring new geometric configurations for extreme high performance microfluidic and thermal transport



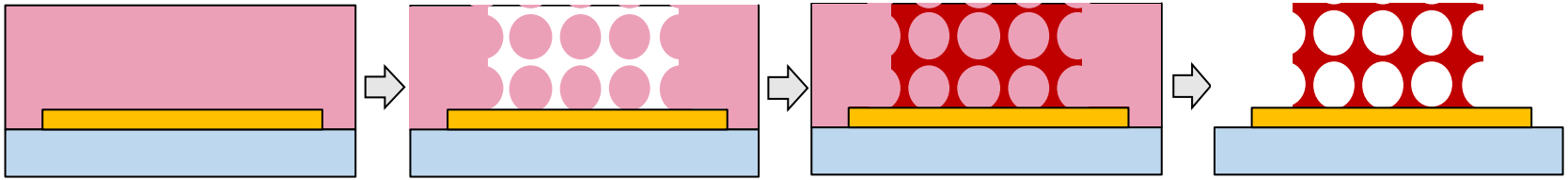
Testing configuration:
- Lateral liquid supply by wicking
- Flow boiling with phase change
- Vertical vapor removal





With 2-photon lithography, we can make anisotropic templates that utilize both advantages of SC and FCC
- High capillary wicking pressure
- Low vapor removal resistance

Fabrication overview of inverse VALCP structure



Substrate: Ti-Au on glass
Spin coat resist SPR220-7

Nanoscribe patterned 3D template

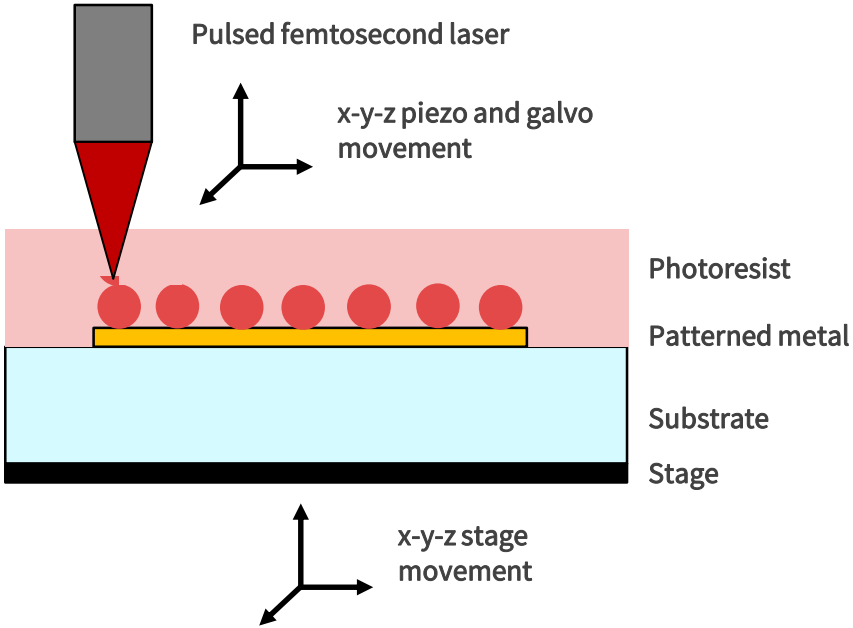
Copper plated into the interstices

Porous VALCP structure revealed

Direct Laser Two-Photon Lithography

Working Principle

Non-contact, through air mode



Nanoscribe Photonics Professional GT

Location: SNF ExFab
Lateral Feature Size: 200nm
Lateral Resolution: 500nm
Piezo Range: 300µm x 300 µm x 300 µm

Thick, positive photoresist on patterned metal substrates

Positive Photoresists

Pros	Cons
• Better control of template dimensions • Easier to dissolve	• Higher dose (slower) • Not as well characterized

AZ4620

Pros	Cons
• Previously used by Wendy Gu • Single coat (17 um)	• Inconsistent exposure • Expired • Carcinogenic

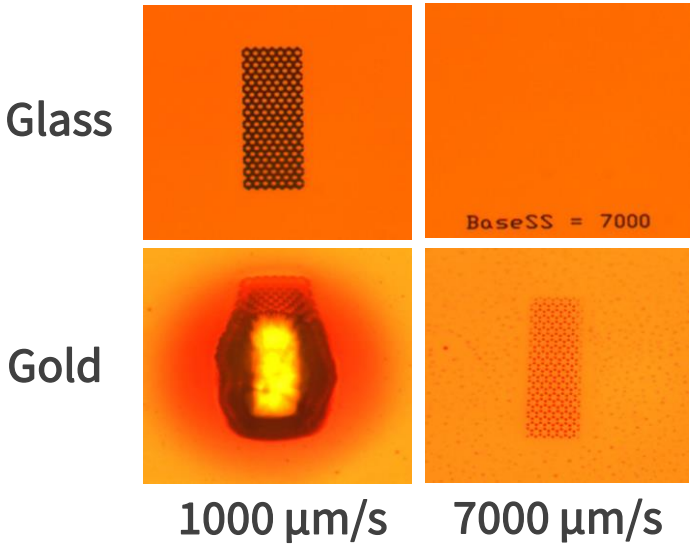
SPR 220-7

Pros	Cons
• Thick resist (~29 µm) • More common in SNF	• Two plus coats required

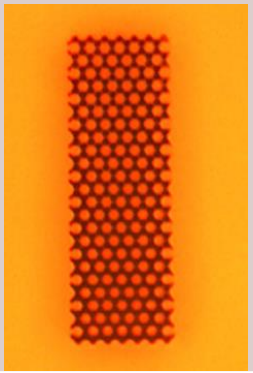
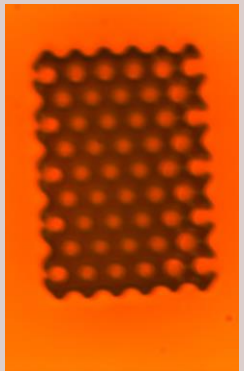
Patterned Metal Substrates

Extending SNF capabilities
- Not ITO (conductive) or glass
- Alignment

Affects writing parameters
- Reflective
- Must write from top through air

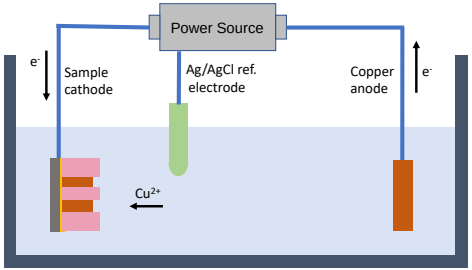


Parameter sets for different photoresists

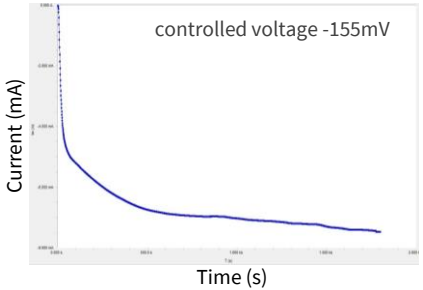
	IP-dip	SPR220-7	AZ4620*
Tone	-	+	+
Coating	Drop cast	Double coat	Single coat
Thickness	N/A	29 µm	17 µm
Laser Power	30%	100%	100%
Scan Speed	20K	5K	4K
Power Scaling	1	1.2	1.2
Developer	SU-8 dev + IPA	MF-26A	AZ400K:DI water = 1:3
Develop Time	20 + 5 min	2 min	5 min
Structure under Optical Microscope			
	Footprint = 100µm x 30µm; Pore size = 5µm	Footprint = 100µm x 30µm; Pore size = 5µm	Footprint = 30µm x 25µm; Pore size = 5µm

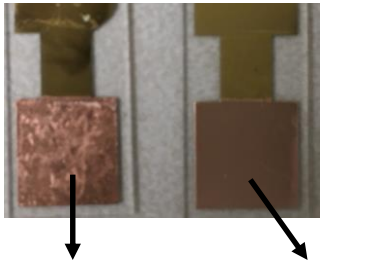
Template-assisted electrodeposition: 1D to 2D (to 3D soon)

Three-electrode setup for copper electrodeposition

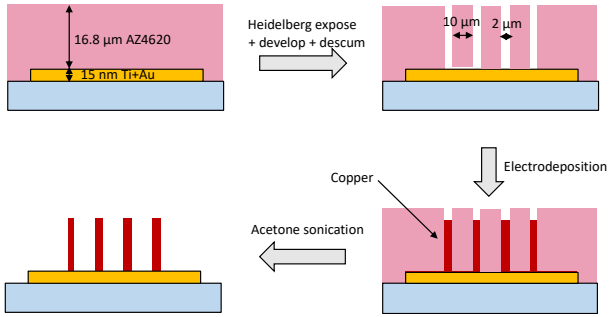


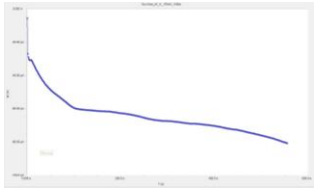
1D copper electrodeposition: no stirring for shiny copper finish

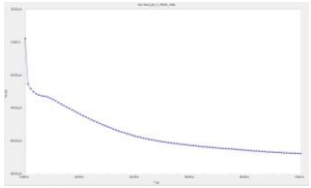




2D copper inverse pin fin structure with litho-generated template: to tune electroplating conditions





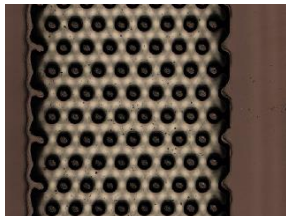
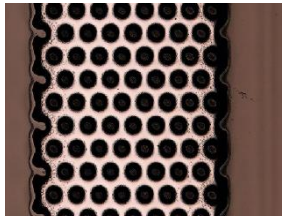
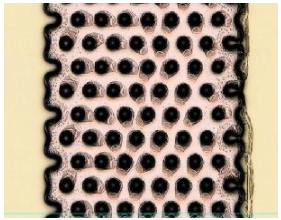
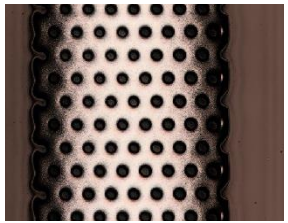
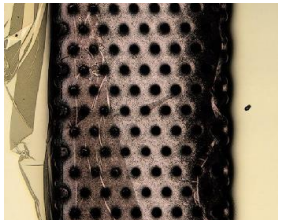
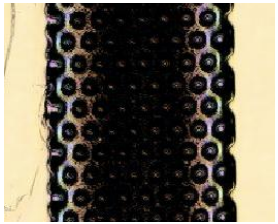


Electric charge supplied	Measured thickness	Effective Faraday efficiency
36 mC	17.7 µm	49.2%
15 mC	7.7 µm	51.3%

- AZ4620 exposed in Heidelberg (dose 1000; defocus -2)
- Descum in technics (1.5 min)
- **Cleanly exposed seed layer is the key for successful plating**
- Copper plating solution from Sigma-Aldrich (-155 mV)
- Acetone bath sonication for 10 min+ to remove AZ4620

1. Integrate i-t curve to determine electric charge supplied
2. Estimate deposition thickness using Faraday efficiency

Characterization of electrodeposition and template removal

	Keyence Interferometer (SNSF)	+ 3 min acetone + IPA (SNSF)	+ 10 min UV/O_3 (SNSF)
Template (16.8µm)		N/A	N/A
After ED (15 mC, 7.7µm)			N/A
After ED (36 mC, 17.7 µm)			

Footprint = 100 x 1000µm; Pin fin d = 10µm, pitch = 12µm

- Successful electrodeposition proved the exposure and descum parameters can expose Au seed layer
- Template removal condition is influenced by structure aspect ratio: PR inside 7.7 µm inverse pin fins can be removed with 3 min acetone + IPA, but not with 17.7µm structures
- For 36mC sample: copper has been over-plated and partially deposited on the pin fin template (pores become smaller)
- UV/O_3 would oxidize copper

Summary and Future Work

Fall Quarter Contributions to SNF community

- ❑ Extended the use of Nanoscribe to positive and thick resist
- ❑ Explored the influence of reflective substrate on Nanoscribe
- ❑ Combined electrodeposition with litho-generated templates

Winter Quarter Goals

- ❑ Finalize writing parameters for 220-7 resist
- ❑ Write large porous structures
- ❑ Physically characterize template
- ❑ Determine best method for producing clean gold-solution interface
- ❑ Identify optimal electroplating parameters
- ❑ Physically characterize electroplated structure
- ❑ Electrically characterize electroplated structure
- ❑ Fluidically characterize electroplated structure

Fall Quarter Spending: $3305.97