Development of a MEMS Tool to Study the Physics of Water and Ice

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NYSTAR
National Nanotechnology Coordinated Infrastructure
NSF

Freezing Damage

https://www.flickr.com/photos/roadscanners/11045409695/in/photostream/

http://www.pavementinteractive.org/frost-action/

Phase Behavior

LaPlace Equation

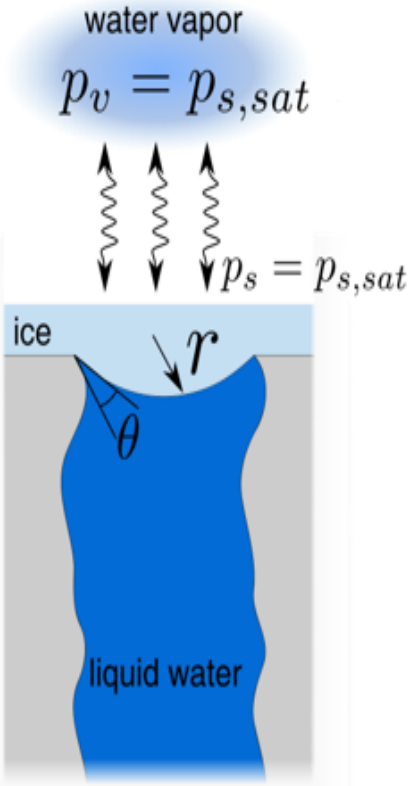
$$p_l - p_s = \frac{2\sigma}{r} \simeq p_l - p_{l,sat} \quad (1)$$

Kelvin Equation

$$p_l - p_{l,sat} = \frac{RT}{v_l} \ln \frac{p_v}{p_{l,sat}} \quad (2)$$

Gibbs – Thomson Equation

$$\frac{RT}{v_l} \ln \frac{p_v}{p_{l,sat}} = \frac{L_m \Delta T}{v_l T_0} \quad (3)$$

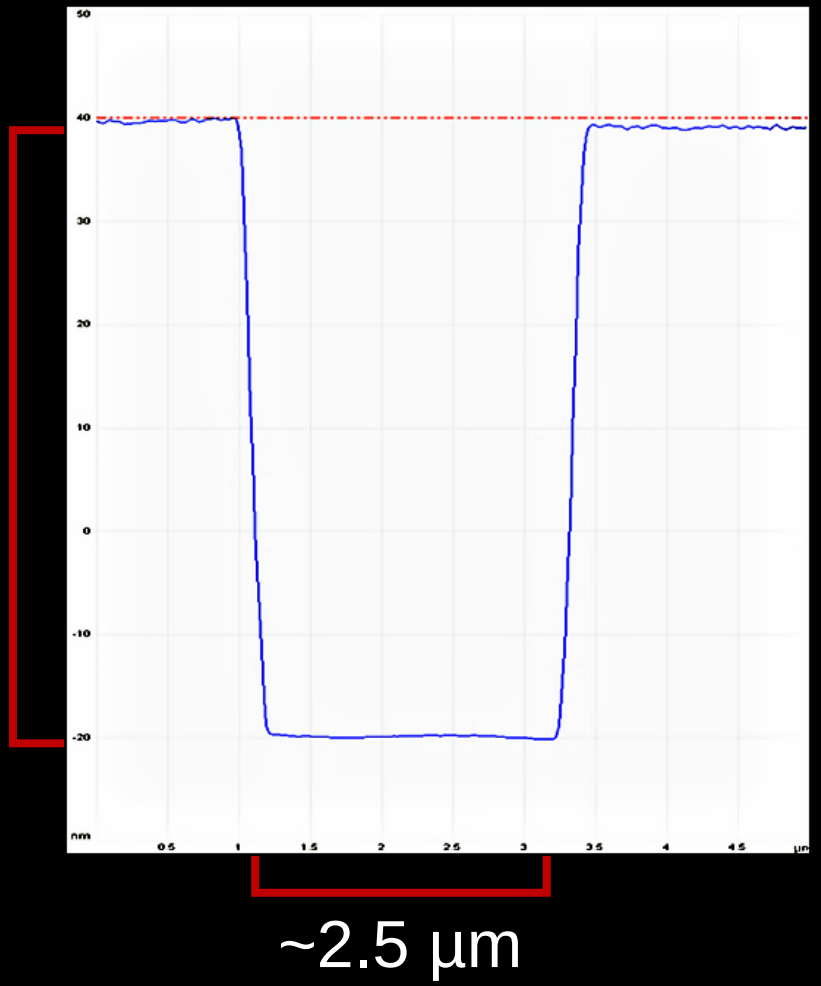


Imaging Challenges

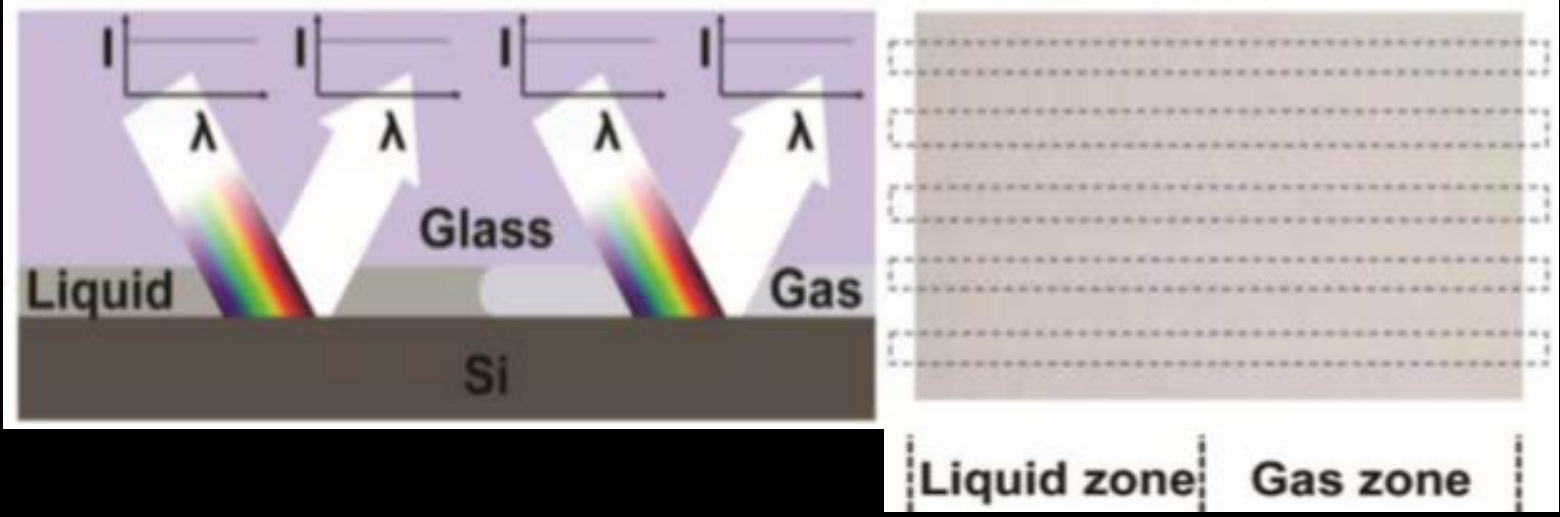
- Nanoconfinement
- Phase Contrast

Nanoconfinement

- **High Aspect Ratio**

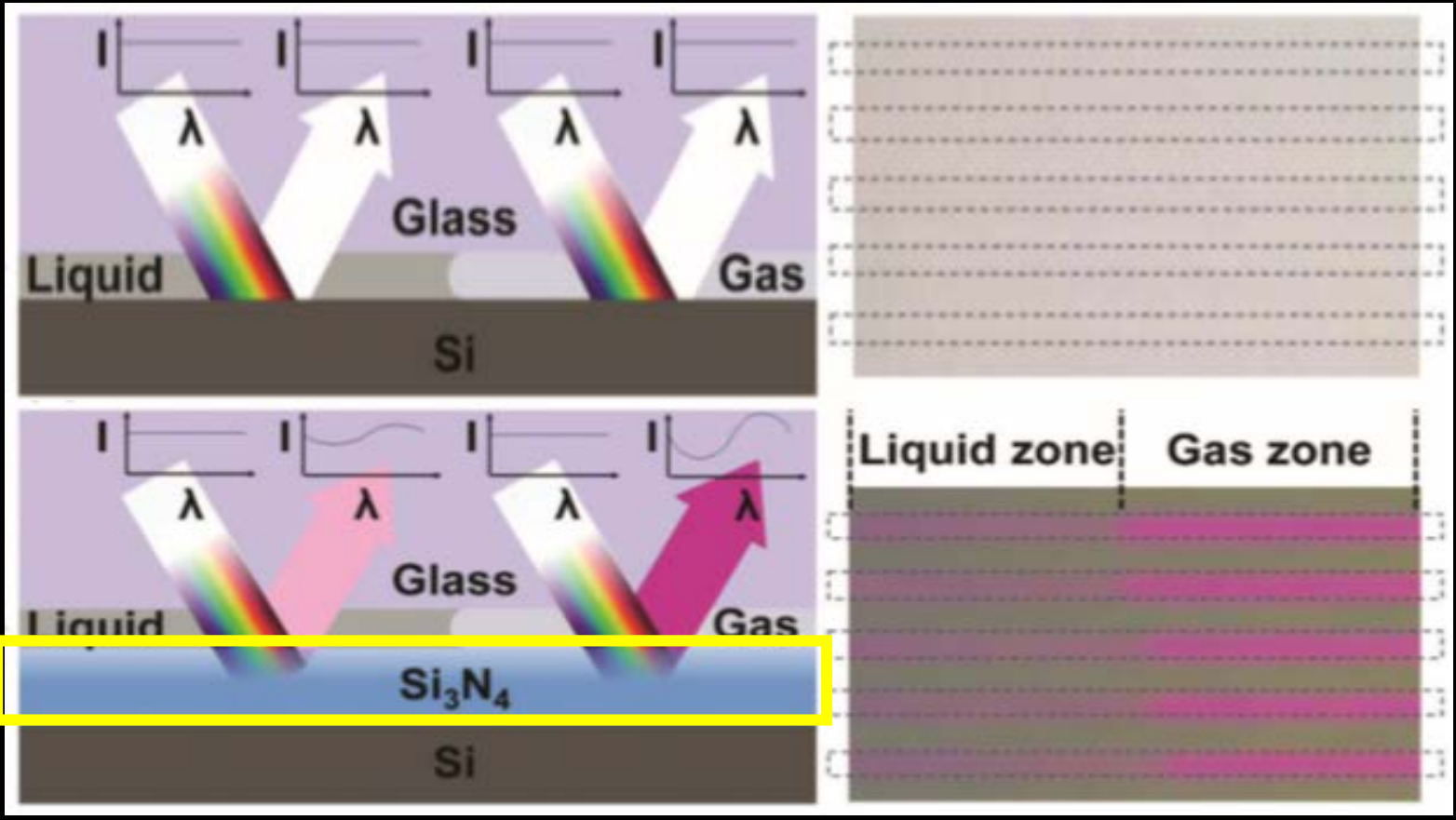


Phase Contrast



Direct visualization of fluid dynamics in sub-10 nanochannels.
Nanoscale, 2017, 9, 9556

Phase Contrast



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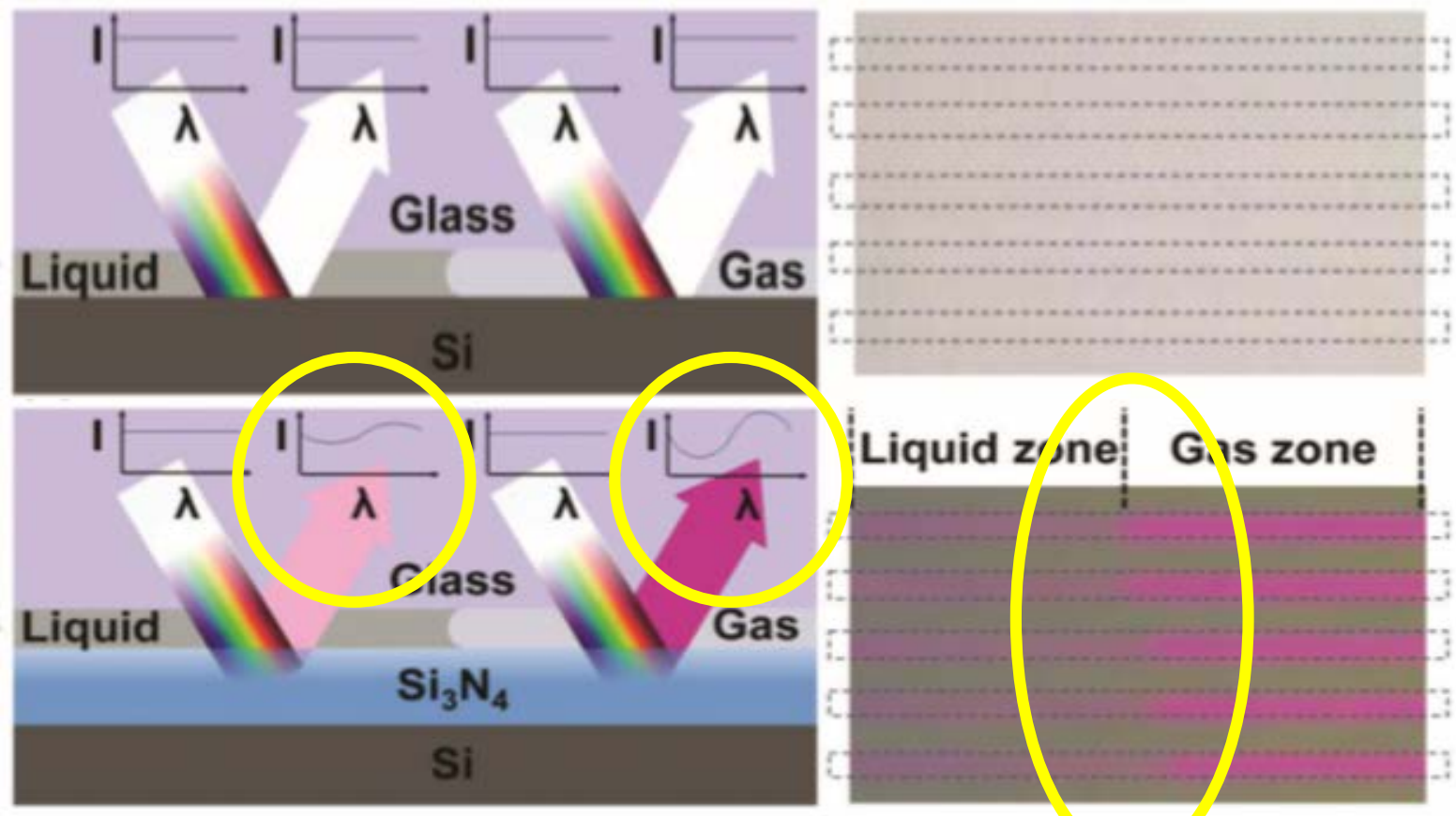
Phase Contrast



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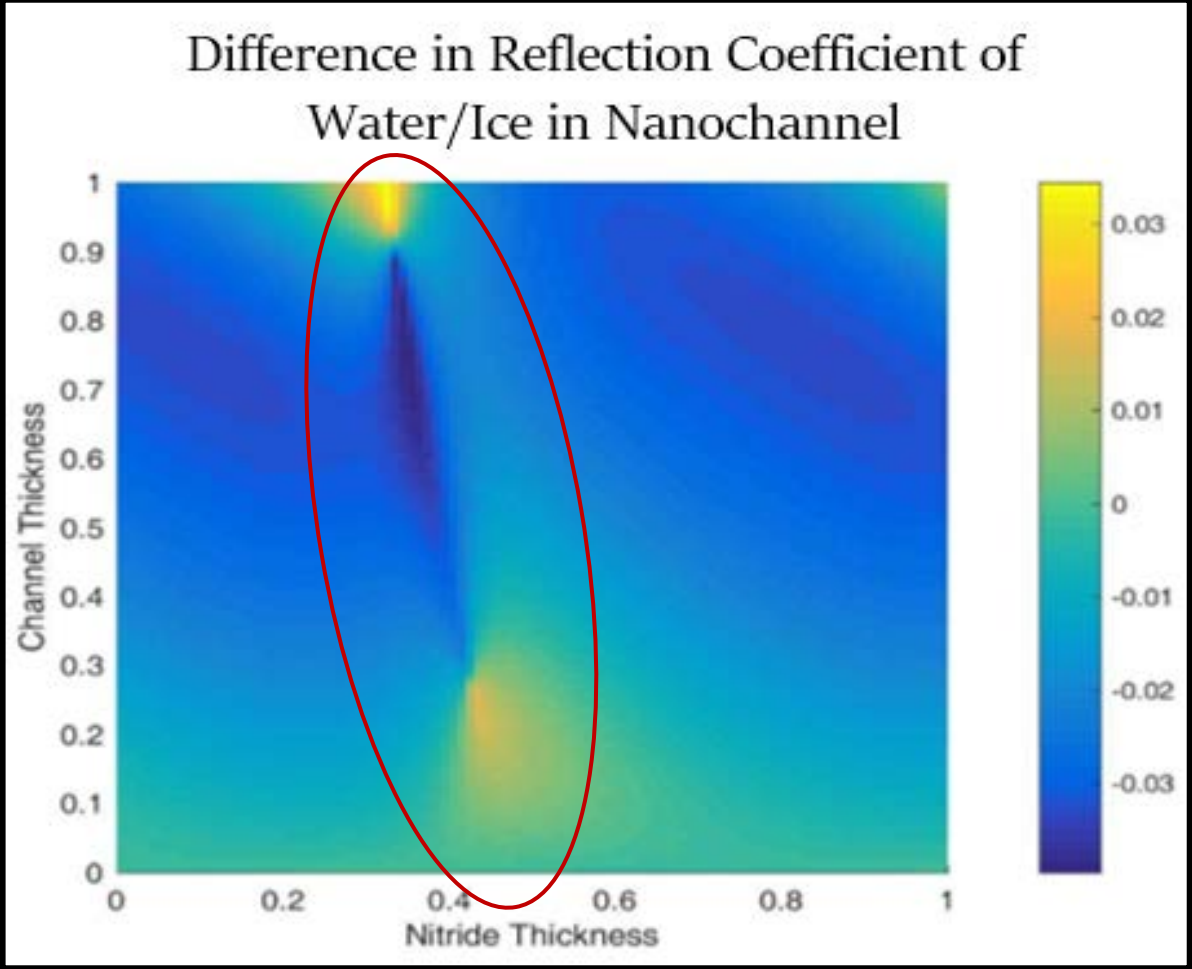
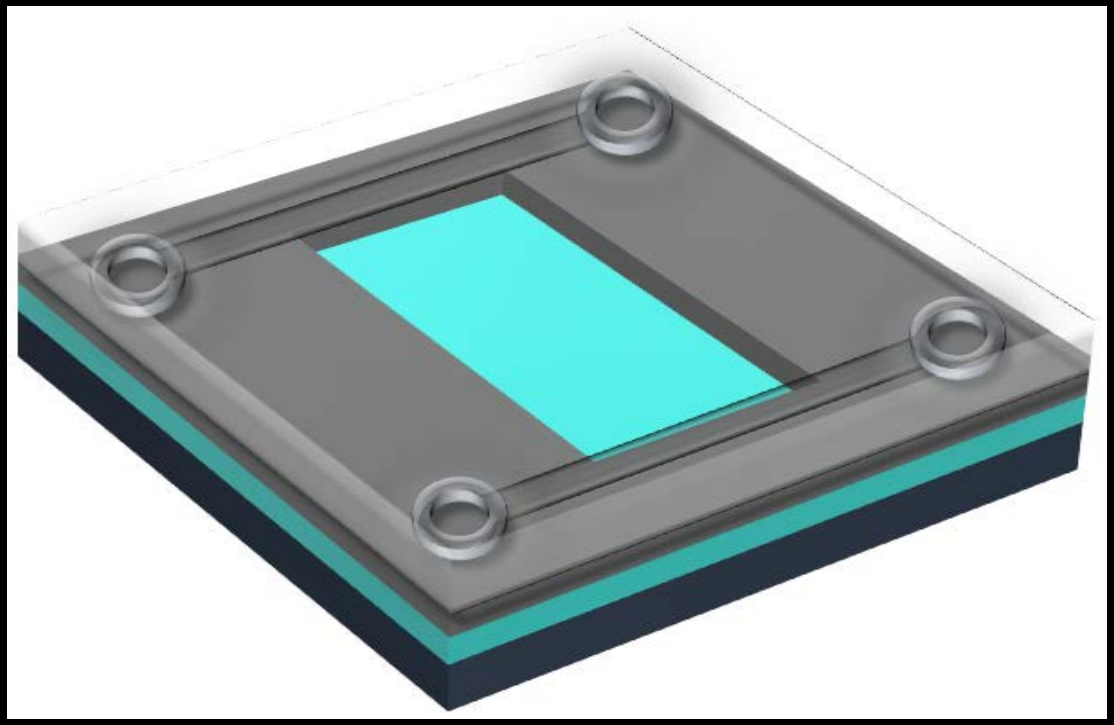


- Nitride Thickness: 130–220 nm

Approach

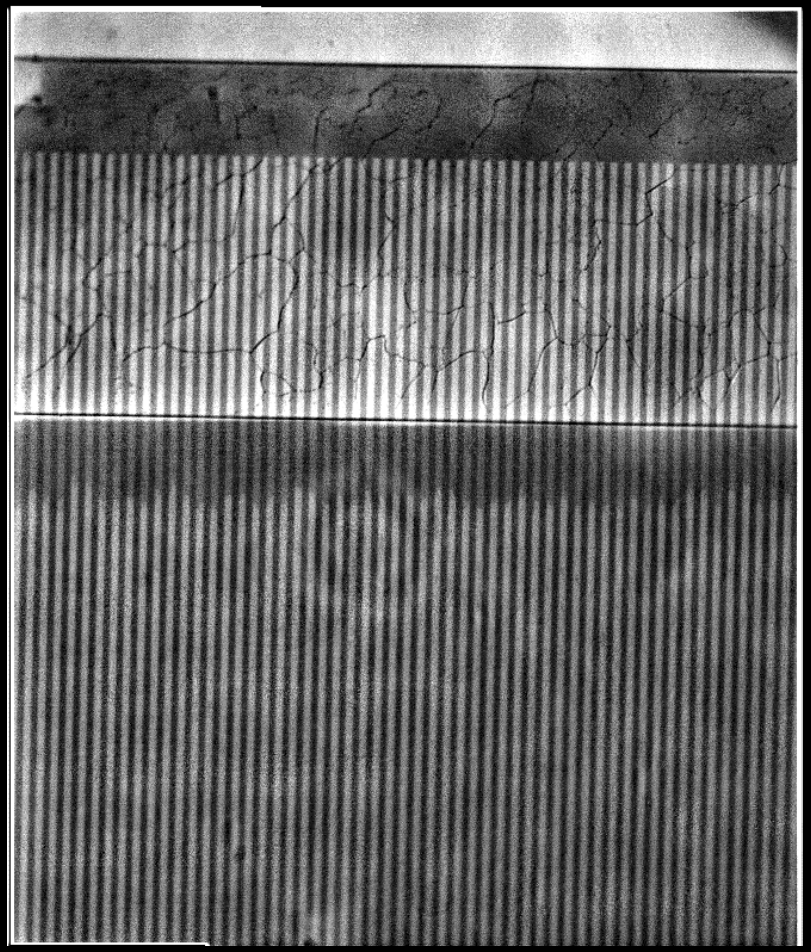
- **Optical Channel Development**



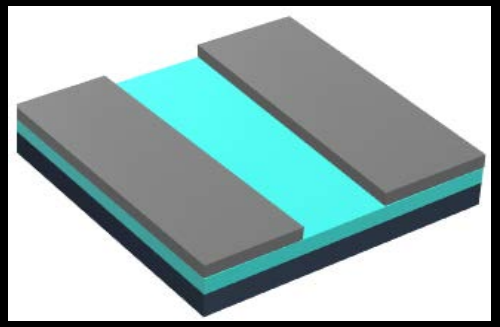
Approach

- Optical Channel Development

- **Channel Testing**



Channel Construction



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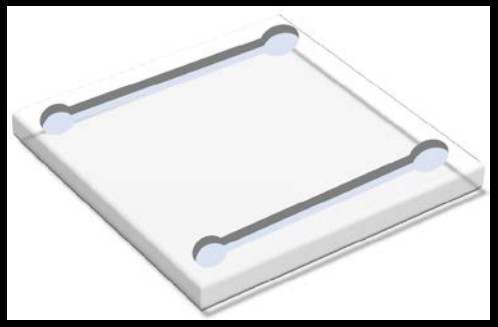
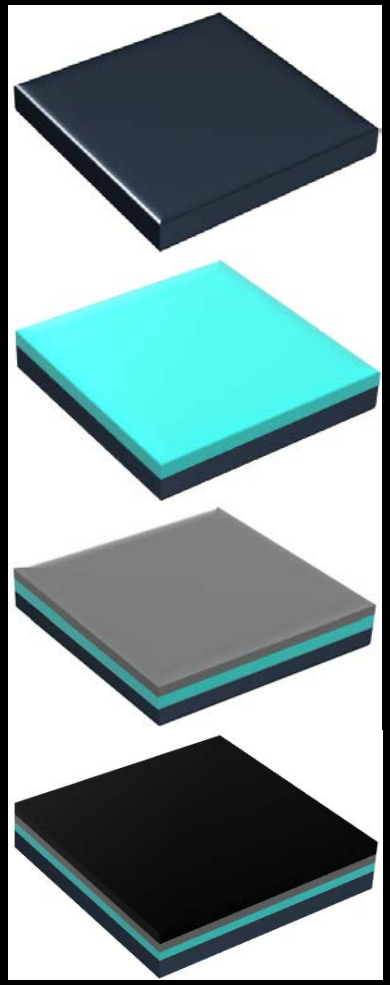


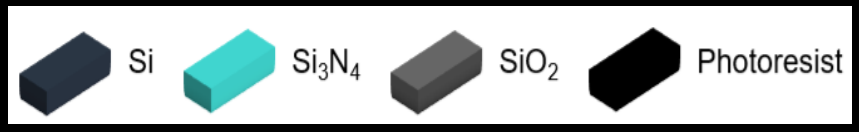
Si Wafer

Glass Wafer

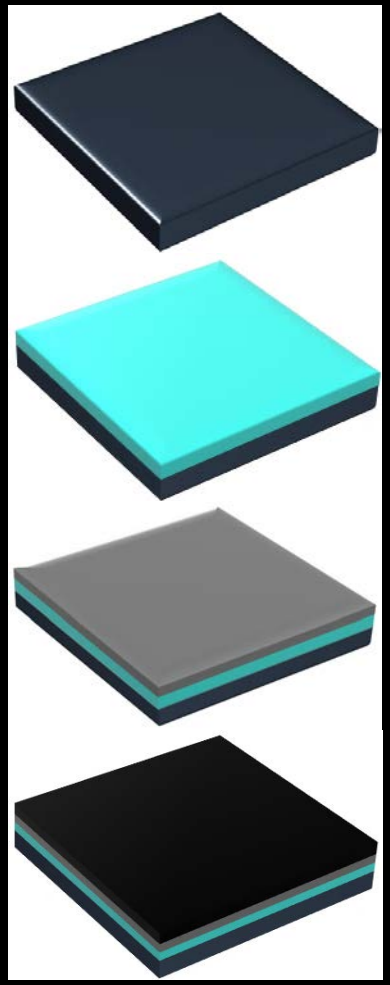
Channel Construction



- Si Wafer
- LPCVD
  - Si_3N_4 Deposition
- PECVD
  - Oxide Deposition
- Photoresist



Channel Construction



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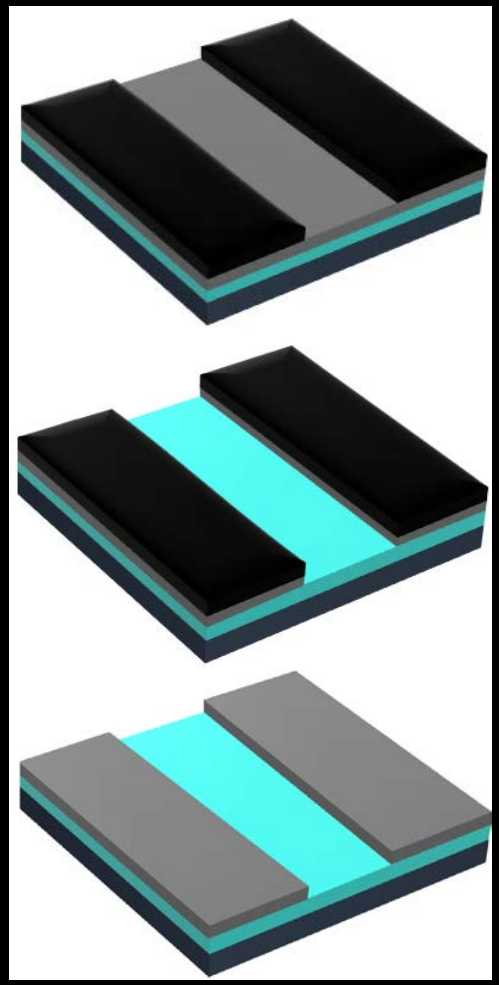
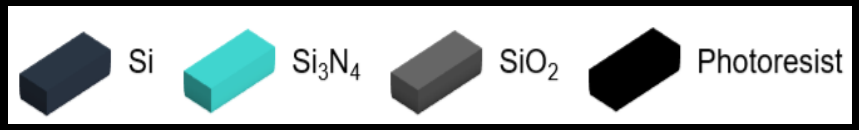
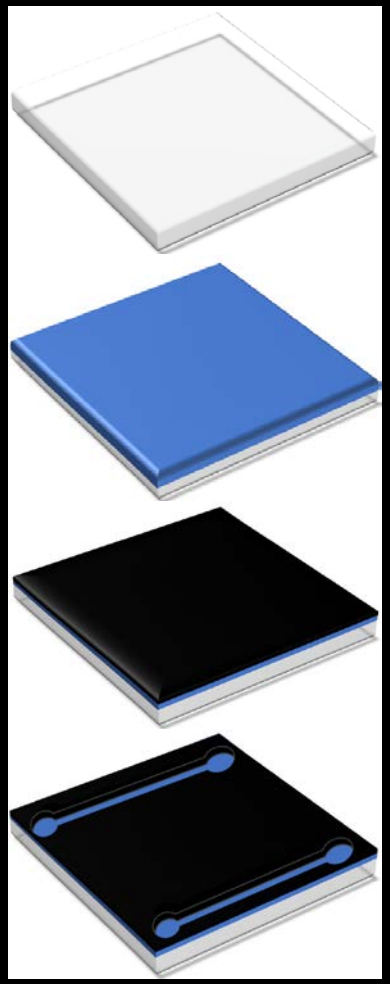


- Contact Aligner
  - Pattern Nano-Channels
- 30:1 BOE
  - Wet Etch
- Strip Resist

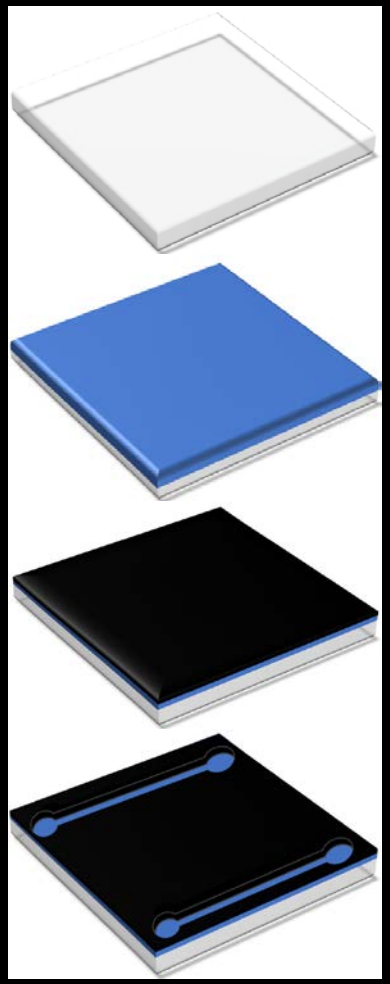


Channel Construction

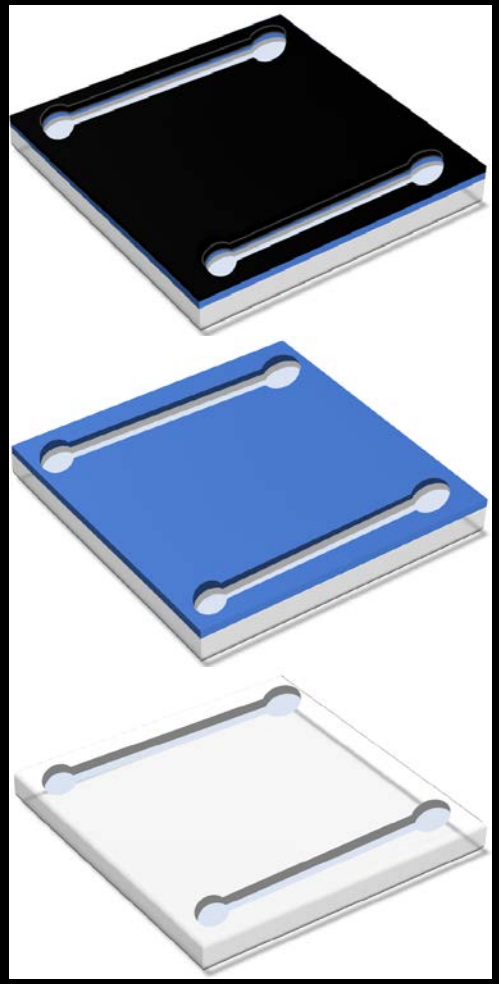


- Glass Wafer
- PECVD
  - A-Si Deposition
- Photoresist
- Contact Aligner
  - Pattern Micro-Channels

Channel Construction

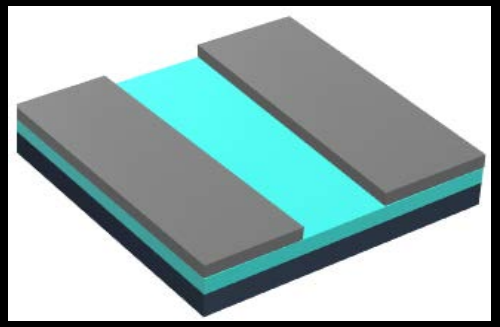


- Glass Wafer
- PECVD
  - A-Si Deposition
- Photoresist
- Contact Aligner
  - Pattern Micro-Channels



- SF_6/O_2 & HF
  - Etch Channels
- Strip Resist
- SF_6/O_2 Etch
  - Remove A-Si

Channel Construction



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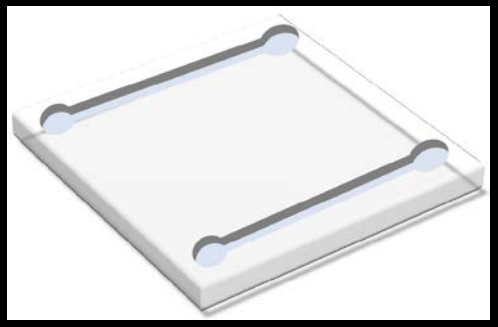

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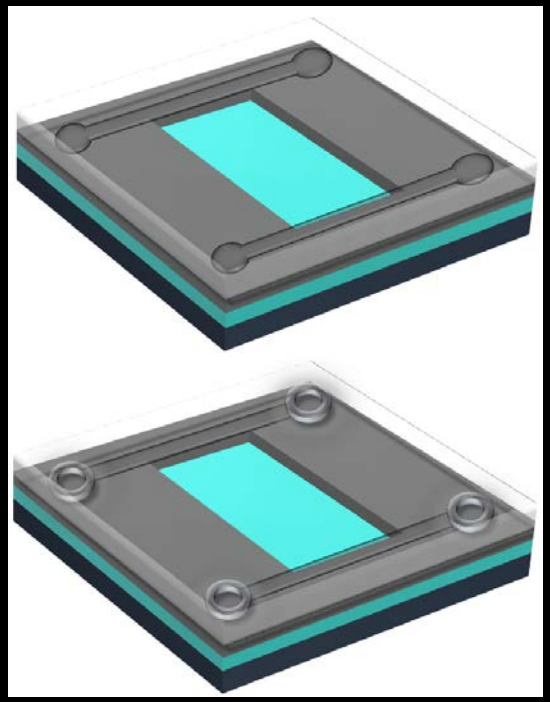
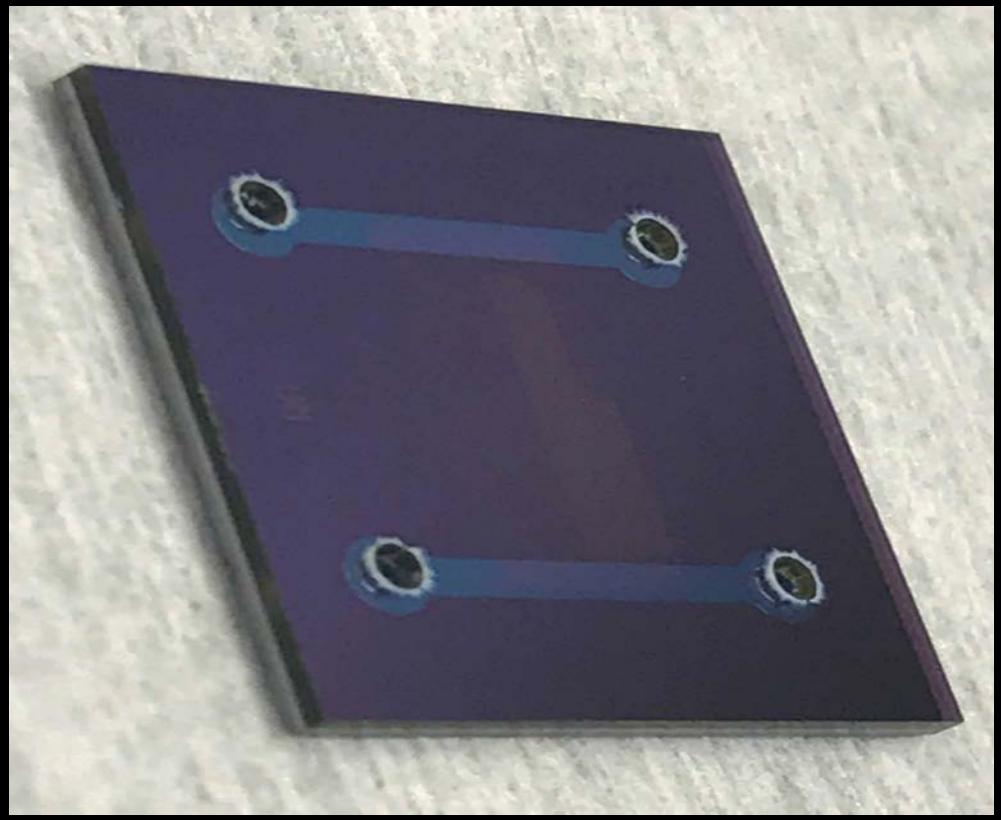
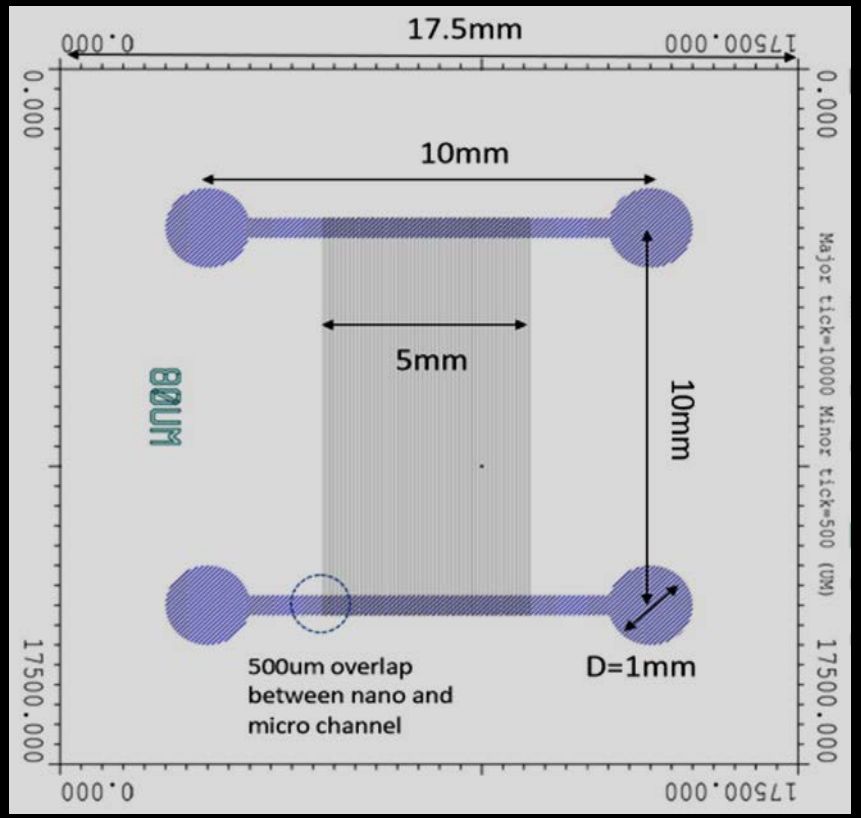


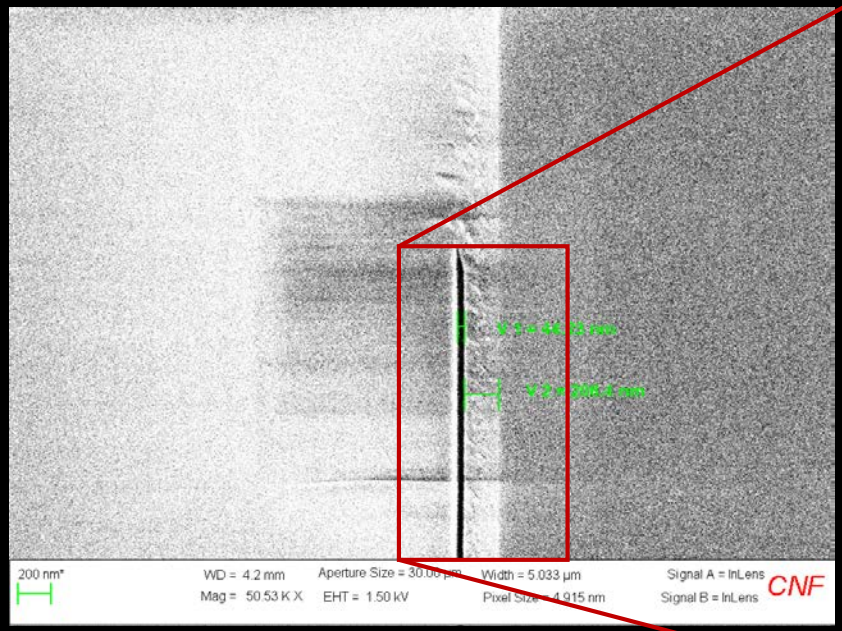
- Bonding
- Dice & Laser Cut

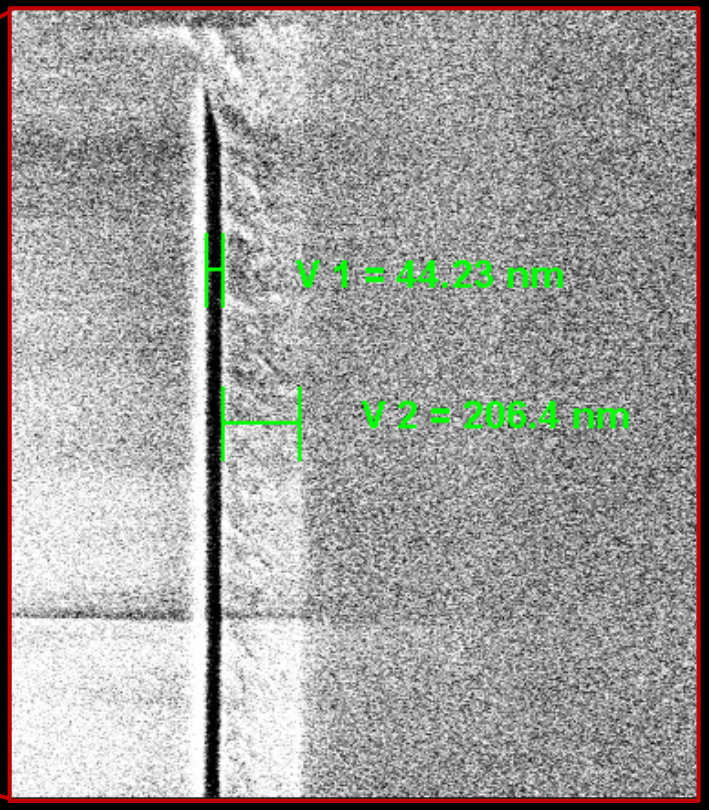
Final Device





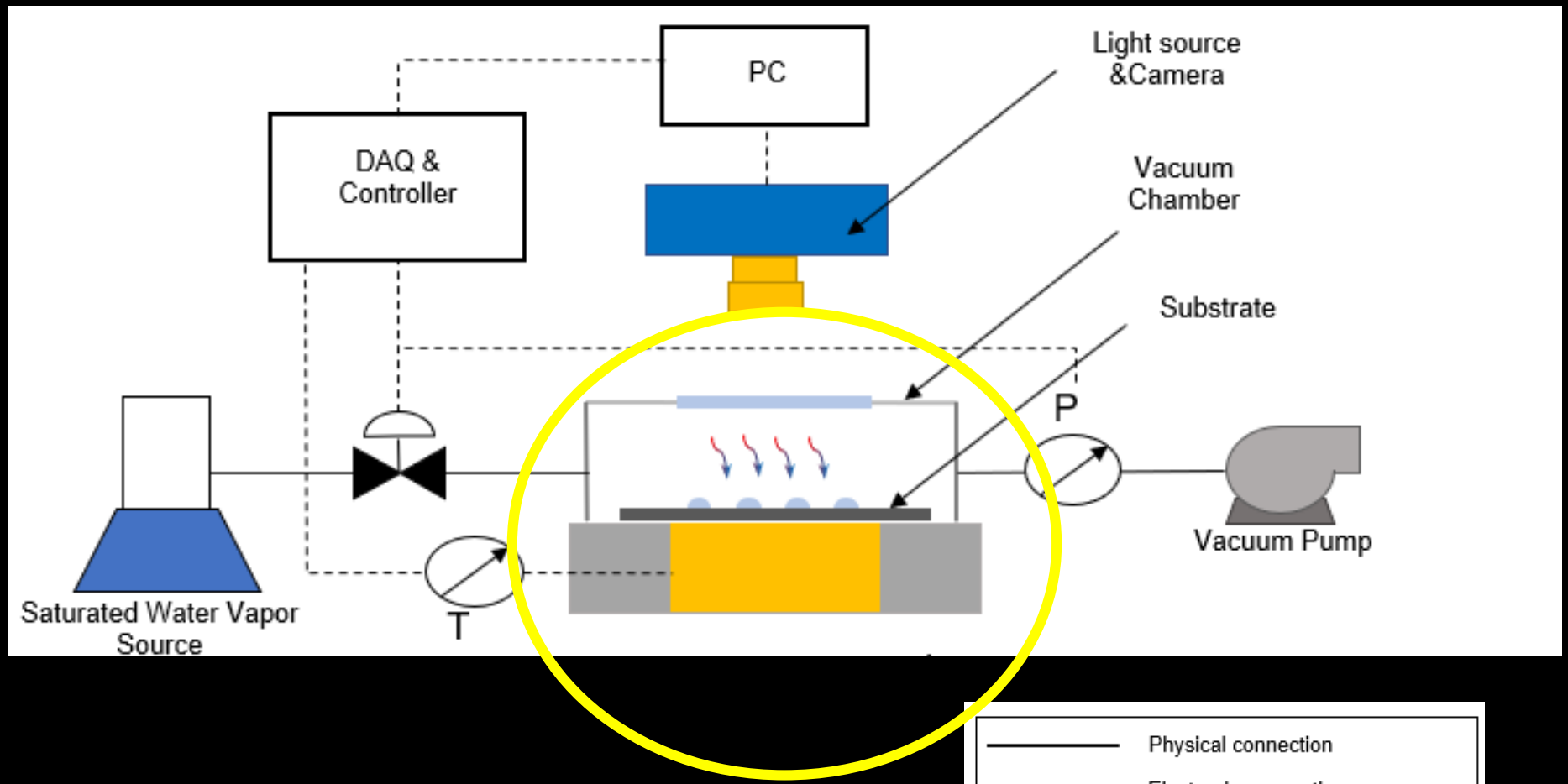
SEM





Channel Height: ~44 nm
Si_3N_4 Layer Thickness: ~206 nm

Channel Testing



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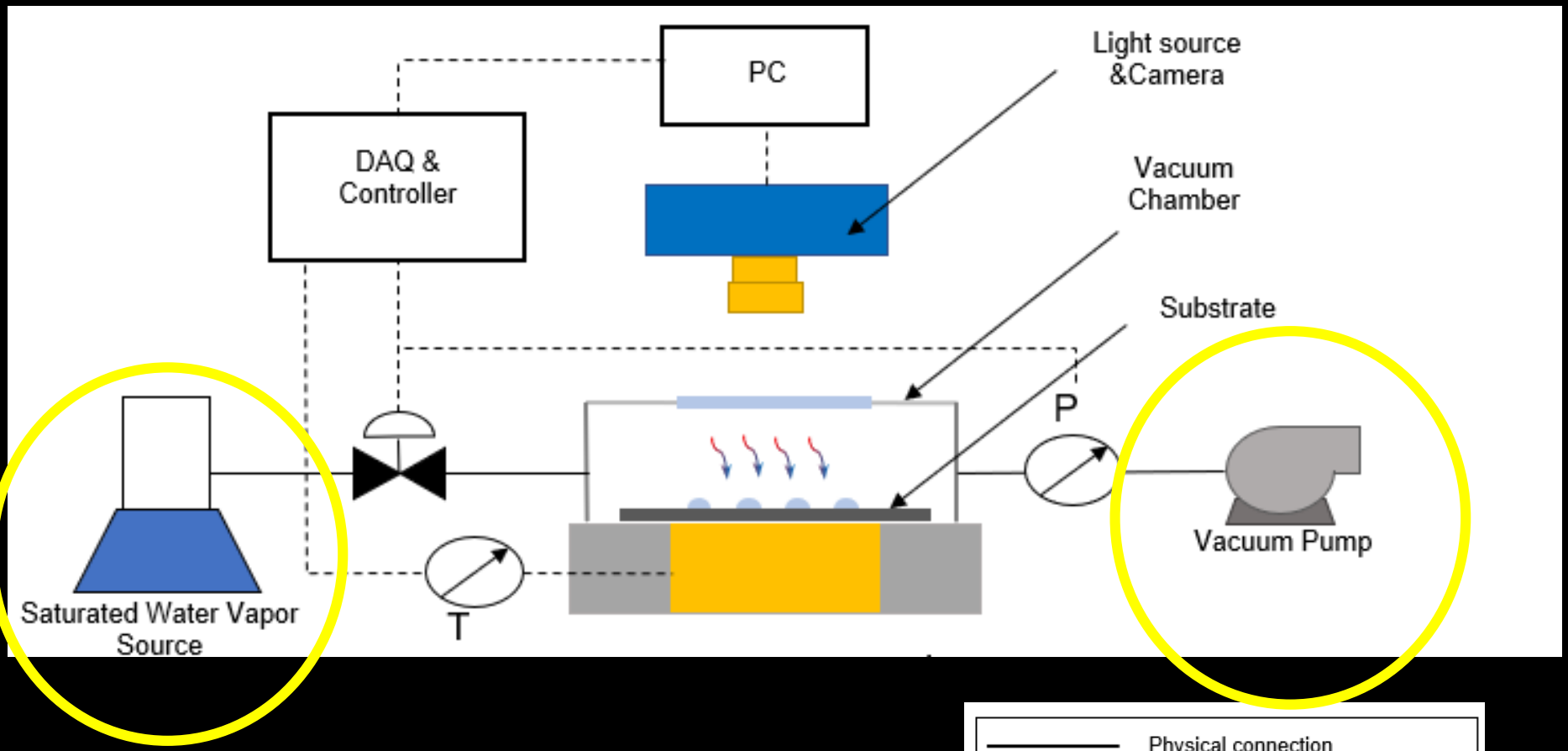

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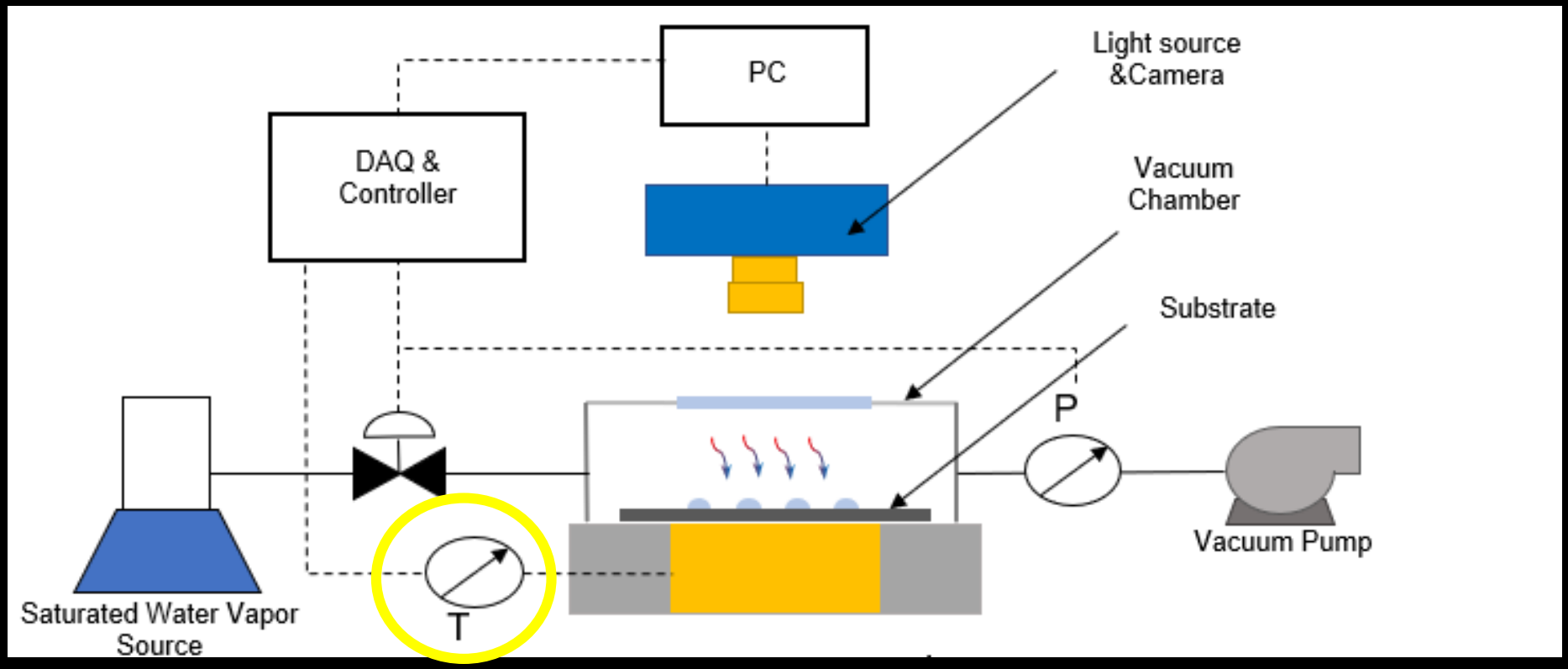

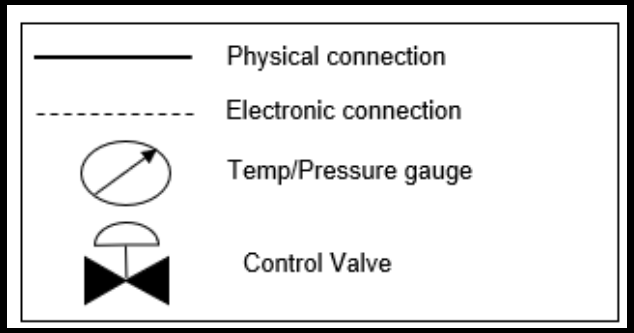

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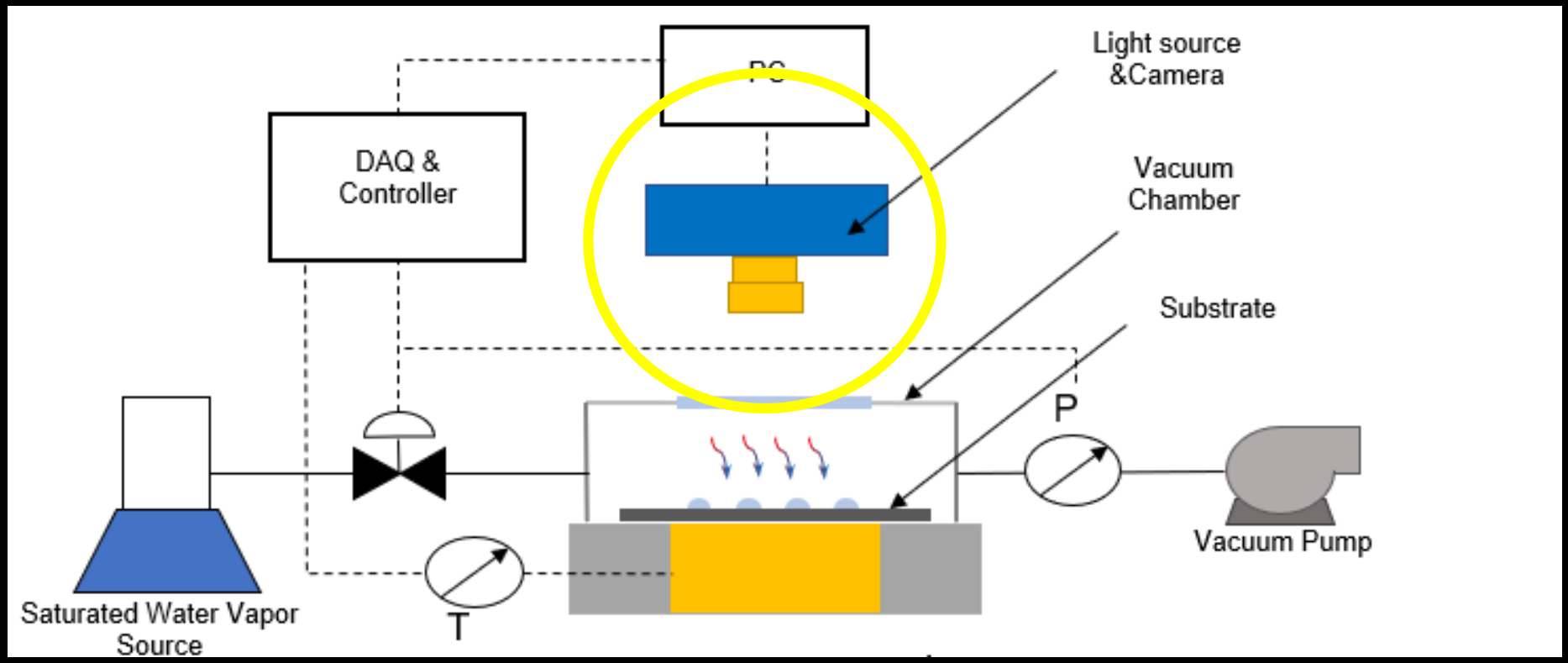
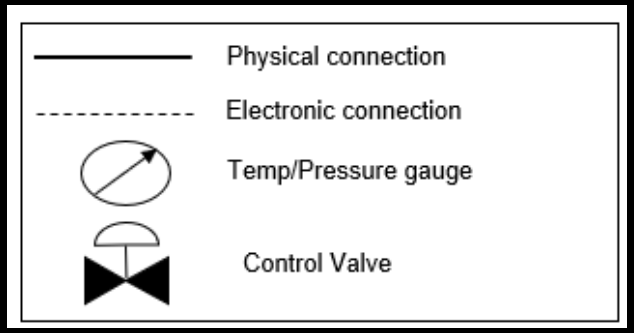
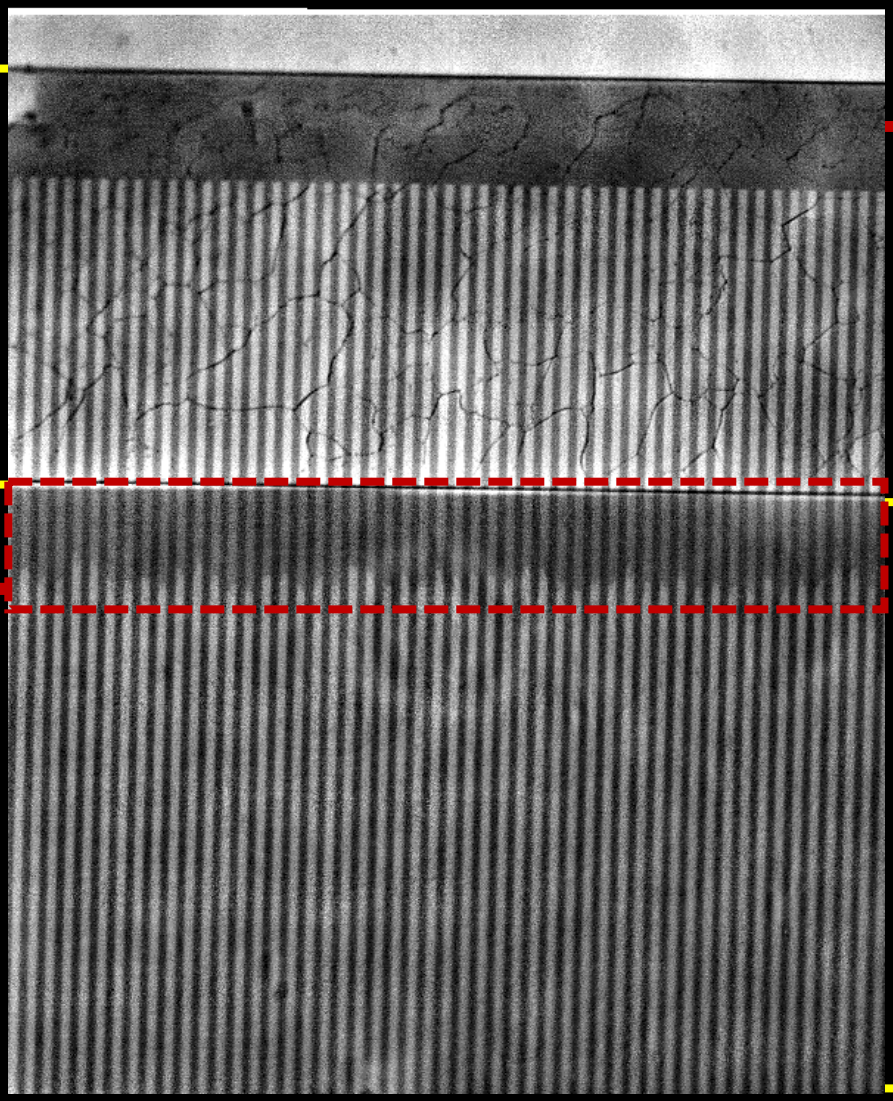




Channel Imaging



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