Design and Fabrication of Si Micro/Nanowires through Thermal Oxidation

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Outline

Applications

Fabrication: Thermal Oxidation

Characterization:

- Scanning Electron Microscopy
- Nanospec 3000

Future Projects

References

Acknowledgements

Contact Information

Biosensors

Nanowires are considered as key nanomaterials because of their electrical controllability for accurate measurement, and chemical-friendly surface for various sensing applications [1].

- DNA sequencing[1-2]
- Proteins [1-3]
- pH sensing [1,2,4,5]
- Drug discovery [1-2,6]
- Viruses [7]

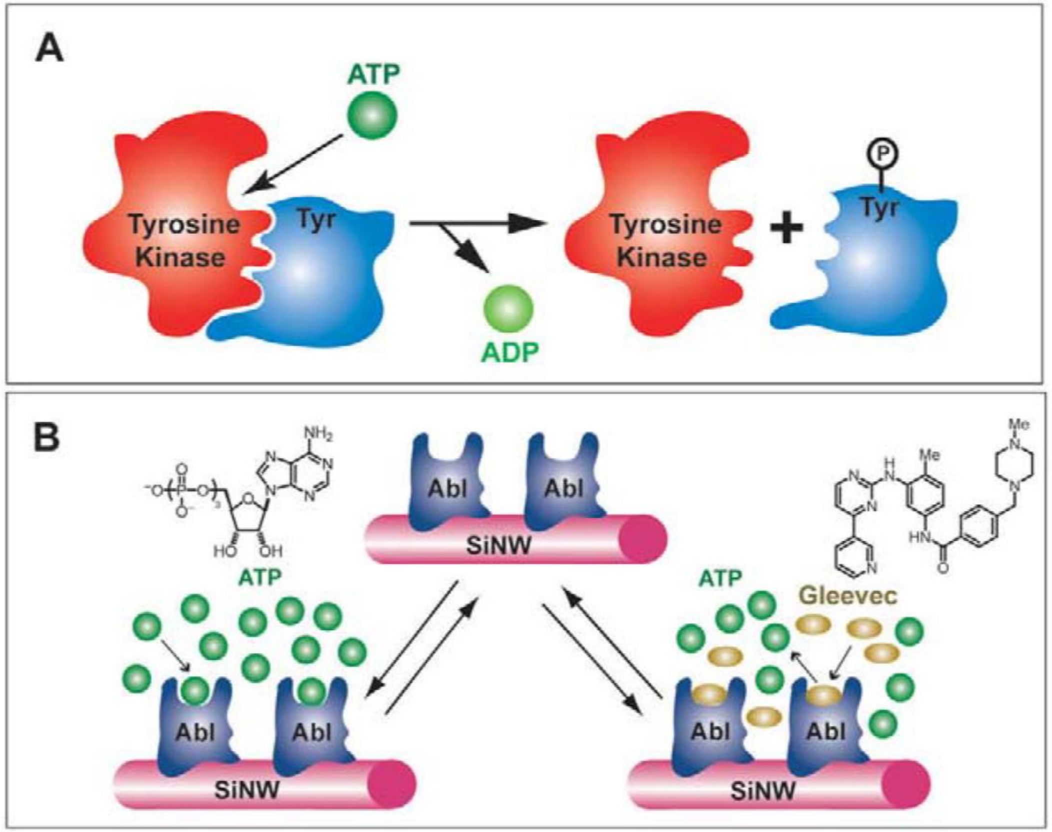


Fig. 1. Identifying molecular inhibitors Abl enzyme [2]

Introduction

- Electrical and Optical Properties of Si
  - Indirect band-gap (E_g = 1.12 eV)
  - Unique luminescence properties (size and shape) [8]

Thermal Oxidation

- Parameters
  - Gas flow – 70 psi
  - Temperature – 1000 °C
  - Time - varies

Fig. 2. Si Wafer[9]

Thermal Oxidation - Experimental Setup

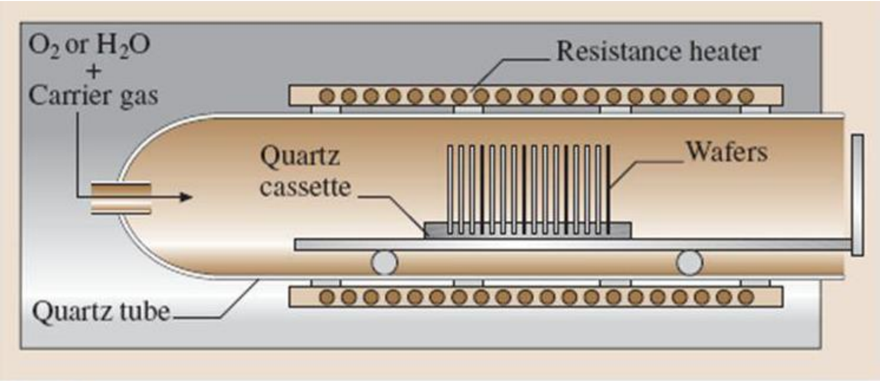


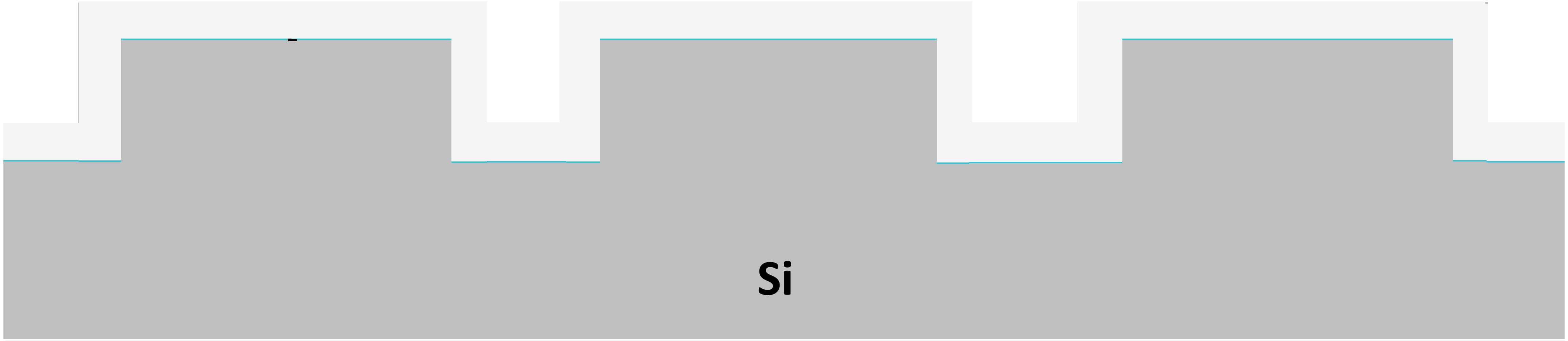
Fig. 3 Oxidation Furnace [10]

Fig. 4 Experiment Setup

What is Wet Thermal Oxidation?

$$Si + 2H_20 \longrightarrow SiO_2 + 2H_2$$

Fig. 5. Explanation of thermal oxidation



Fabrication Process

- Cleaning:
  - The samples are cleaned in the Nanofab
    - RCA-1: Solution made using H_2O_2-NH_4OH-H_2O with a volume ratio of 1:0.25:5 at 60 °C
    - RCA-2: Solution made using H_2O_2-HCl-H_2O with a volume ratio of 1:1:6 at 60 °C
    - Hydrofluoric (HF) Acid
- Measurements:
  - Measure SiO_2 – Nanospec 3000

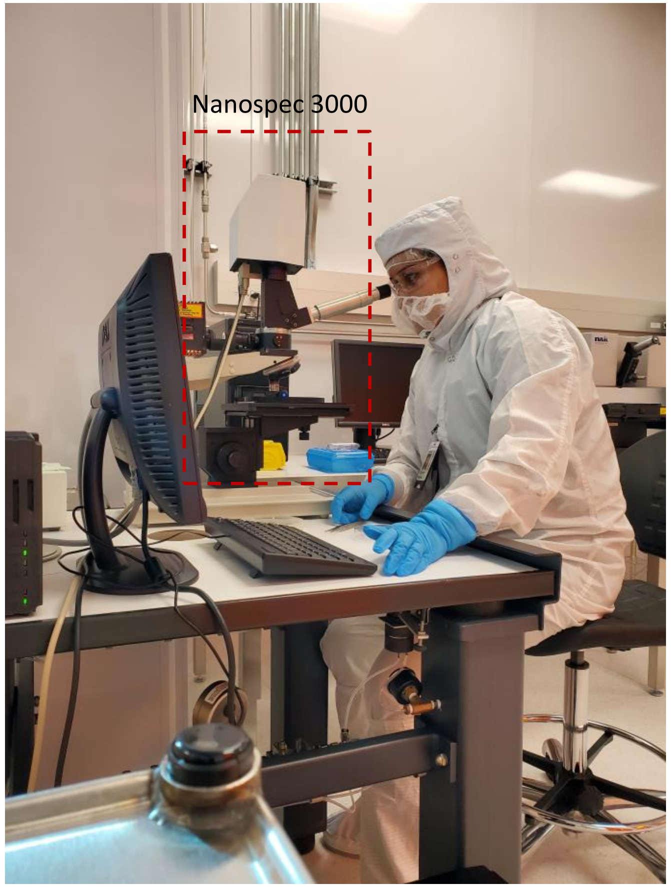


Fig. 6. Using the Nanospec 3000

Thermal Oxidation SOP and Video

Thermal Oxidation Process using Furnace

1. Put Silicon wafer in the furnace before turning on.
   a. Take off the quartz end of the furnace (side with the spherical tube). Hold it on the circular side never on the small tube.
   b. Make sure that the pattern of the Silicon wafer is right side up, the sample needs to be in the middle and try not to scratch the sample with the hook.
2. Put 600 cc of H_20 into the beaker and start heating up the hot plate to 450℃.
3. Start heating up the furnace.
   a. Push the left circular button and hold it, then press again until it says program then press the up-triangle button to change to 1.
   b. Start steps from ssp to tn-3.
   c. Definitions
      i. ssp: starting temp = 25∘C
      ii. sp1: desired temp = dependent on experiment
      iii. tn-1: time it takes to get to desired temperature
      iv. tn-2: time at desired temperature
      v. sp2: running temp = dependent on experiment (same as sp1)
      vi. sp3: cooling down temp = 25℃
      vii. tn-3: time to cool down = 2hrs
   d. hold circular button after tn-3 and press down triangle button to run.
4. About 5 min before desired temperature is reached turn on the N_2 nob to 30 PSI.
   a. Write in green log book date/exp.
5. Once desired temperature has been reached on the furnace open the water vapor stopcock (vertical direction) and close the black stopper on the beaker.
6. Check the flow meter and adjust it to 70.
7. Continuously check each parameter to make sure everything is functioning properly and how much time the process has left.

Cool Down process

8. Once the furnace starts to cool down carefully open the black stopper on the beaker and close the water vapor stopcock (horizontal direction).
9. Turn off the hot plate
10. Turn off the flow meter
11. Wait about 5 minutes
12. Turn off N_2
13. Double check to make sure everything is turned off and that the temperature on the furnace is going down.
14. Once completely cooled down, the sample can be taken out.

Fig. 7 Thermal Oxidation furnace set up and SOP

Scanning Electron Microscope (SEM)

Allows for high resolution imaging at the nano and microscale [11].

Backscattered Electron Detector (BSED): Intercepts the surface and return to the surface - composition

SE – surface detail

Monte Carlo simulation

- Interaction Volume
- Energy Dispersive X-Ray Spectroscopy (EDS)

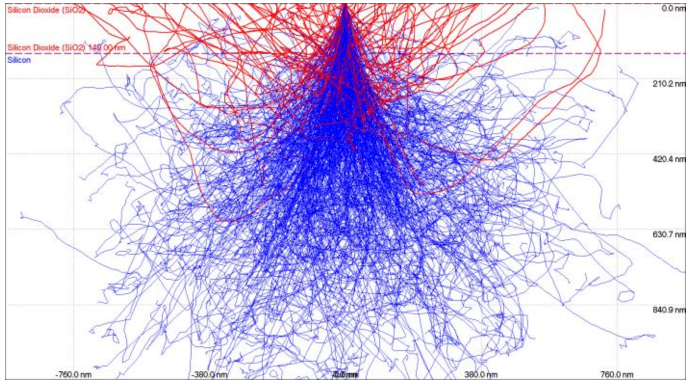


Fig. 8 Monte Carlo Simulation 10 kV – 0° tilt

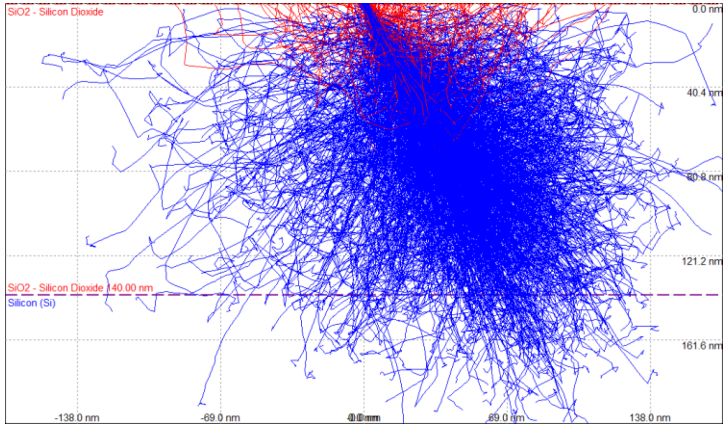


Fig. 9 Monte Carlo Simulation 3 kV – 30° tilt

Results and Discussion

1. Planar

2. Trenches

3. Si Micropillars

4. Si Nanowires

Trenches

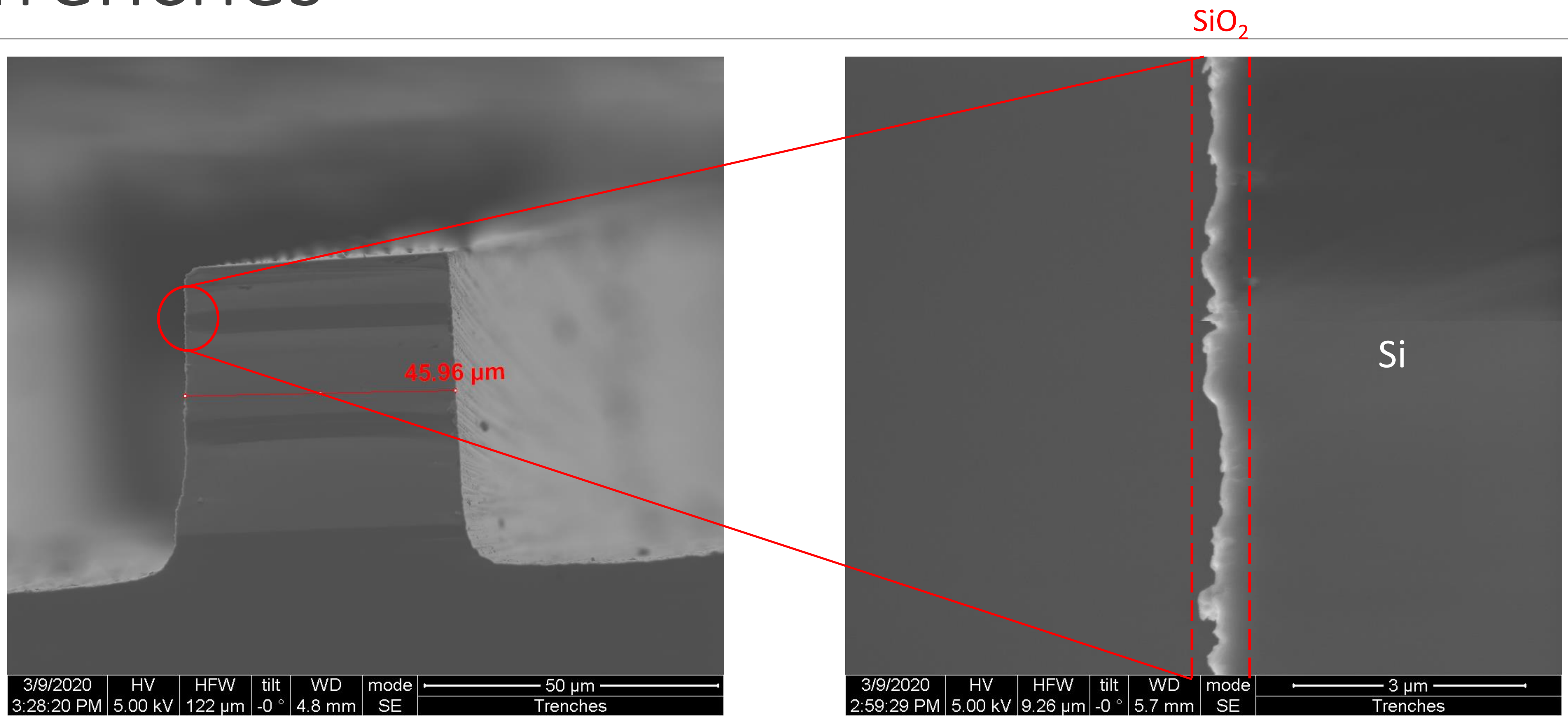


Fig. 10 SEM image of Trench

Fig. 11. SEM image of SiO_2 layer on trenches

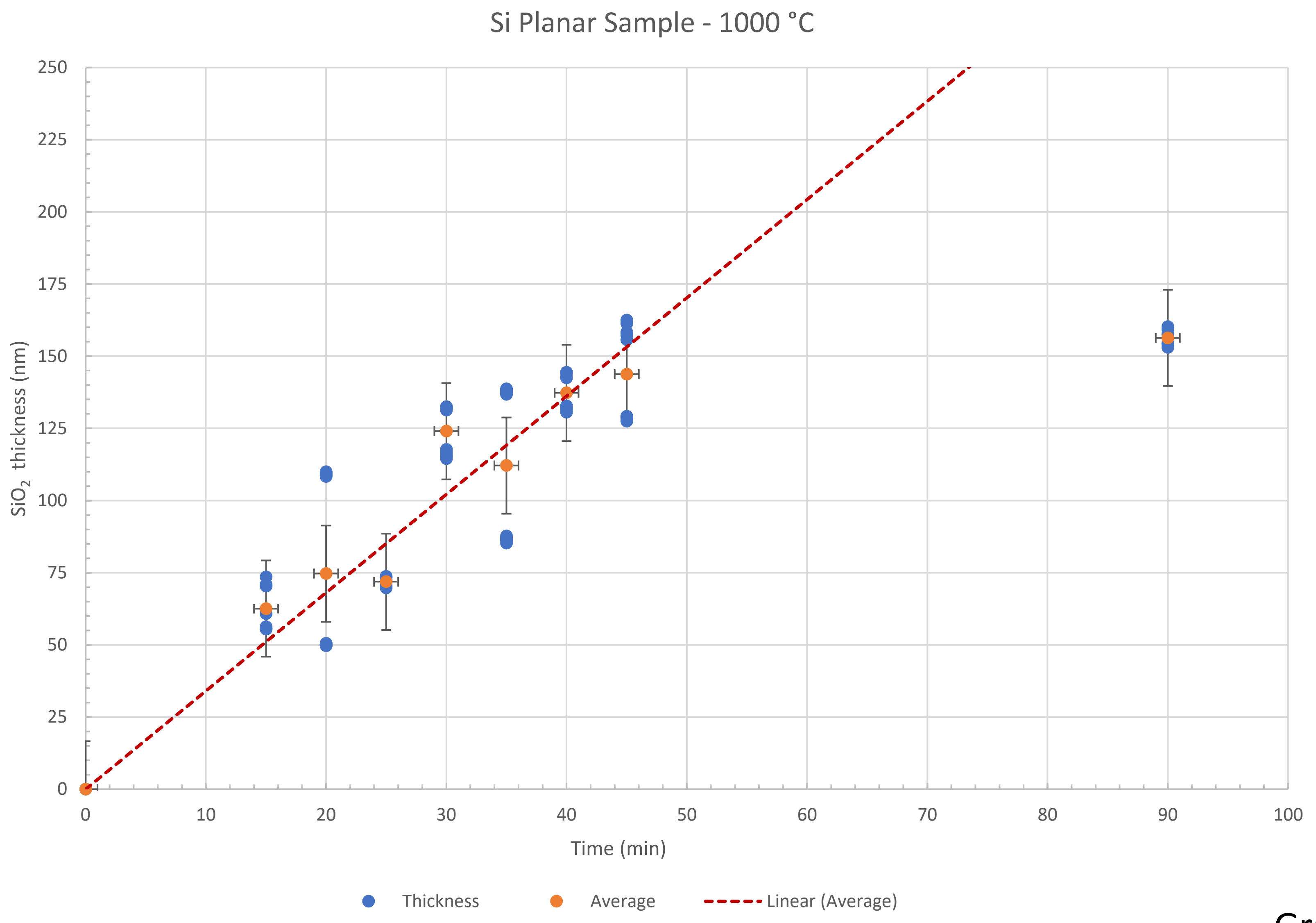
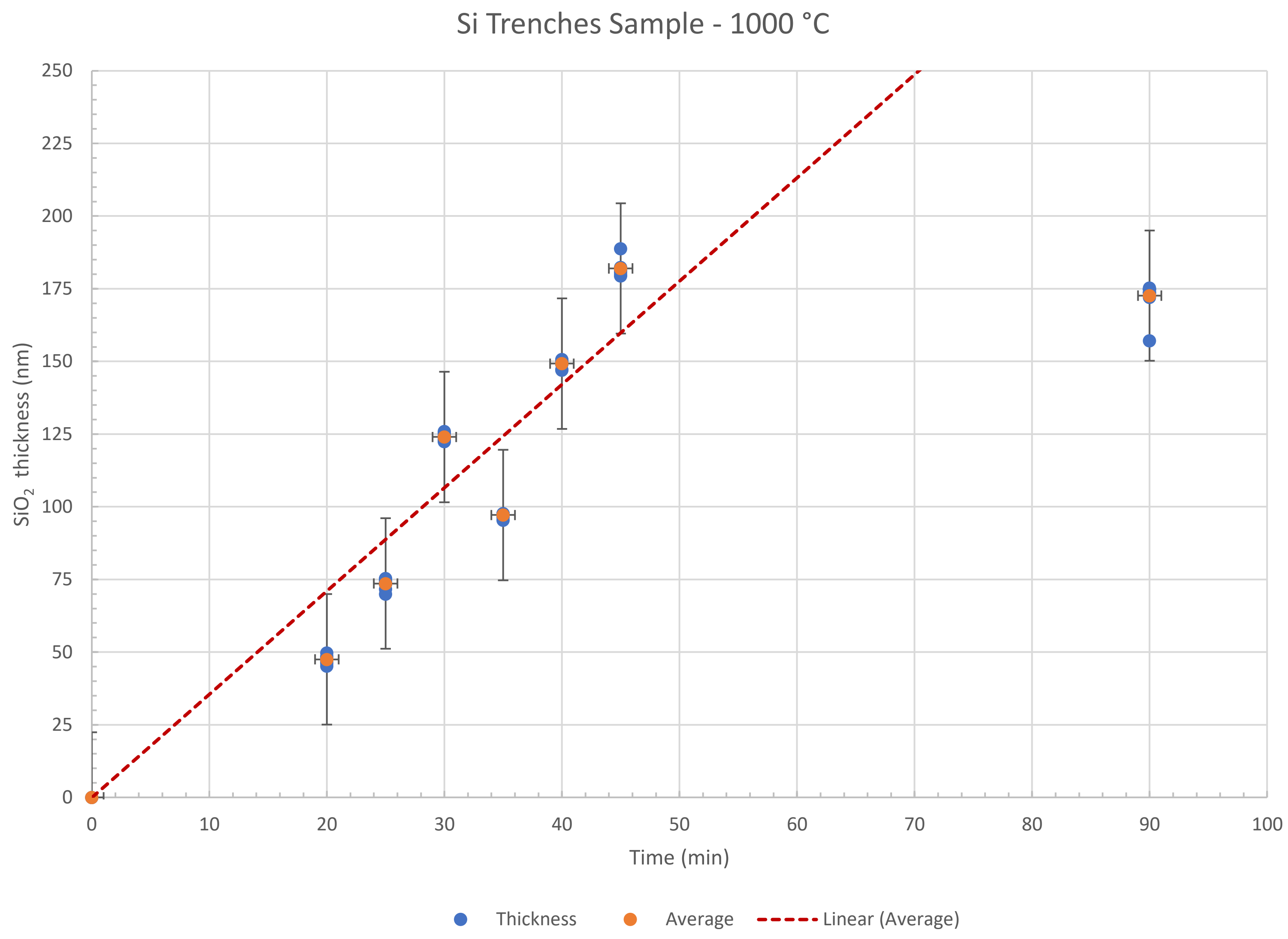


Fig. 12 Si Planar Sample Thermal Oxidation Graph time vs. SiO_2

Fig. 13. Si Planar sample 1000° C (30 min)

Growth Rate ~ 3.4049 nm/min



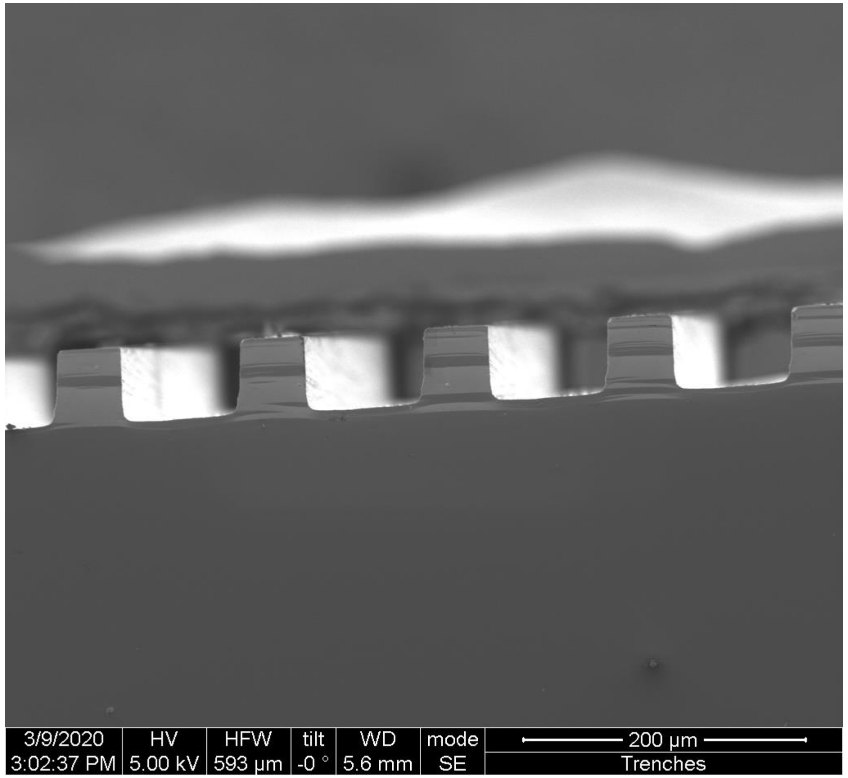
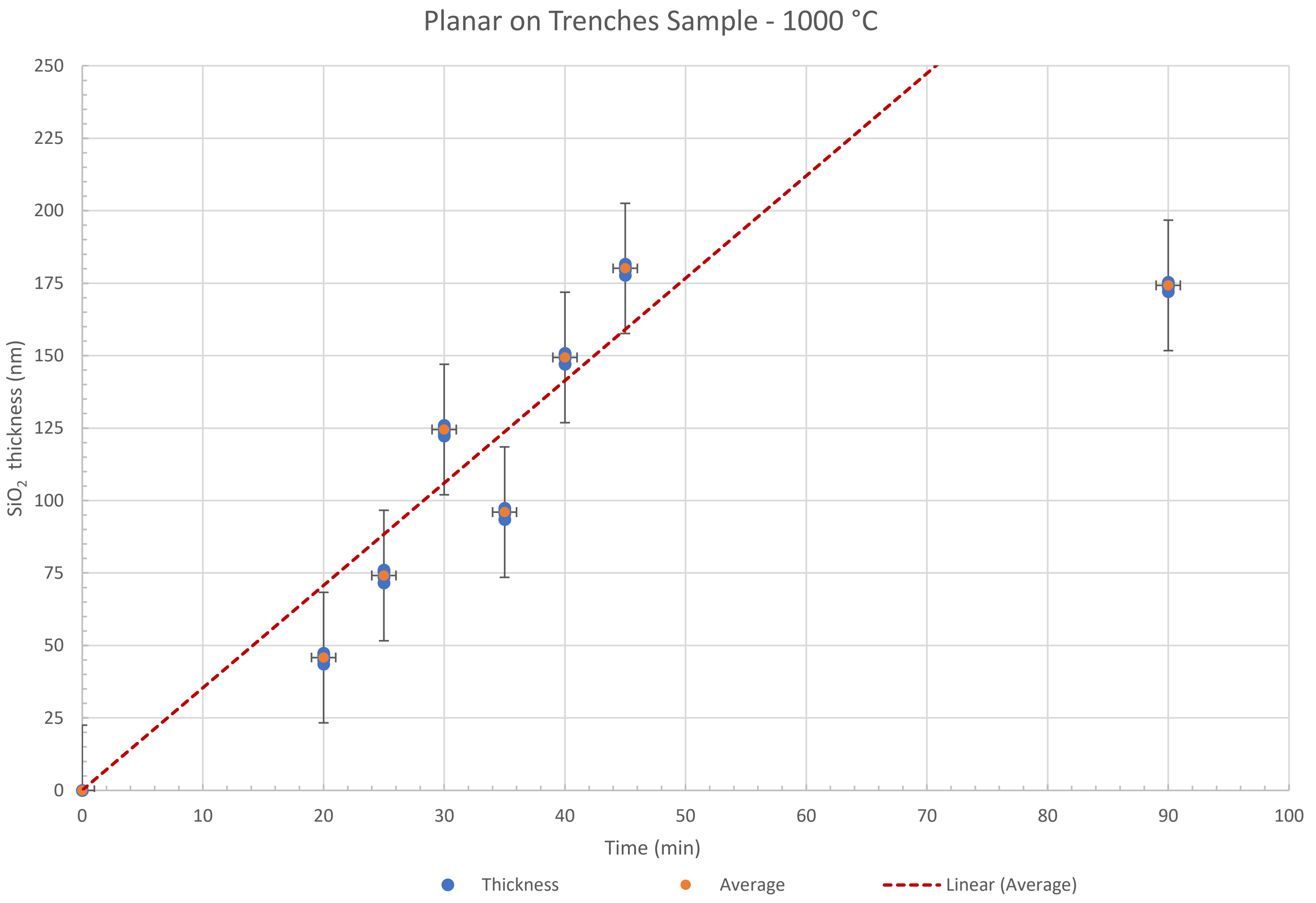


Fig. 15. Si Trenches SEM image

Growth Rate ~ 3.5529 nm/min

Fig. 14 Si Trenches Sample Thermal Oxidation Graph time vs. SiO_2



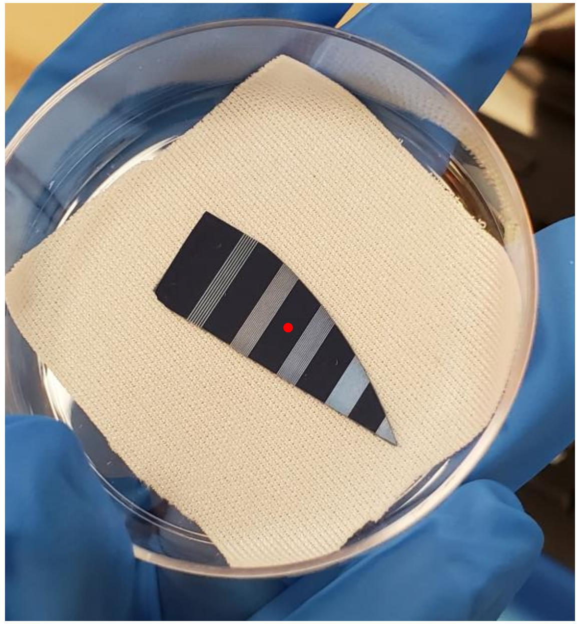
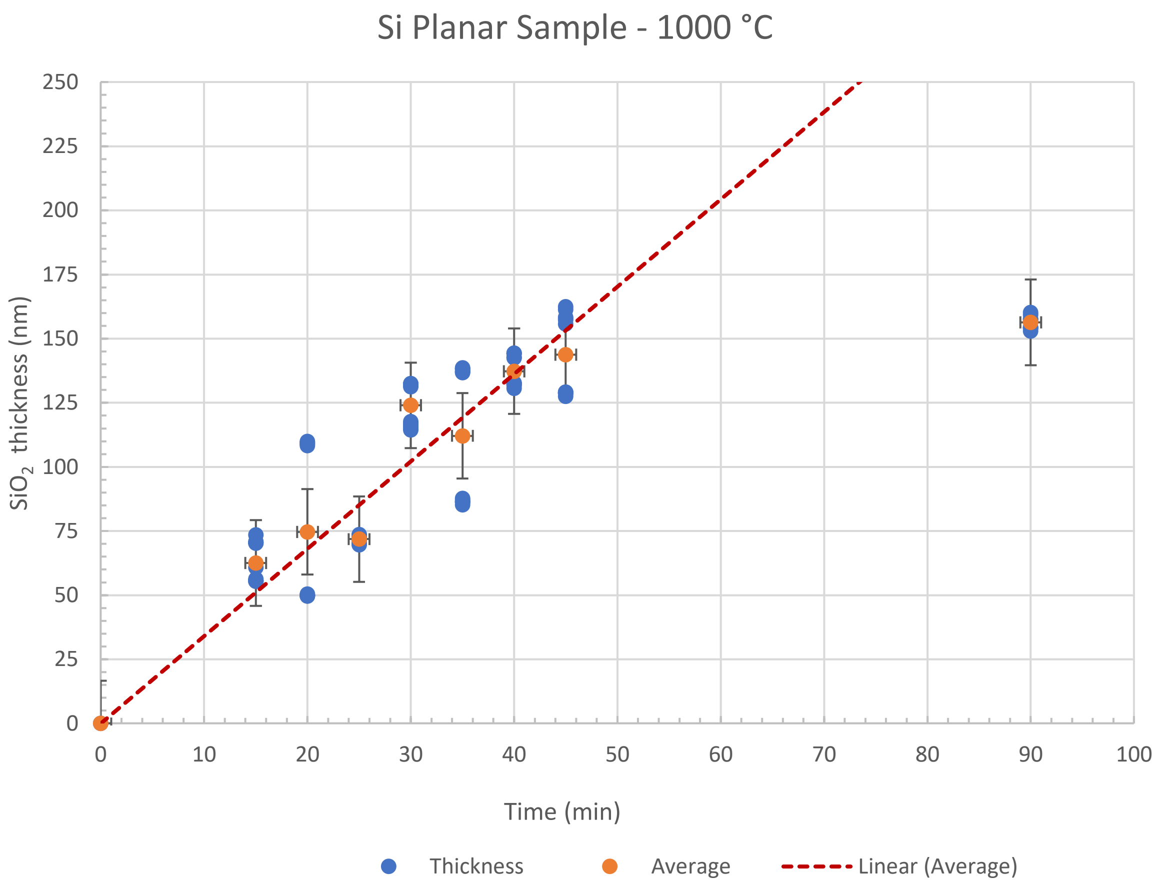


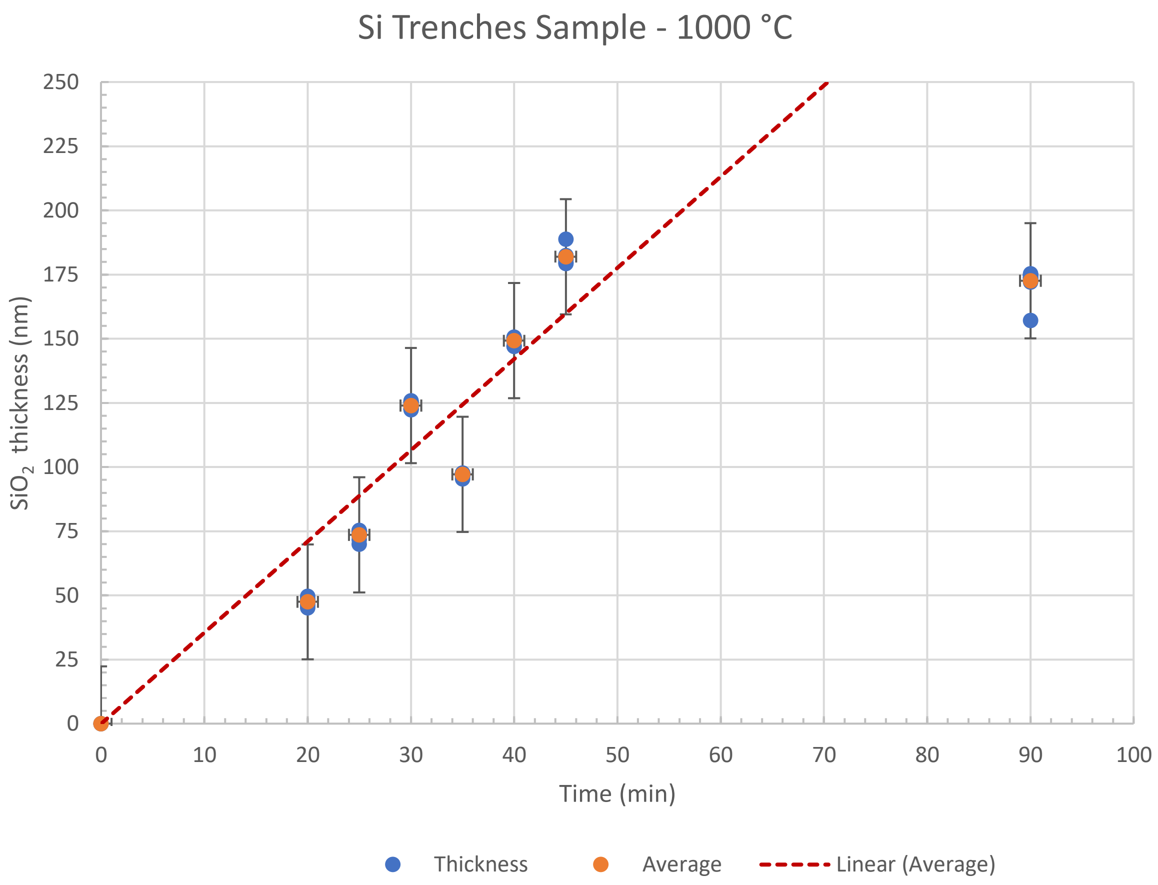
Fig. 17. Si Trenches sample 1000° C (30 min)

Growth Rate ~ 3.5346 nm/min

Fig. 16 Si Planar on Trenches Sample Thermal Oxidation Graph time vs. SiO_2



Growth Rate ~ 3.4049 nm/min



Growth Rate ~ 3.5529 nm/min

Fig. 18 Comparison of graphs

Si Micropillars

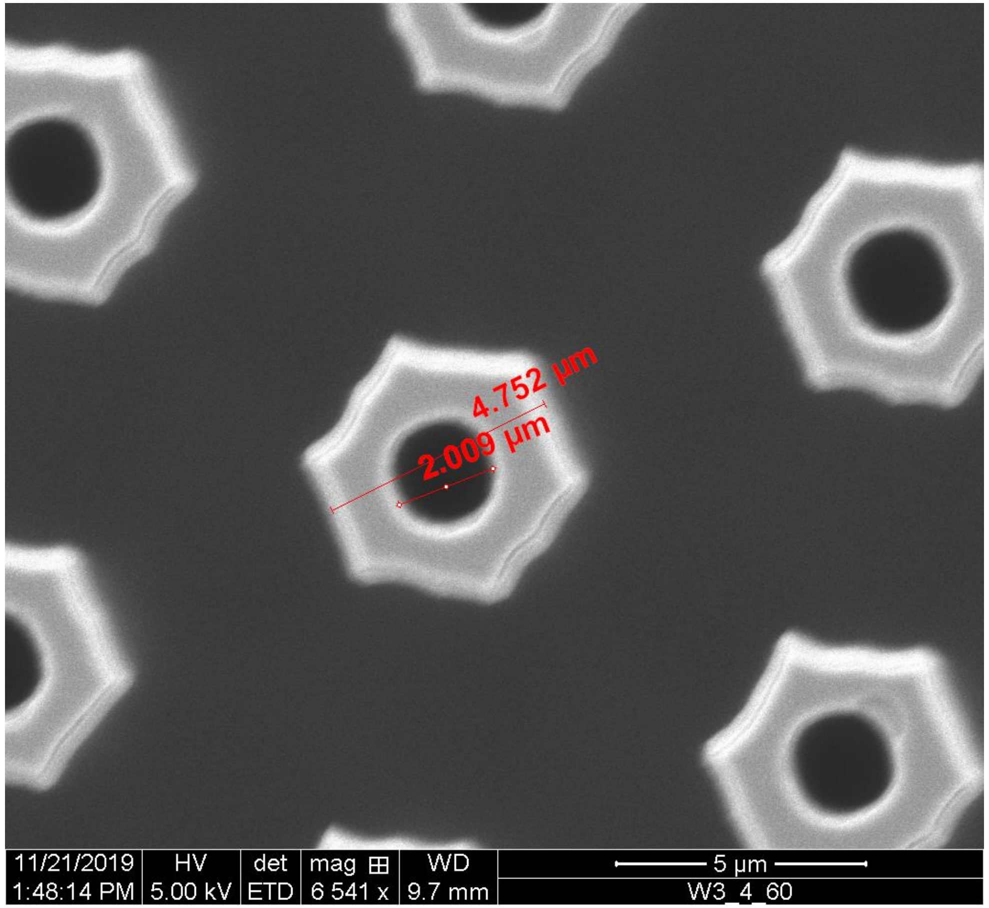


Fig. 19 Top view of Si Micropillars

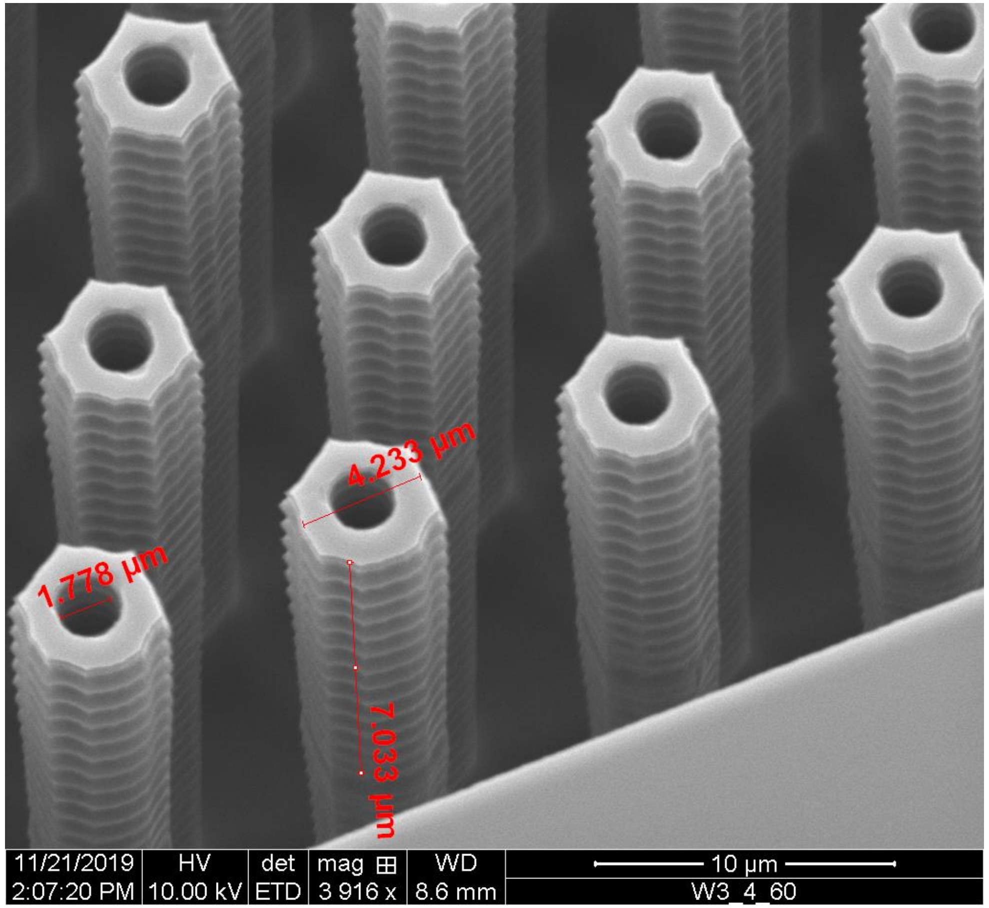


Fig. 20 Top view of Si Micropillars at 32° tilt

Si Pillars with SiO_2

Run time: 40 min

Temperature: 1000 C

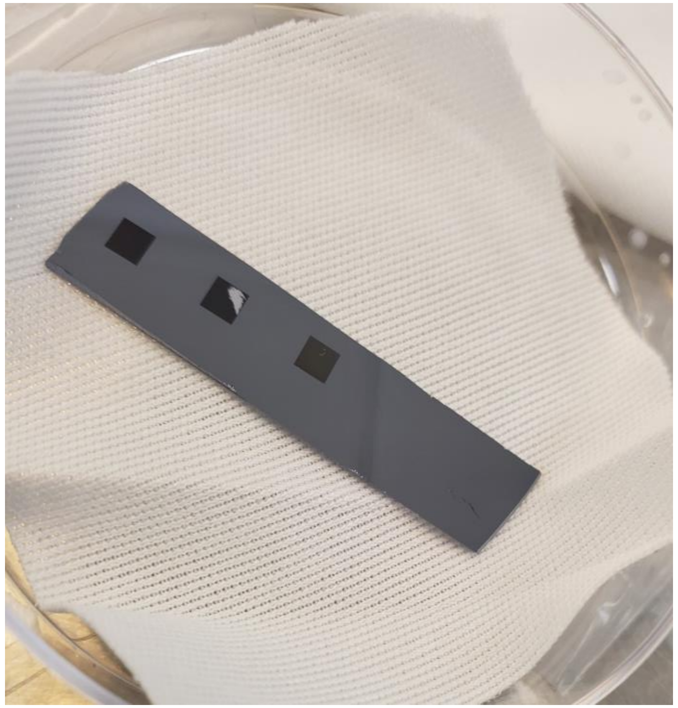
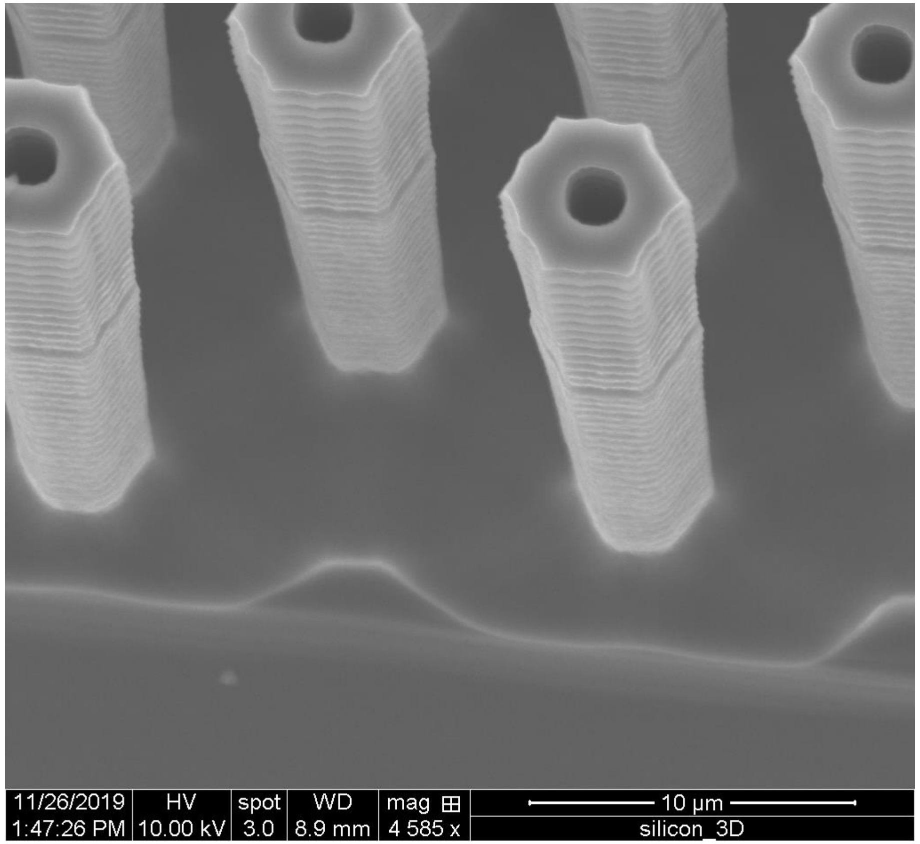


Fig.21.Micropillar sample



28° angle

Fig. 22. Si Micropillar with SiO_2

Si Nanowires

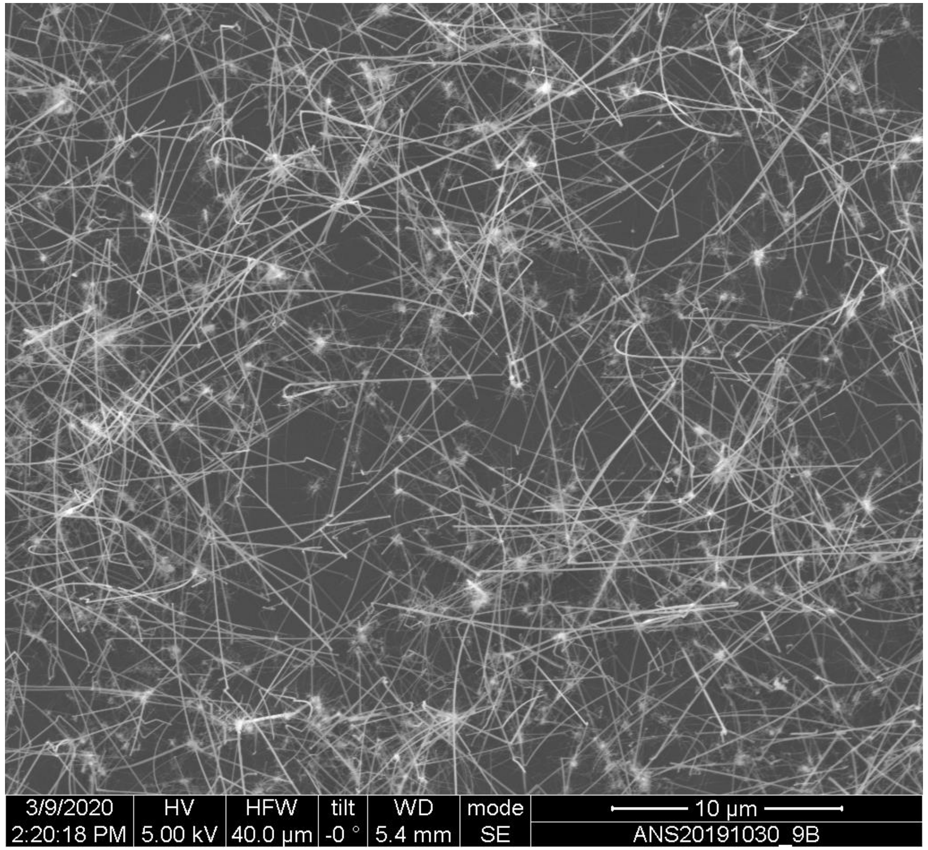


Fig. 23 SEM image of Si Nanowires

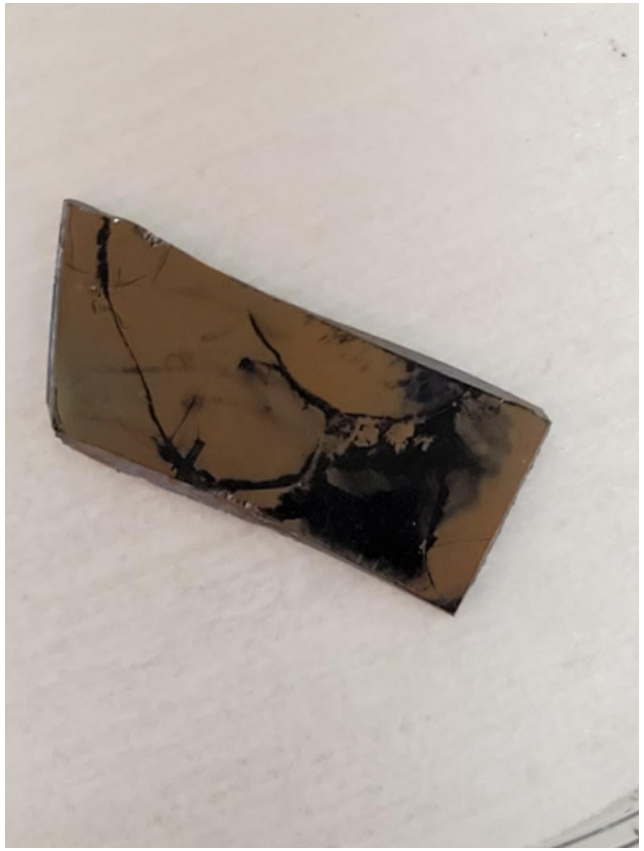


Fig. 24. Si Nanowires sample

Conclusion

- Fabrication: Thermal Oxidation (shape and size)
- Characterization:
  - SEM and Nanospec 3000
- Growth Rate of SiO_2 ~ 3.4049 nm/min

- Future Projects
  - Use Photoluminescence to measure optoelectrical properties
  - Optimization of thermal oxidation for Si nanowires or Si micropillars

Resources

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