Growth of Carbon Nanotubes Via Chemical Vapor Deposition

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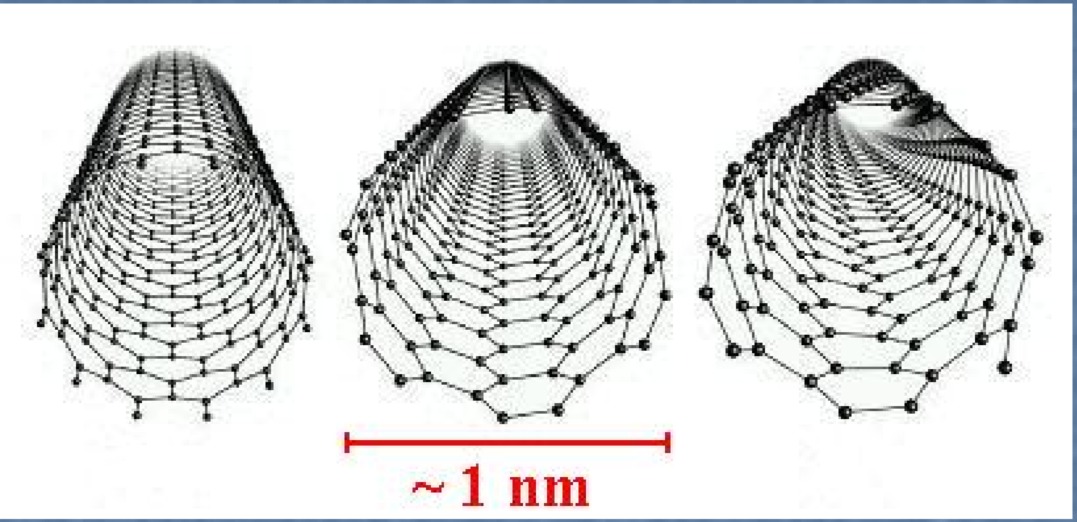
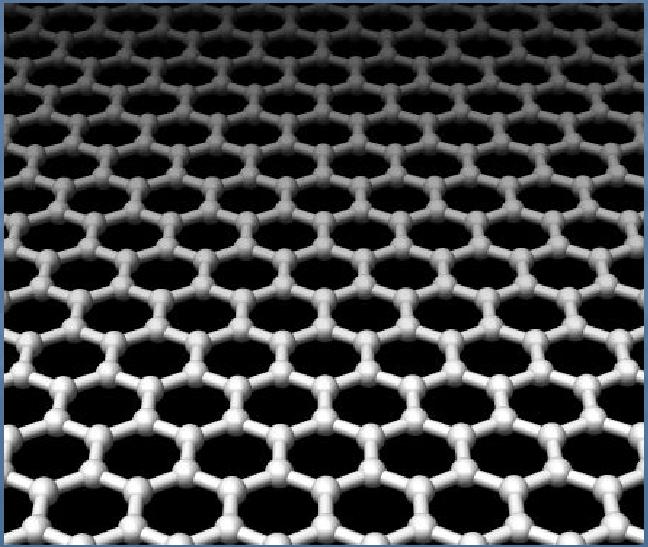
Charlie Johnson Group

Carbon Nanotubes



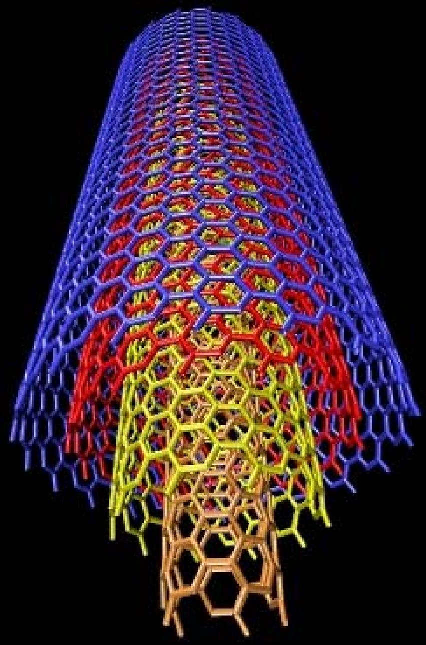
- Pure carbon lattice
- Like rolled up graphene



- Discovered in 1991 by Iijima
- Diameter: nanometers (10^{-9}m)

Carbon Nanotubes

- Highest tensile strength: 63 GPa
- Steel alloys only 2 GPa
- Current density 1,000x as high as copper



- Multiwalled or single-walled
- Metallic or semiconducting

Objectives

Optimize growth of long nanotubes

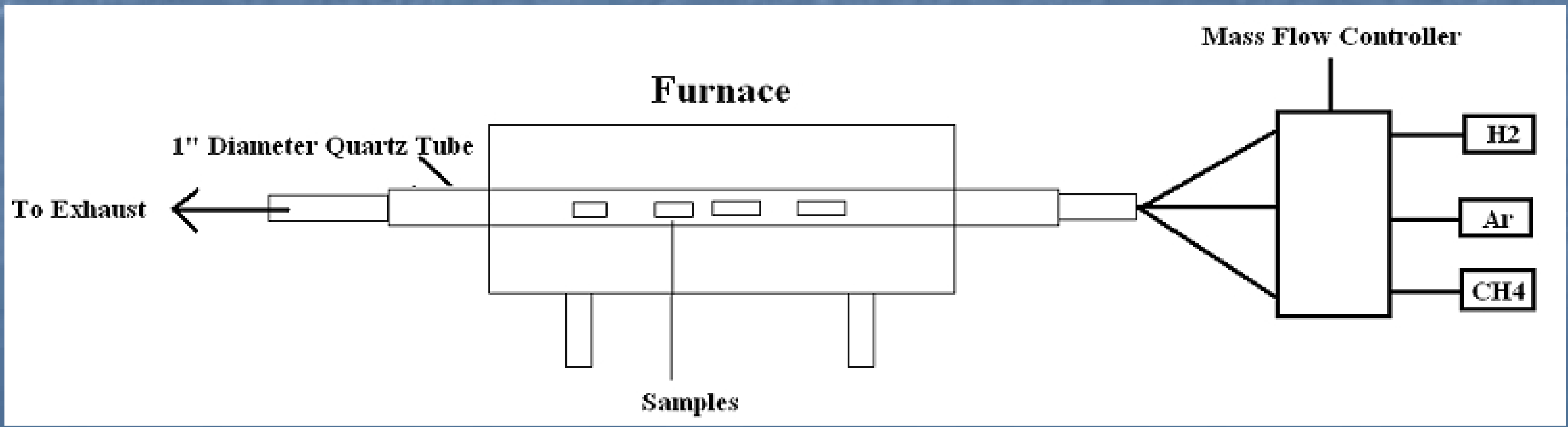
Grow nanotubes as long as possible

As aligned as possible

As dense as possible

Chemical Vapor Deposition (CVD)

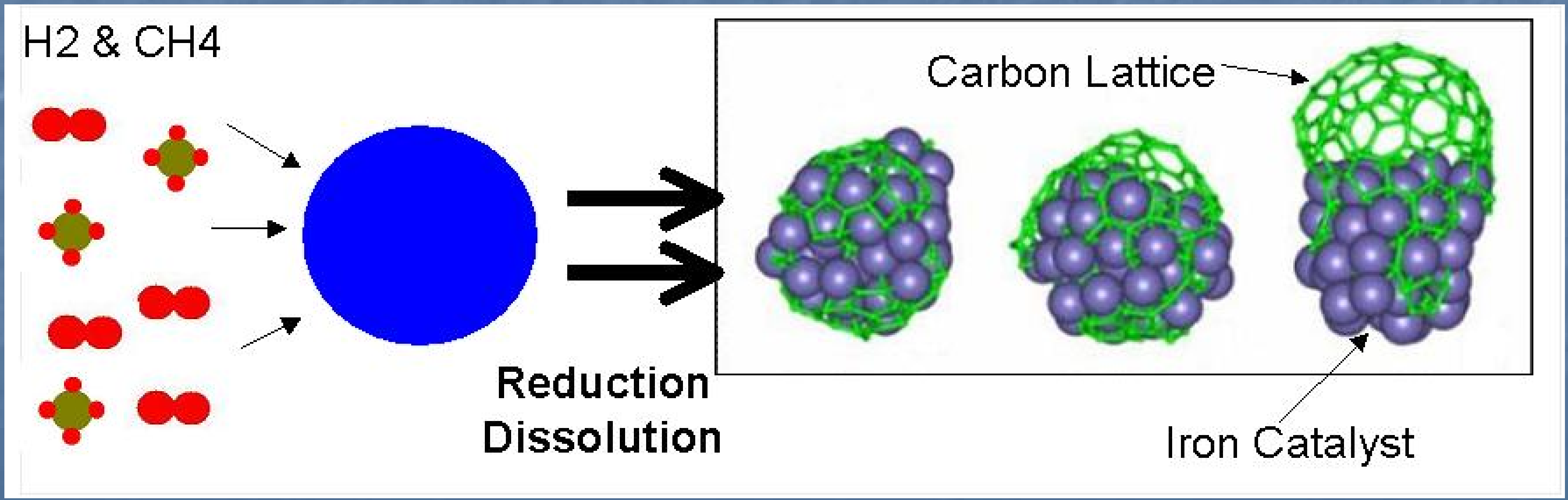
- Probably best potential for nanotube mass production
- We use methane (CH_4) as carbon source



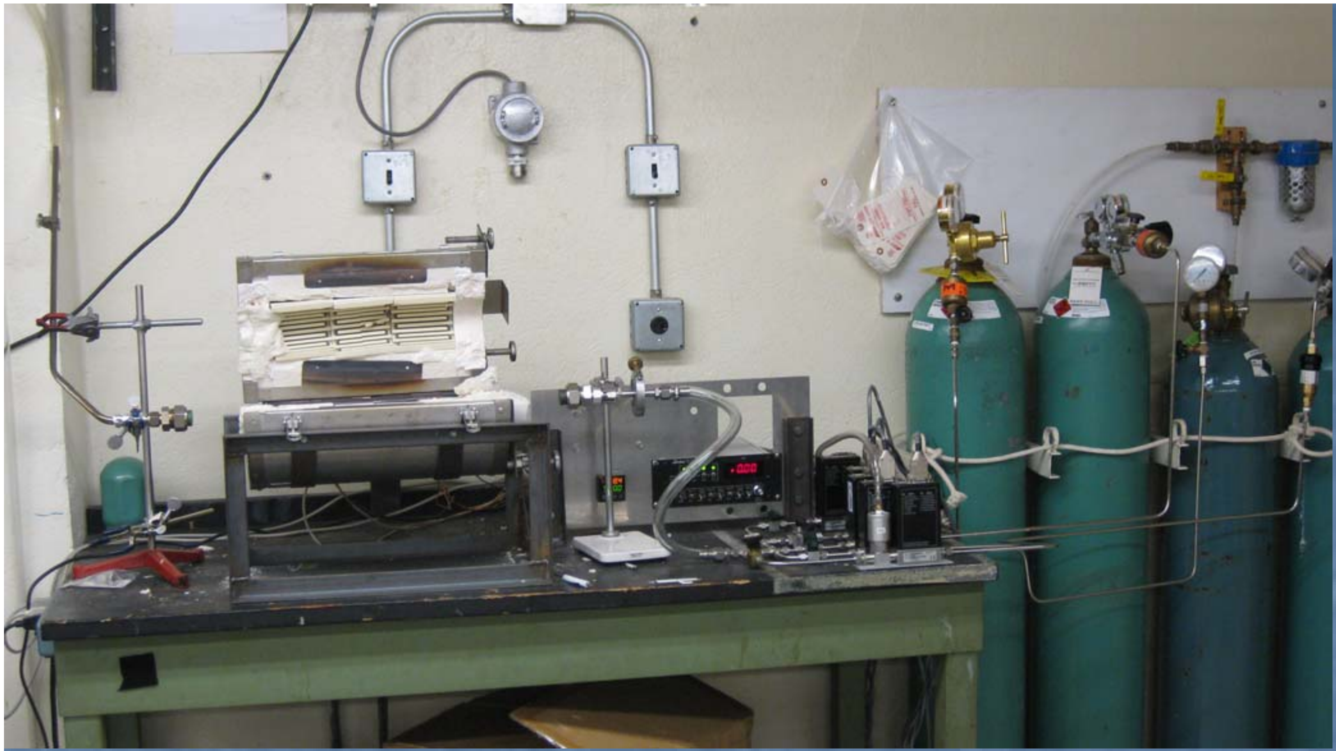
Courtesy of Sam Khamis

Chemical Vapor Deposition (CVD)

- ~900 °C
- Iron Nitrate → iron



Courtesy of Dan Singer



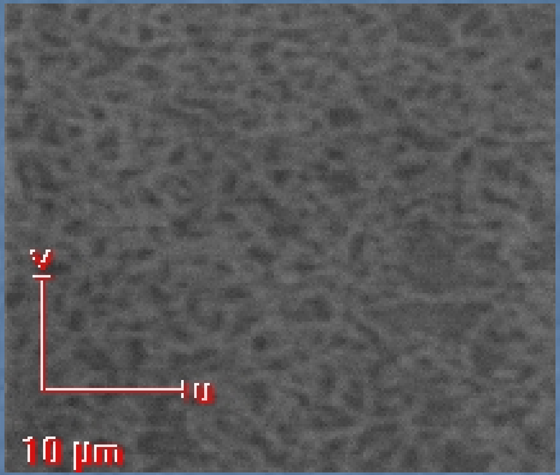
CVD furnace

Scanning electron microscope (SEM)

Two growth methods

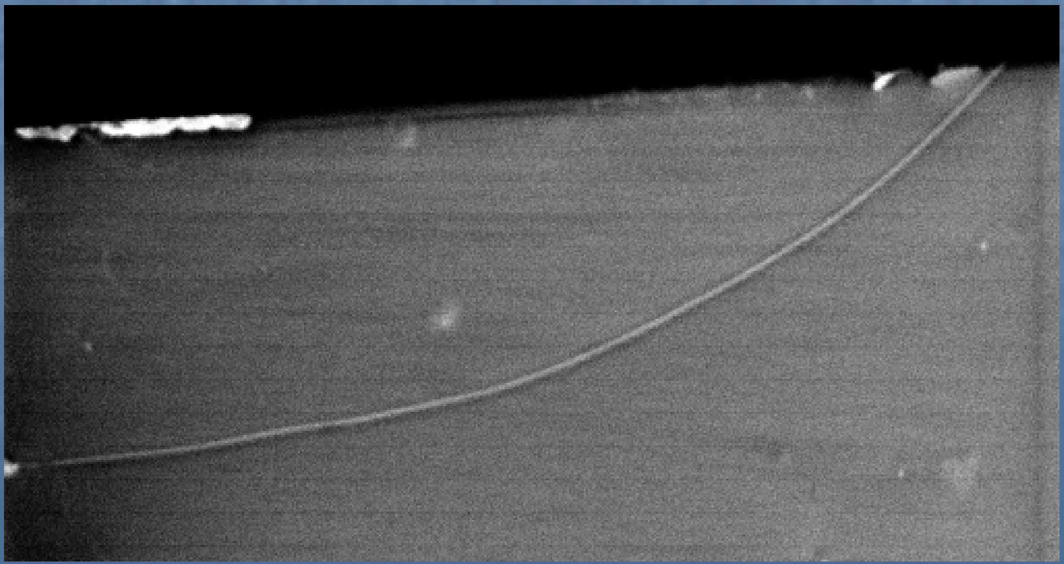
1. Short, dense nanotubes

- "standard" method

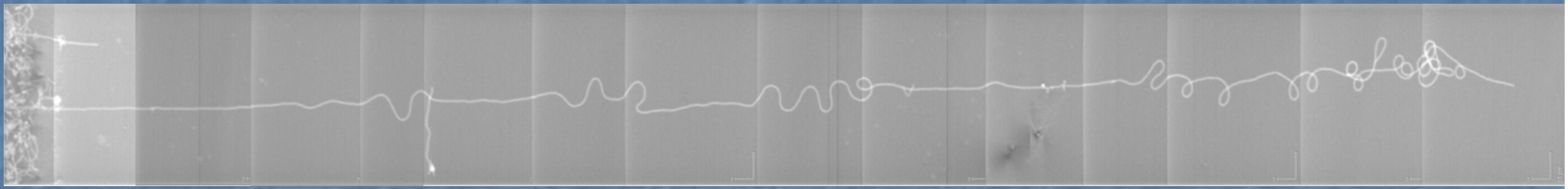


2. <u>Long nanotubes</u>:

- Ultra-low gas flow
- Higher temp
- Longer time



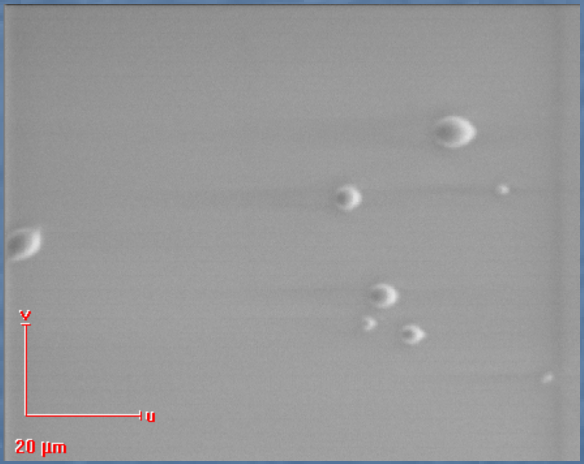
Long Nanotubes on Silicon Wafer Chips

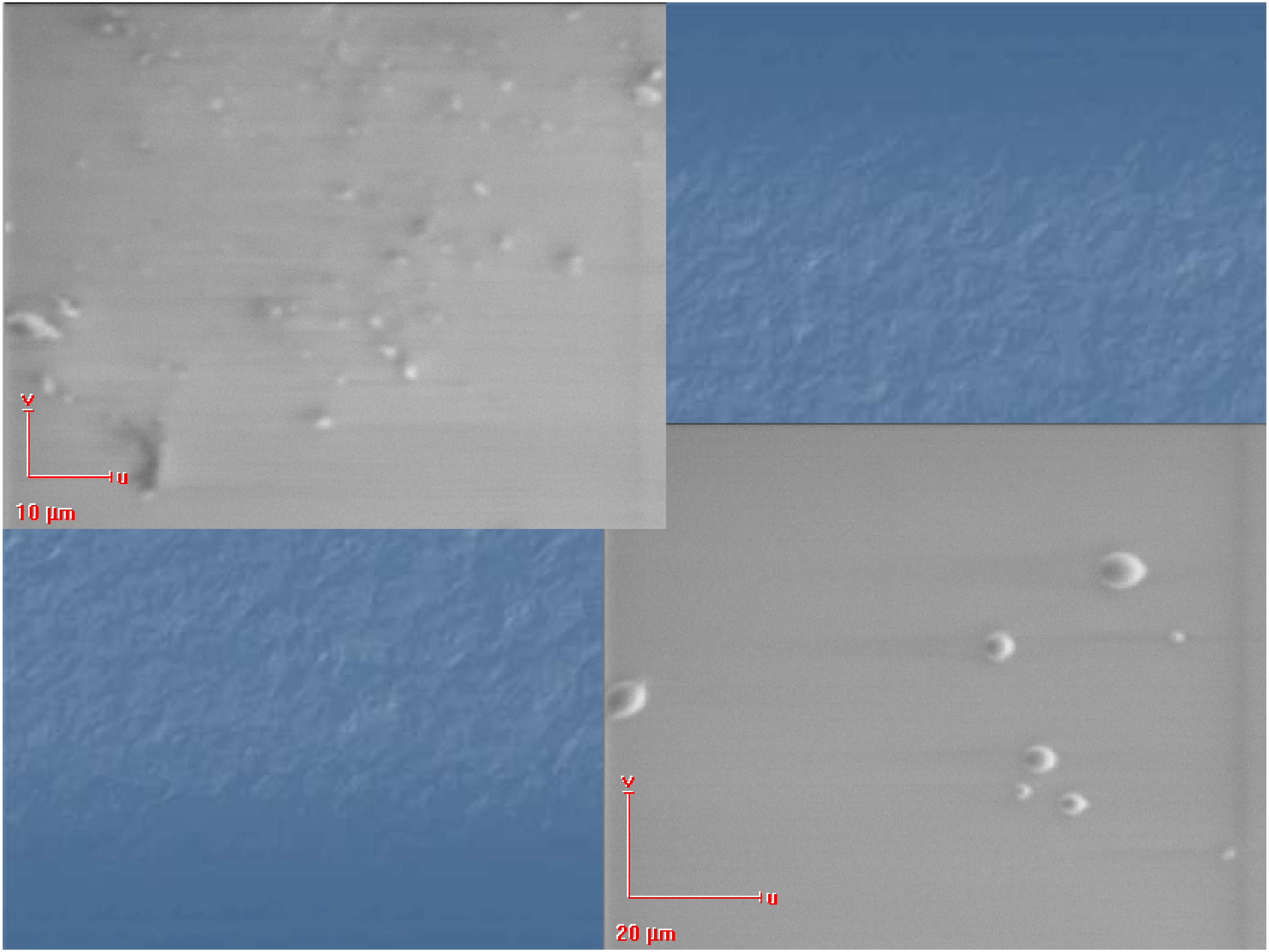


~ 800 microns

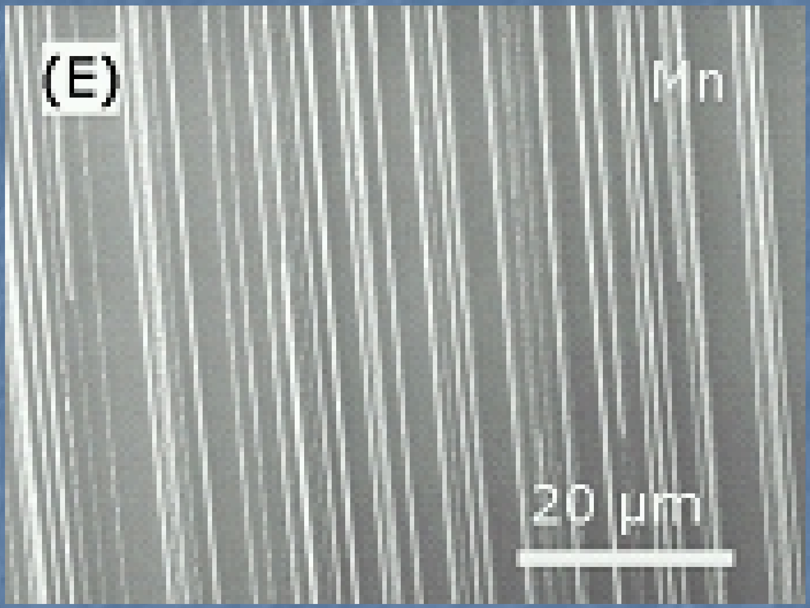
Long Nanotubes on Silicon Wafer Chips

- worked very consistently at first
- failed consistently since early July




v
u
10 µm
v
u
20 µm

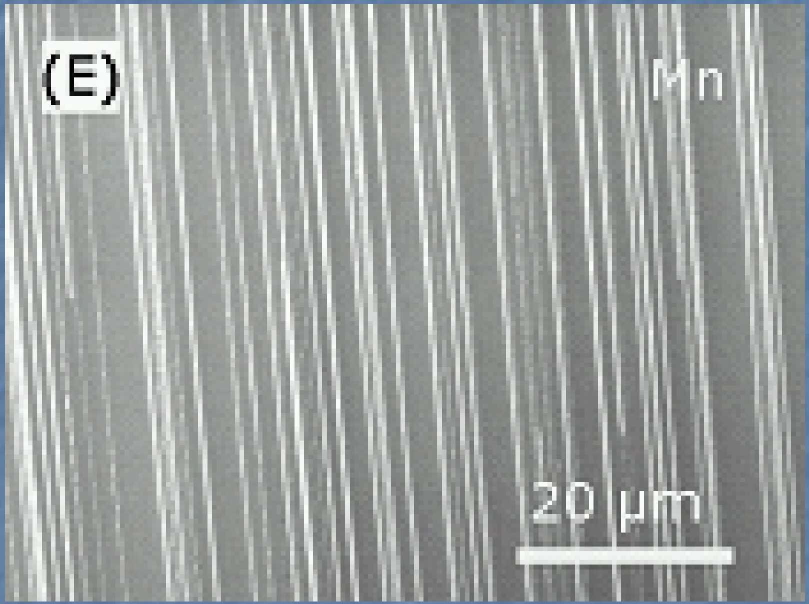
Part 2: Quartz as a Substrate



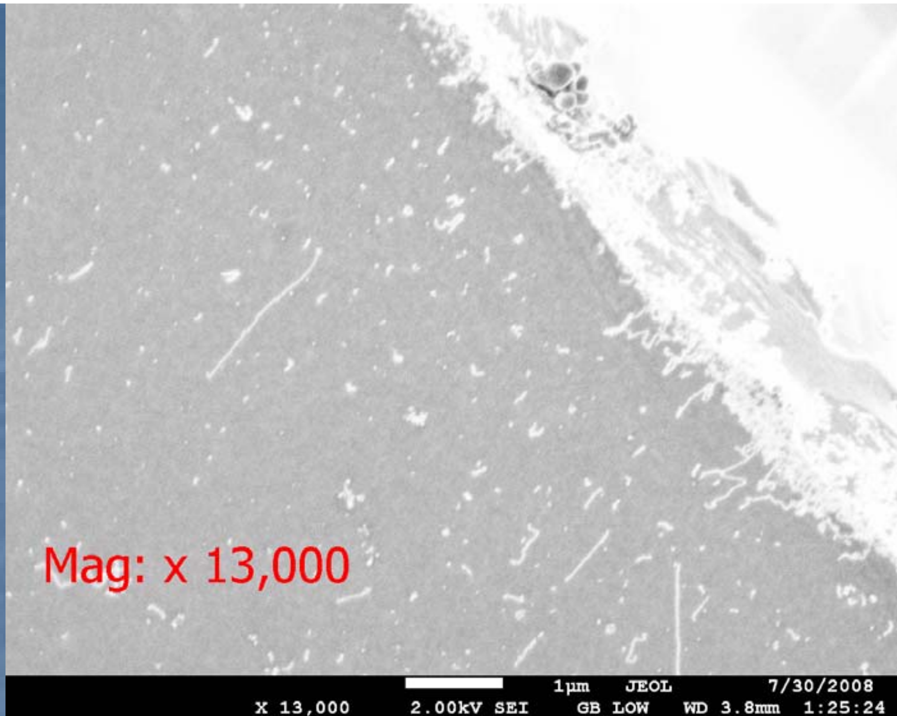
- Extremely good alignment of nanotubes reported on quartz*
- We wanted to try also

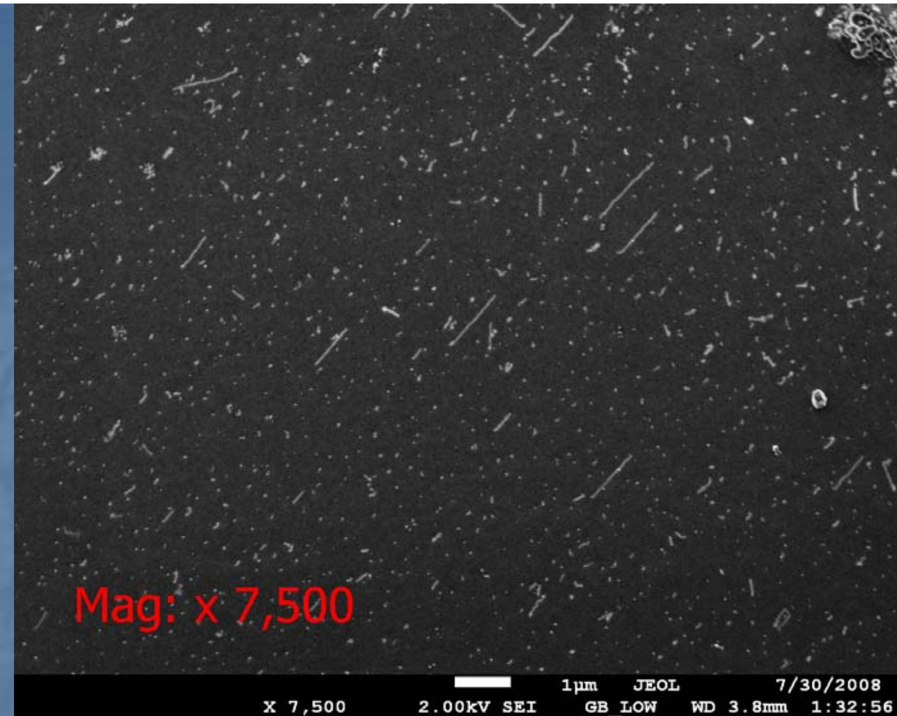
*Source: *Nano Letters,* Dongning Yuan, 2008

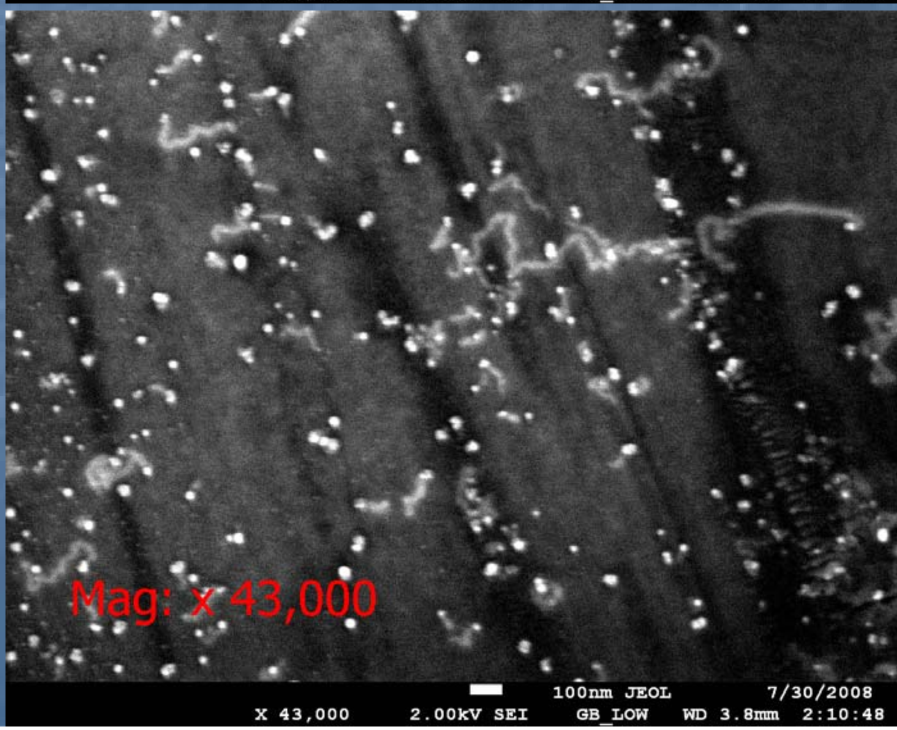
Quartz as a Substrate
Results



- Did observe nanotubes using the “standard” growth method
- However, little alignment, much less than in the images from the paper


Mag: x 13,000
1µm JEOL 7/30/2008
X 13,000 2.00kV SEI GB_LOW WD 3.8mm 1:25:24


Mag: x 7,500
1µm JEOL 7/30/2008
X 7,500 2.00kV SEI GB_LOW WD 3.8mm 1:32:56


Mag: x 43,000
100nm JEOL 7/30/2008
X 43,000 2.00kV SEI GB_LOW WD 3.8mm 2:10:48

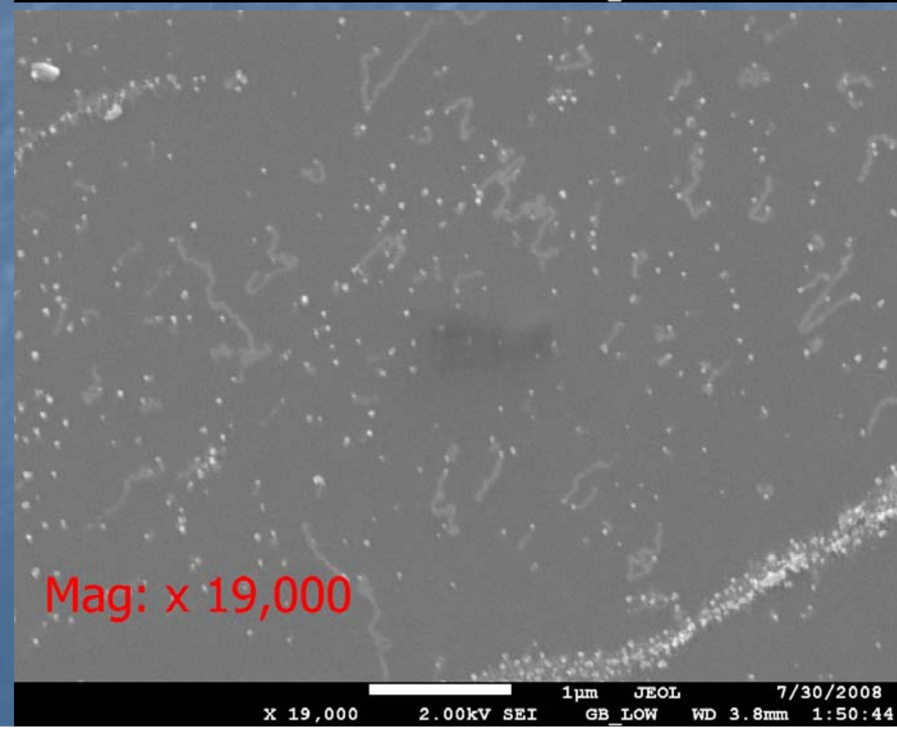
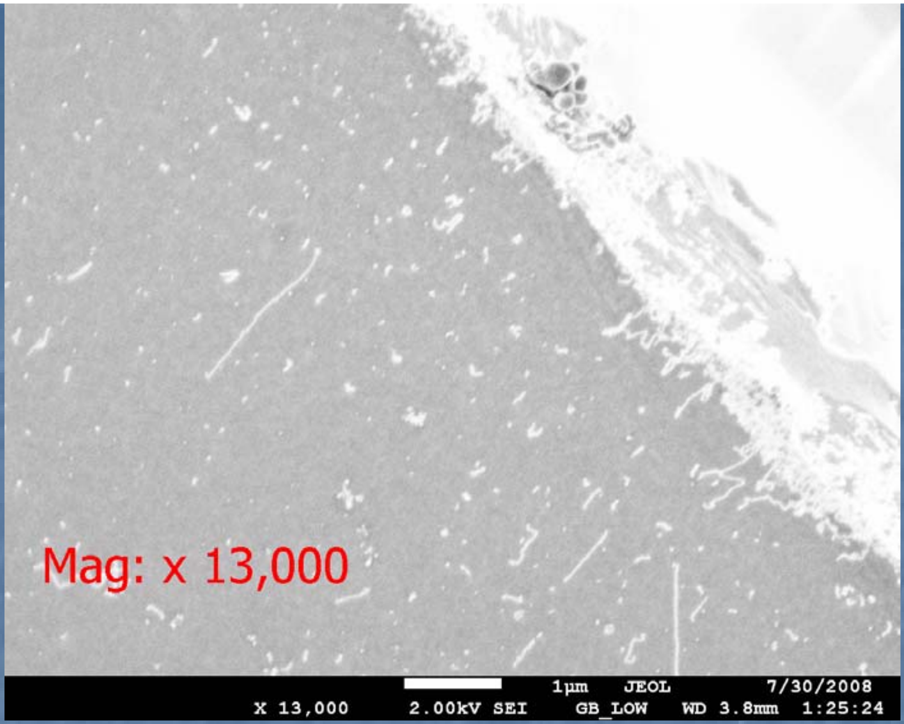

Mag: x 19,000
1µm JEOL 7/30/2008
X 19,000 2.00kV SEI GB_LOW WD 3.8mm 1:50:44

Image Analysis

- Interested in investigating a possible relationship between catalyst particle size and nanotube growth
- Used ImageJ for digital image analysis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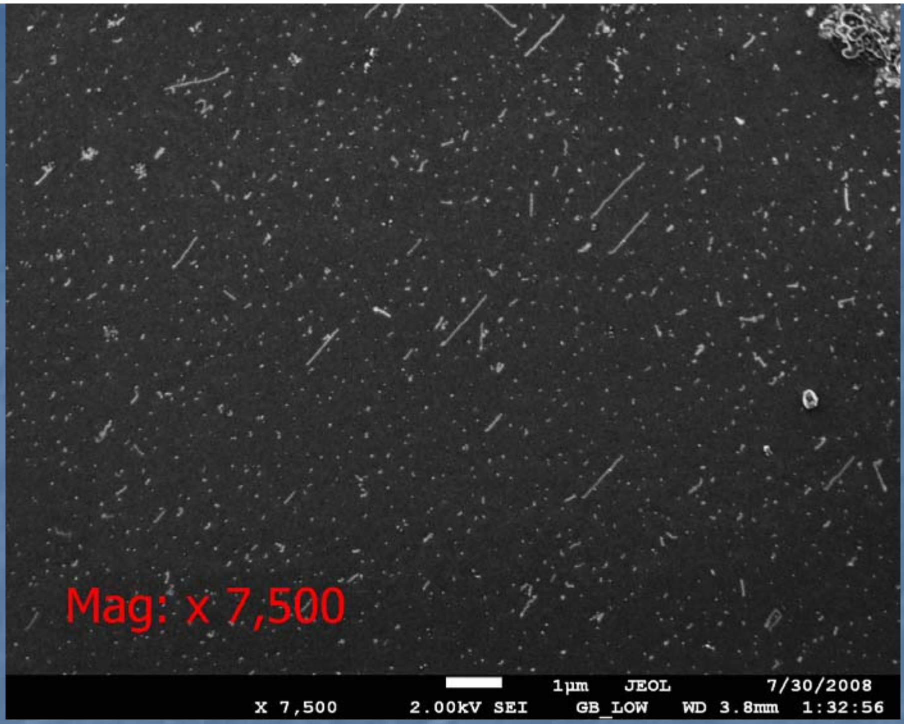
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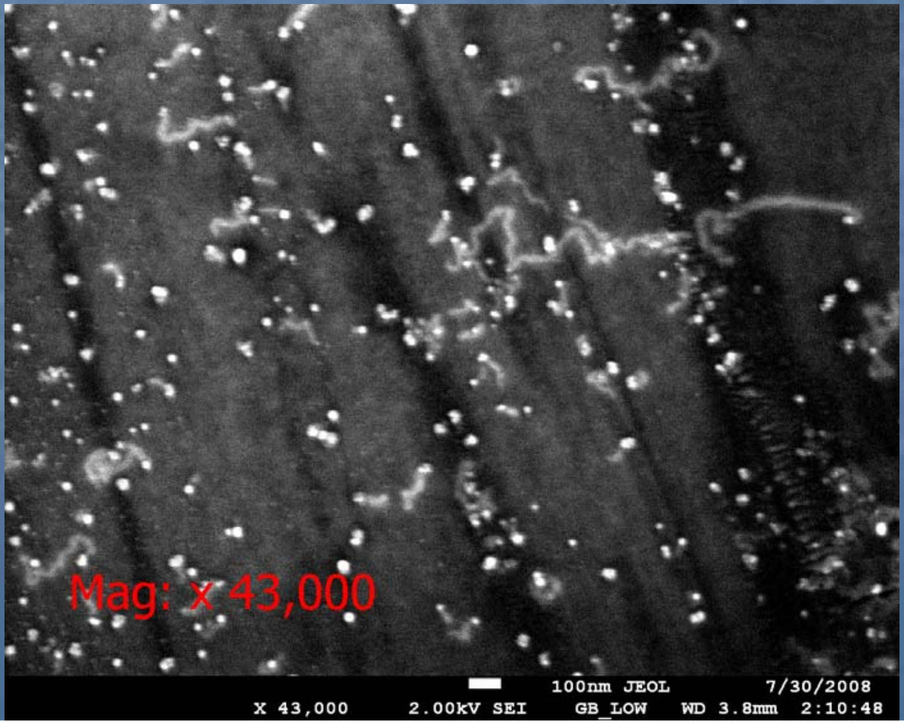
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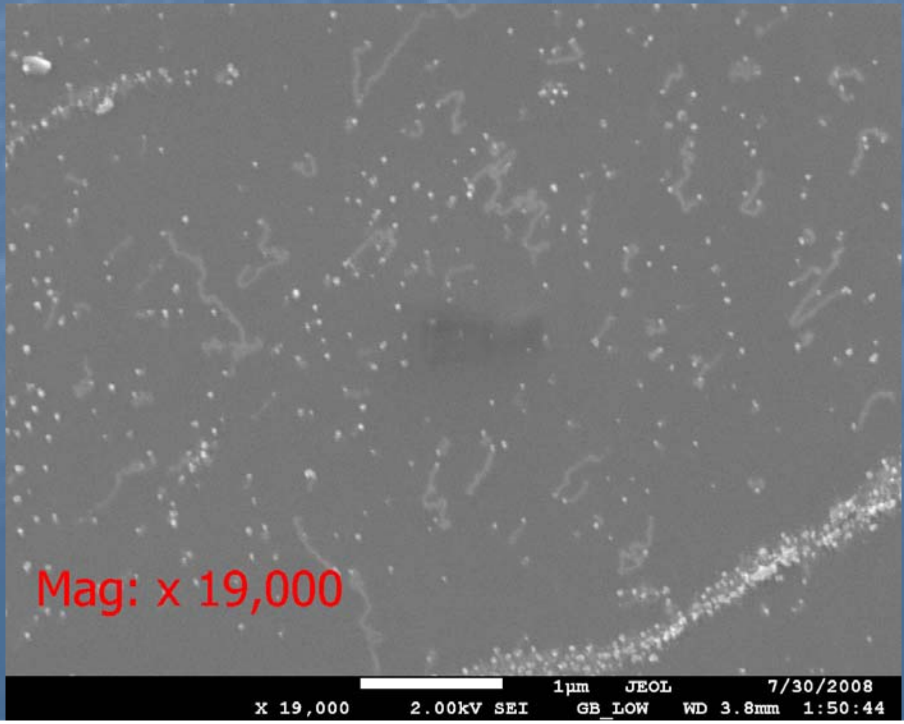
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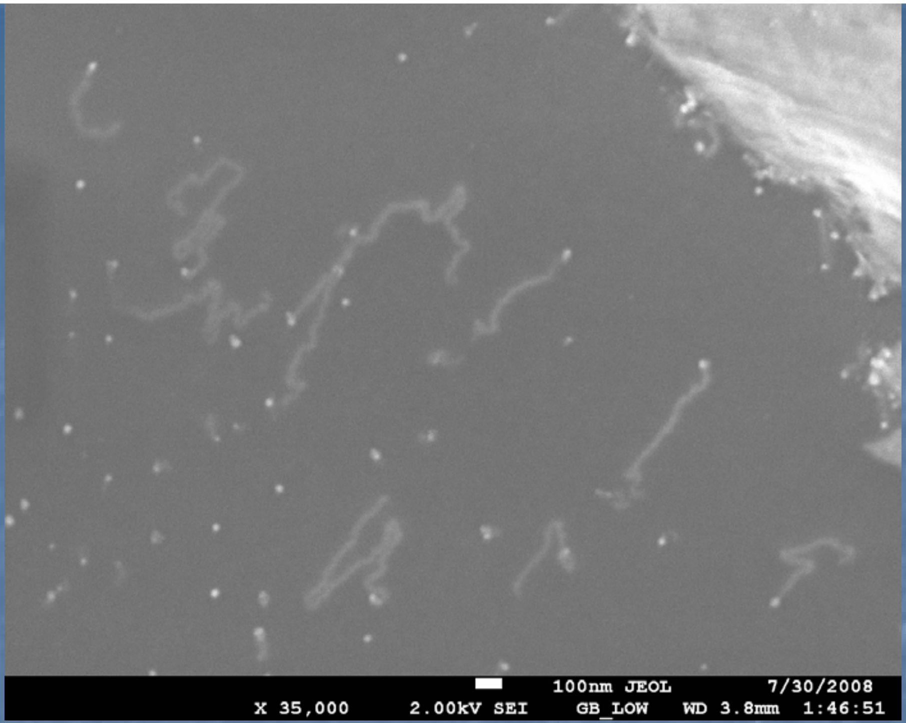
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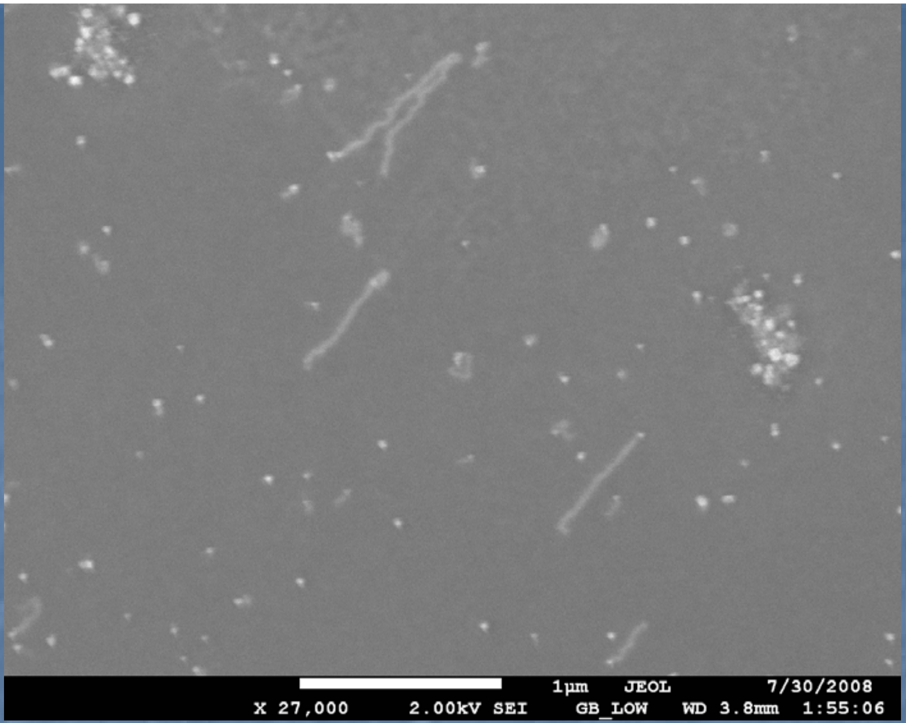
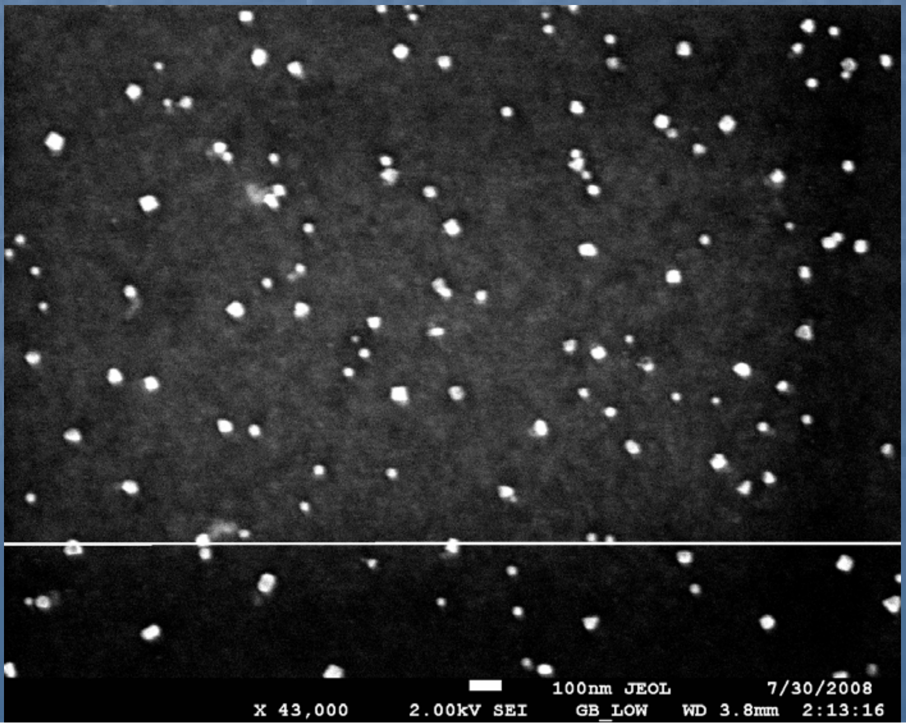
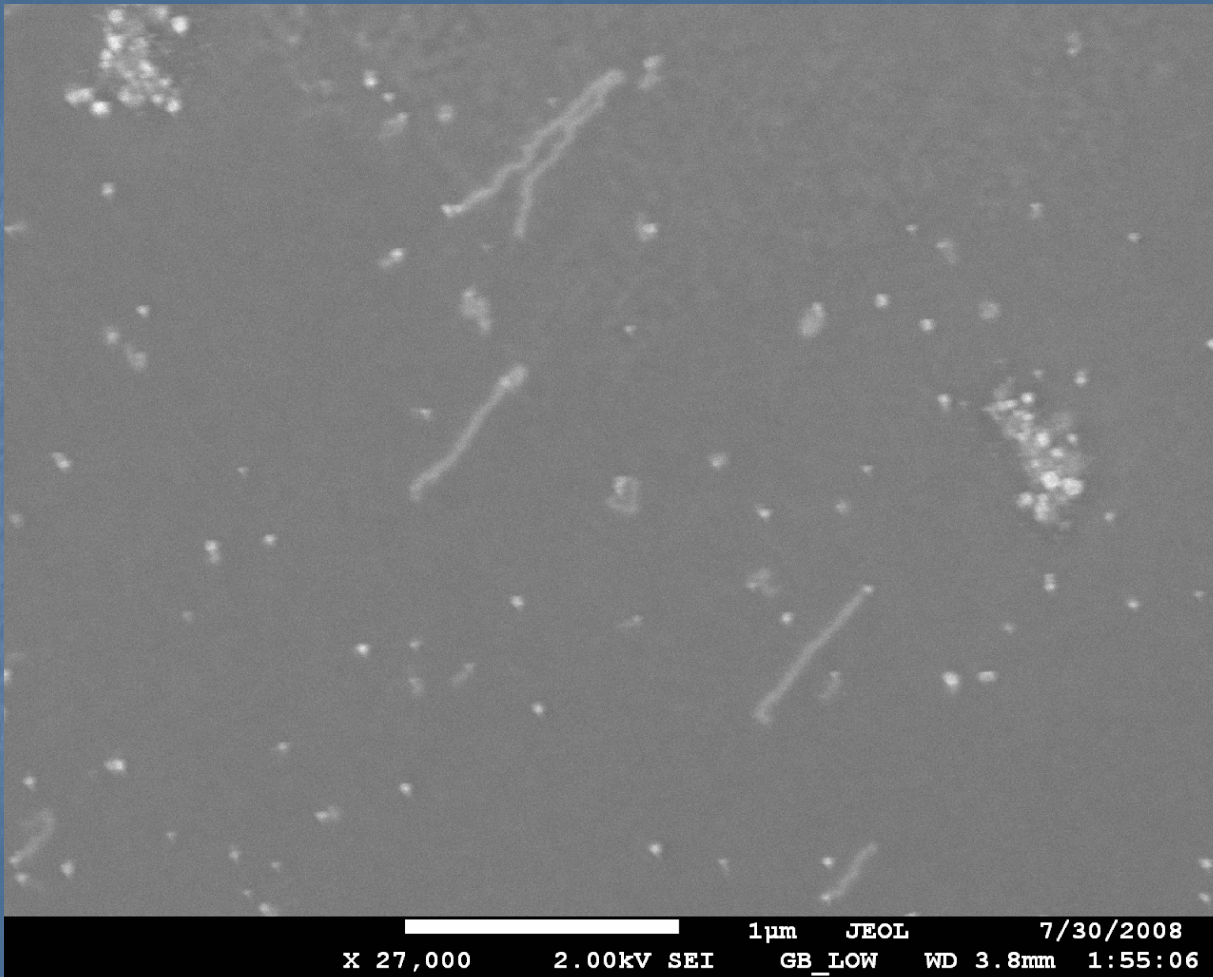

1μm JEOL 7/30/2008
X 27,000 2.00kV SEI GB_LOW WD 3.8mm 1:55:06


100nm JEOL 7/30/2008
X 43,000 2.00kV SEI GB_LOW WD 3.8mm 2:13:16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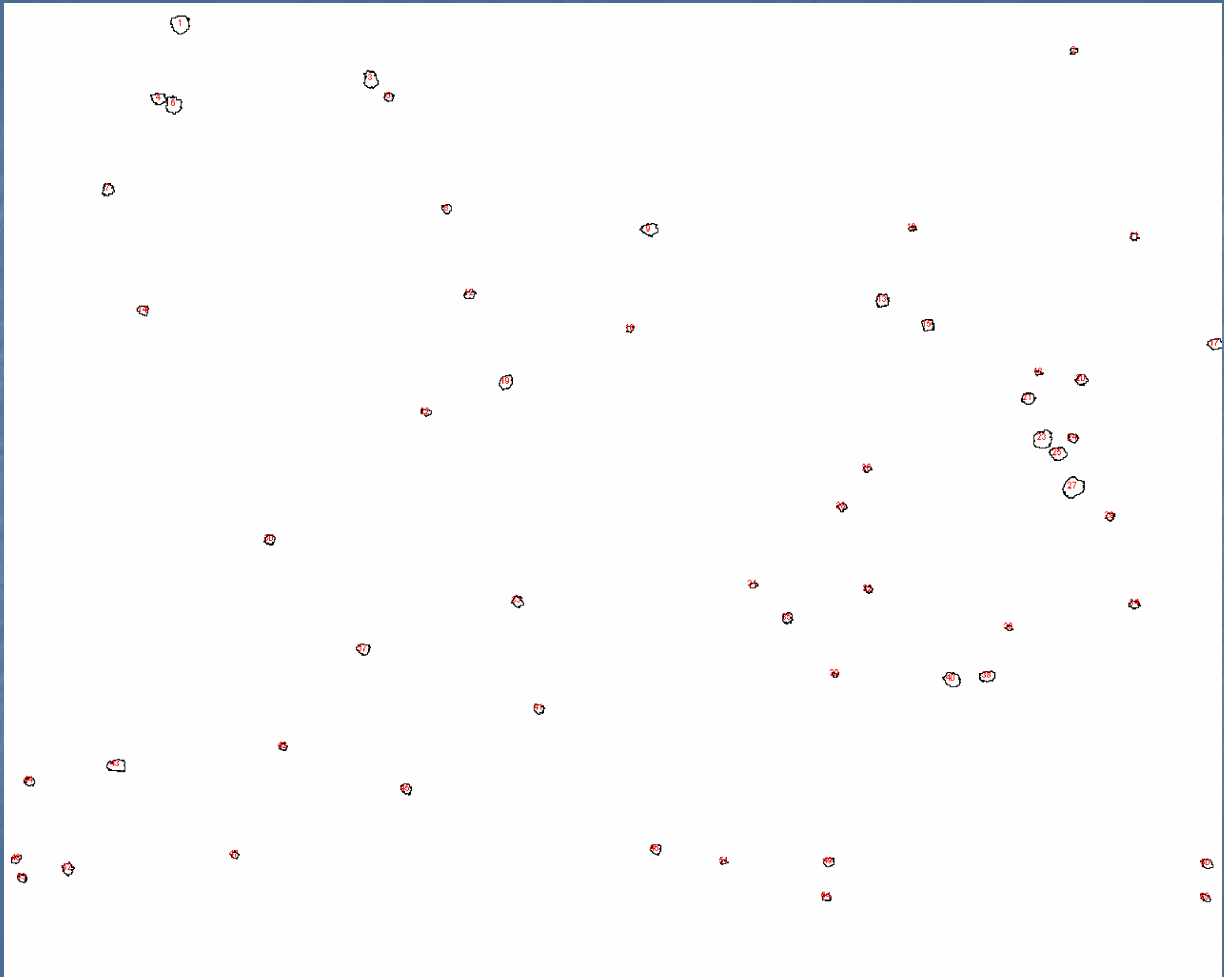
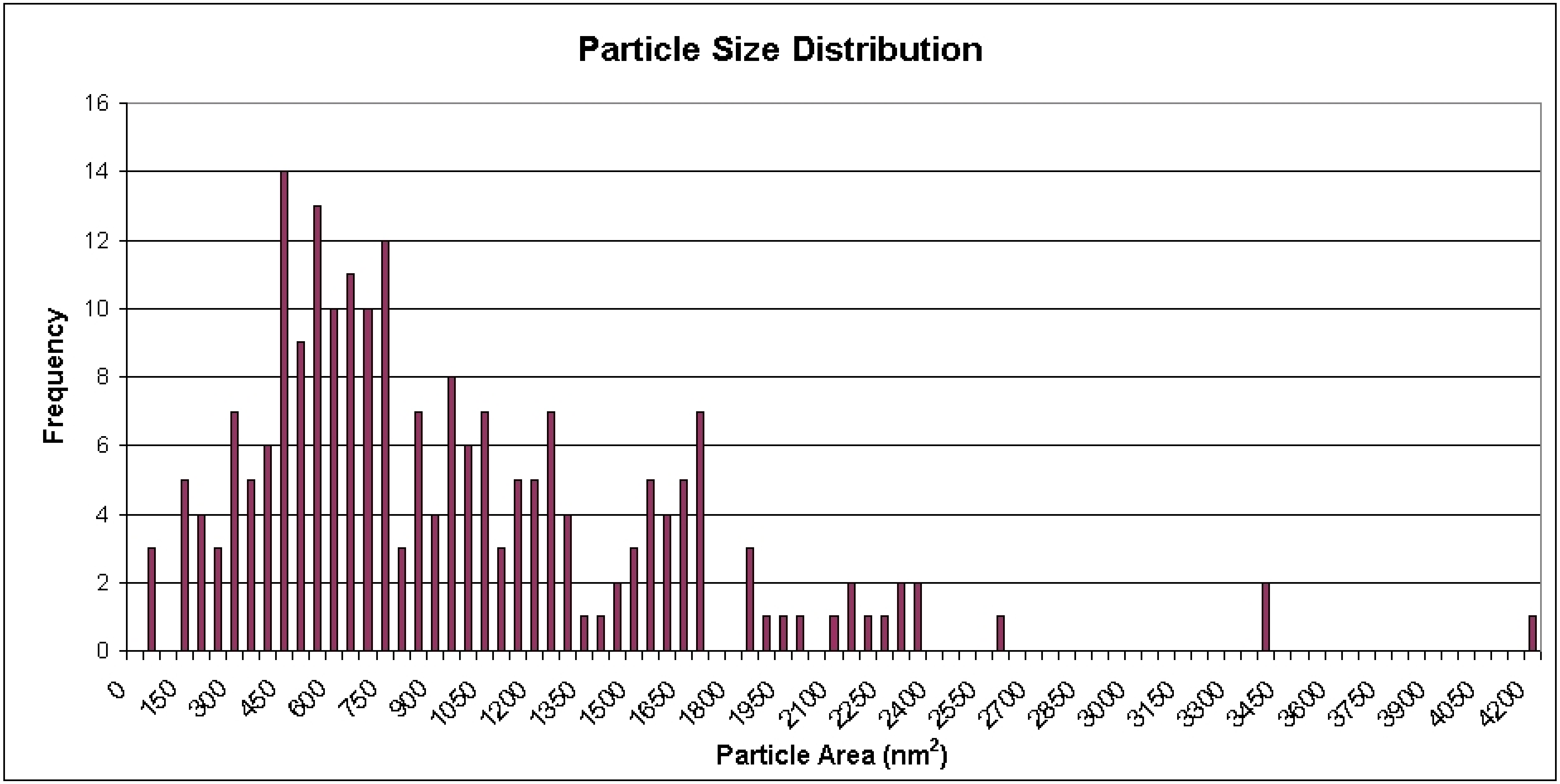
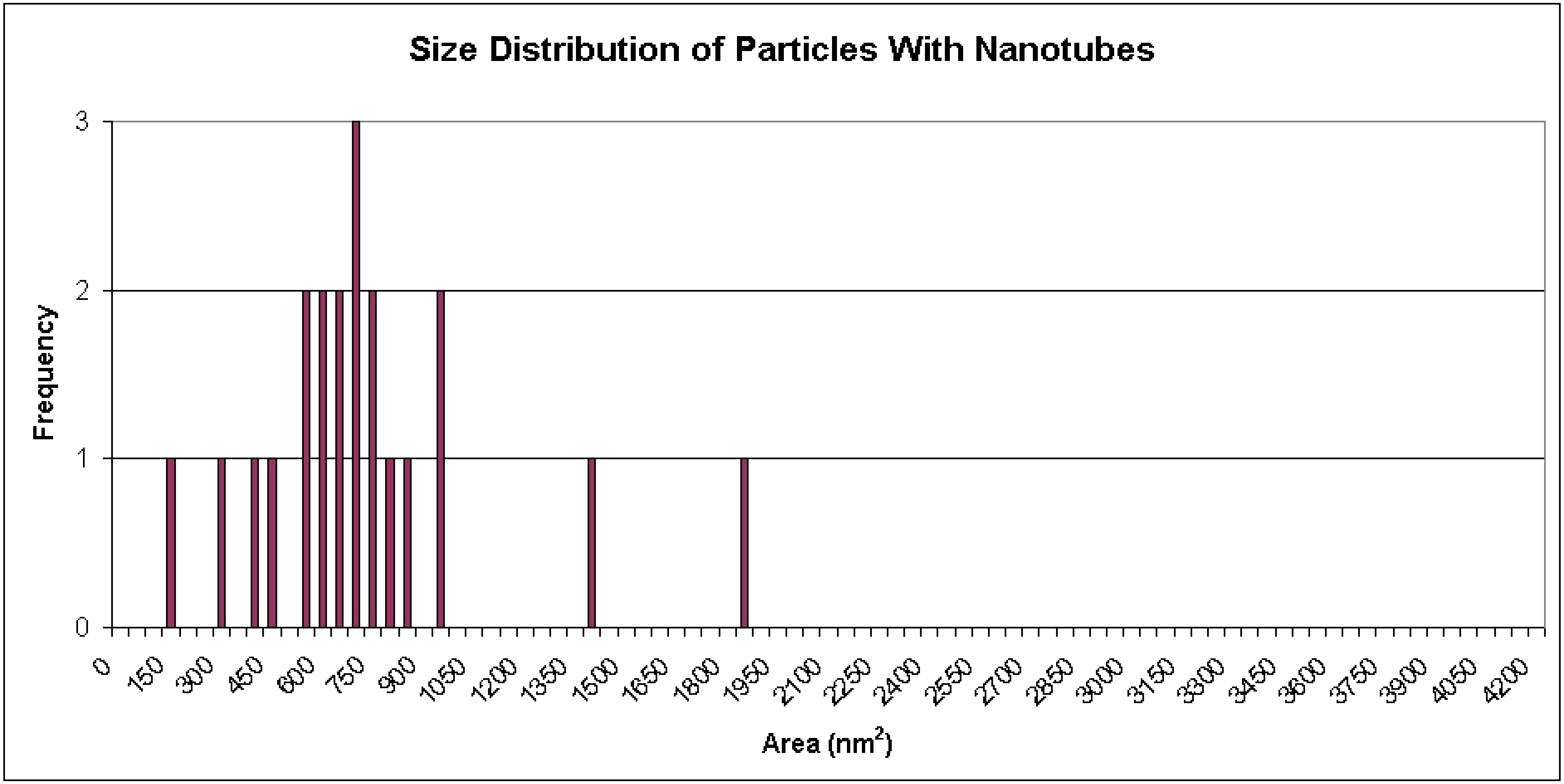
X 27,000 2.00kV SEI GB_LOW WD 3.8mm 1:55:06





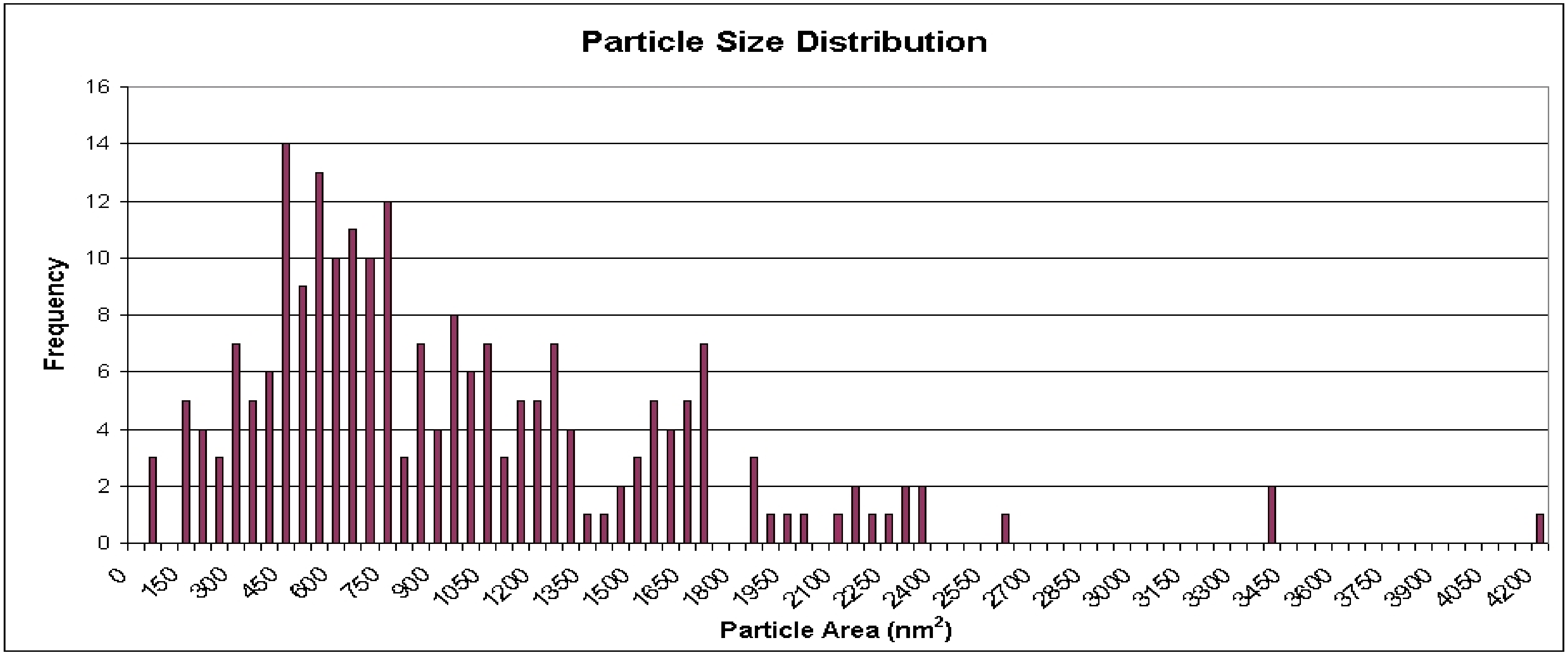
Mean: 927 nm^2

Standard Deviation: 629



Mean: 705 nm^2

Standard Deviation: 364


Particle Size Distribution
Frequency
Particle Area (nm²)
0
2
4
6
8
10
12
14
16
0
150
300
450
600
750
900
1050
1200
1350
1500
1650
1800
1950
2100
2250
2400
2550
2700
2850
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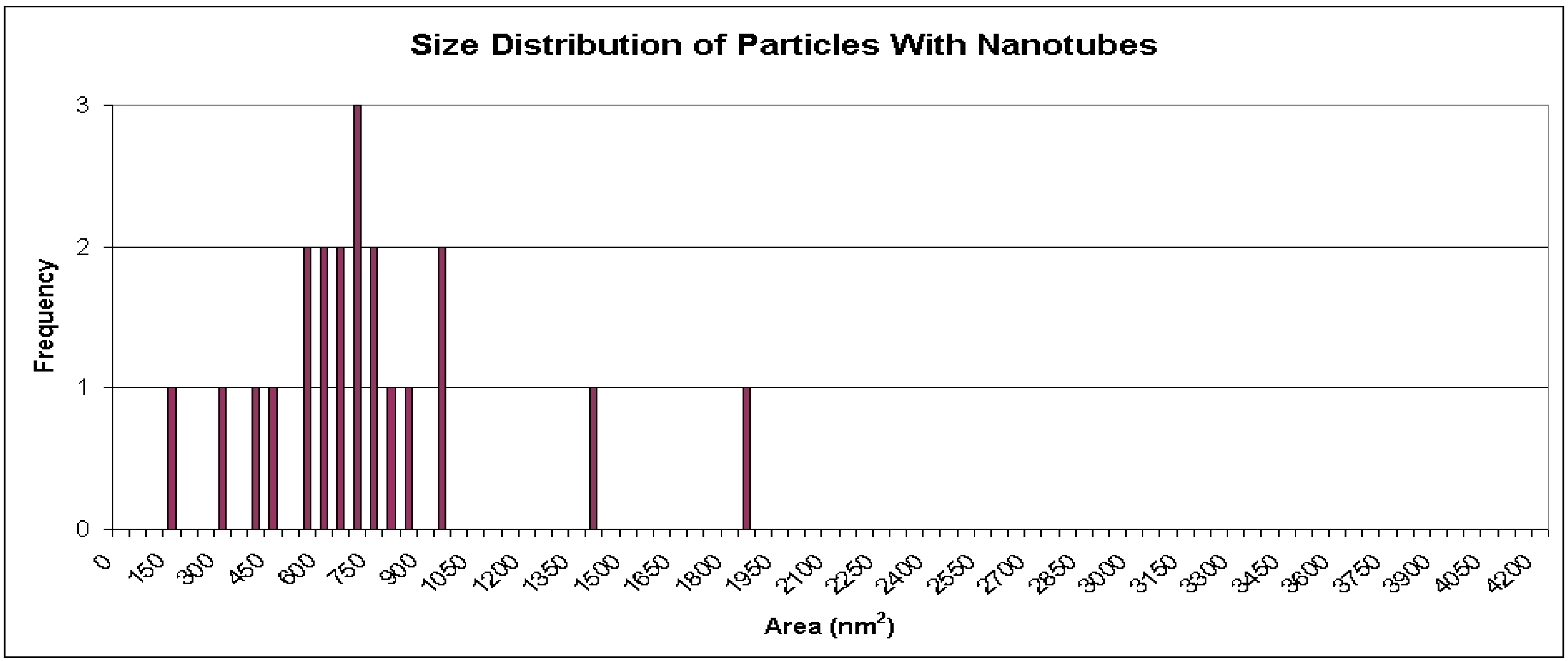
3600
3750
3900
4050
4200


Size Distribution of Particles With Nanotubes
Frequency
Area (nm²)
0
1
2
3
0
150
300
450
600
750
900
1050
1200
1350
1500
1650
1800
1950
2100
2250
2400
2550
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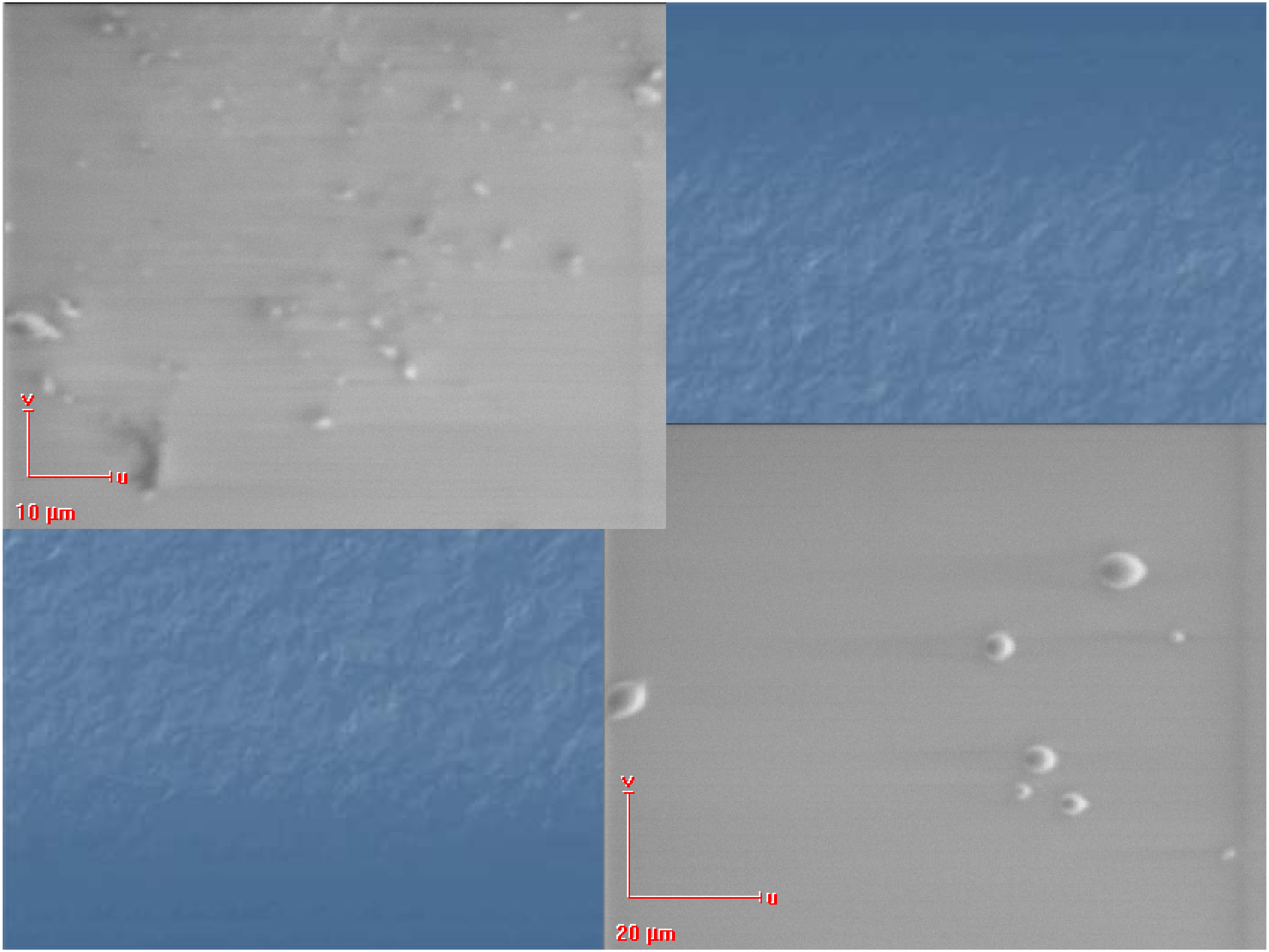
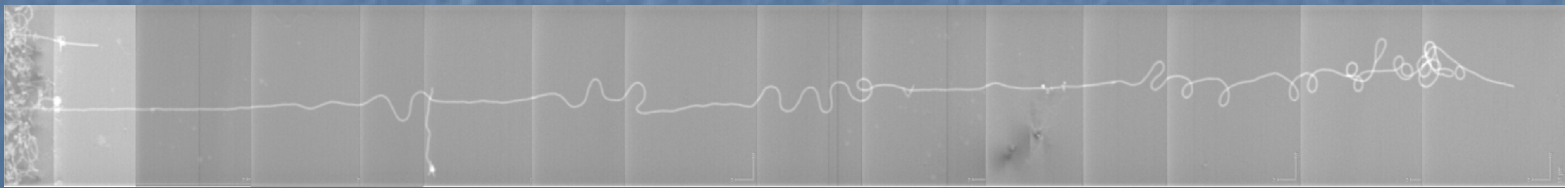
3600
3750
3900
4050
4200


v
u
10 µm
v
u
20 µm

Summary & Implications

- Nanotubes ~1mm achieved
- Growth is inconsistent
- Why? Future investigation?
- No good alignment on quartz. Why?
- Maximize amount of appropriately-sized particles



Acknowledgements

- I thank my mentors Zhengtang Luo, Charlie Johnson, and everyone else in the Johnson group,
- the SUNFEST program and Jan Van der Spiegel,
- and NSF