Lithography and deposition with a sub-nanometer focused helium beam (part III)

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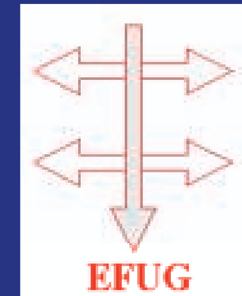


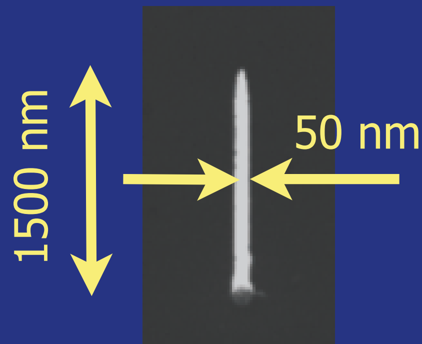
EFUG2009 : Monday 5 October 2009
Arcachon, France

Pt-deposition in spot mode

25 keV He

(spot mode, 2 pA)

(30º tilted view)



* He-IBID is possible
* No detrimental effects on Orion

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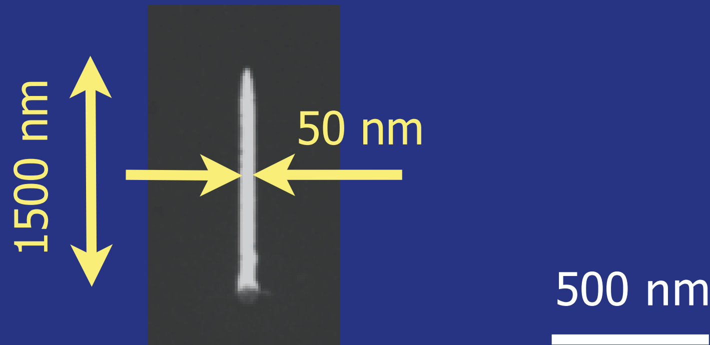
Comparison He - Ga IBID

25 keV He

(spot mode, 2 pA)

(30º tilted view)

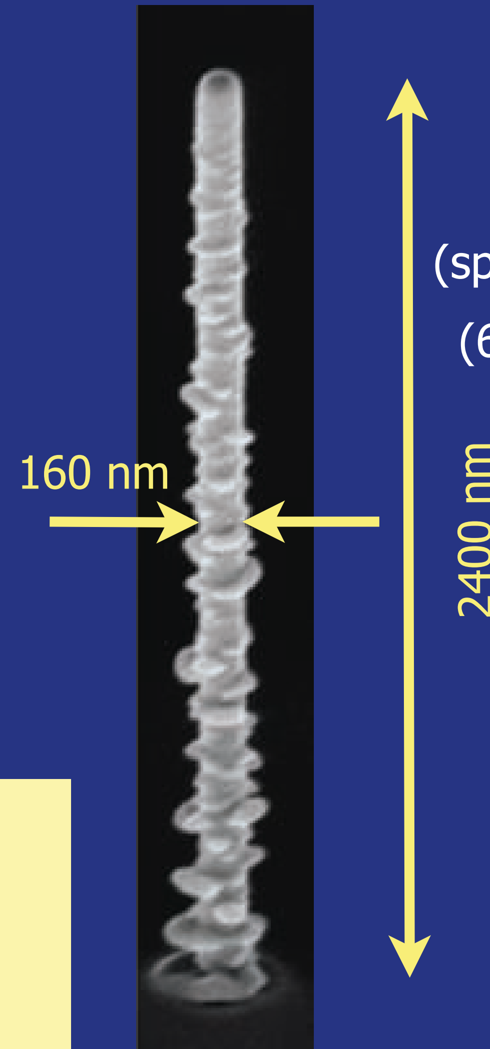


500 nm

30 keV Ga

(spot mode, 1 pA)

(60º tilted view)



He-IBID as compared to Ga-IBID:

* similar growth rate (in nm^3/s)
* narrower pillar
* smooth side wall

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2.a Horizontal & vertical growth rates

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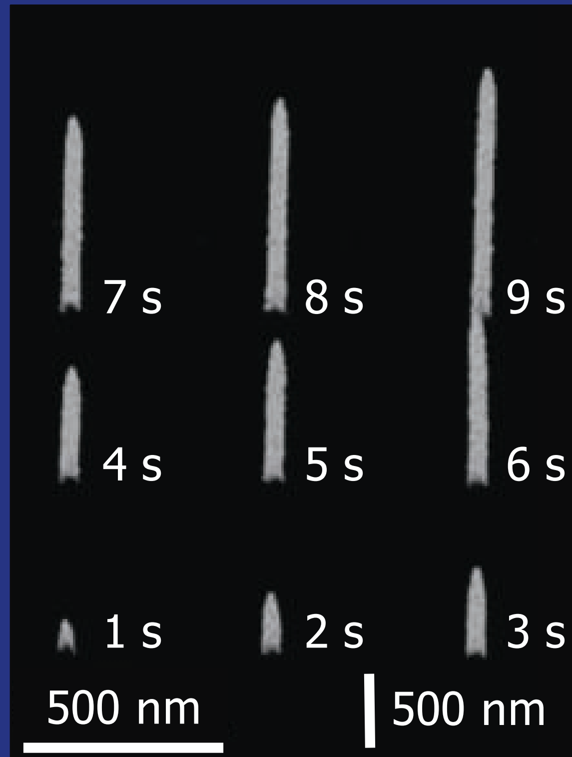
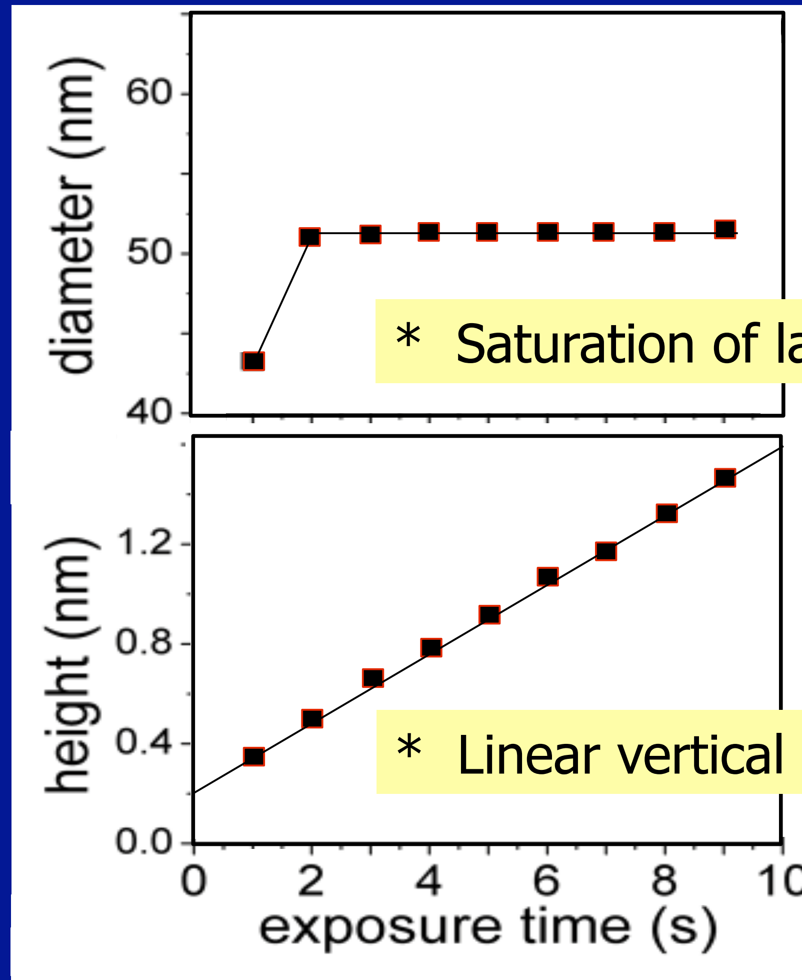
Pillar height & diameter vs. time



Pillar height & diameter vs. time



* Saturation of lateral growth

* Linear vertical growth with time

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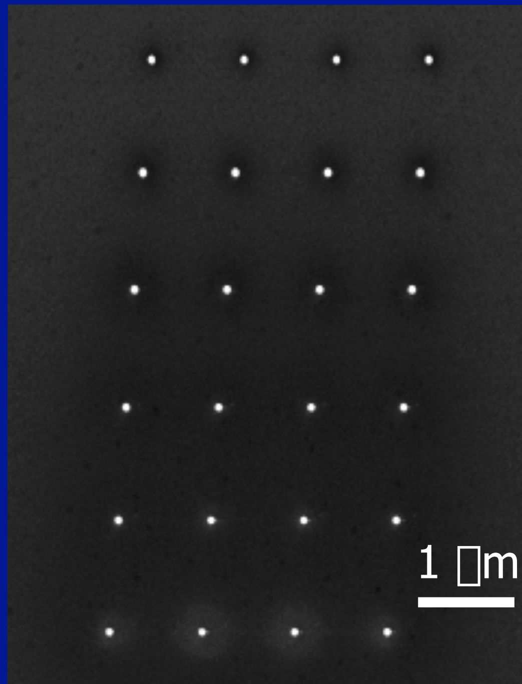
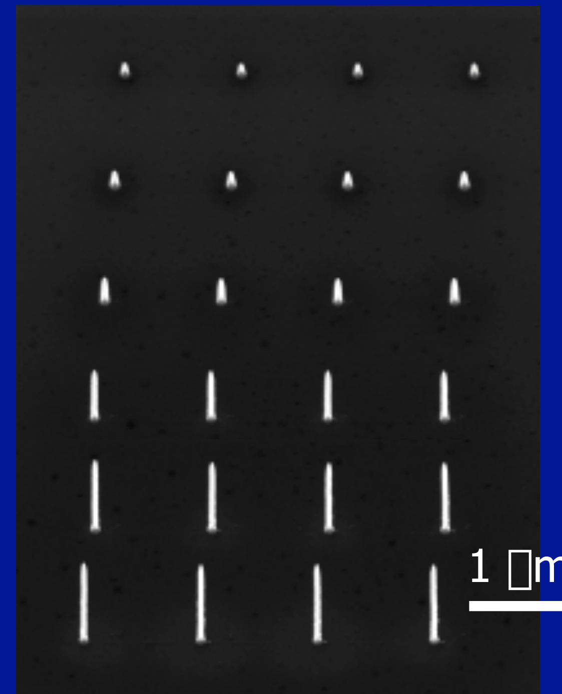
Variable current

* constant time
* constant Pt-supply

top view



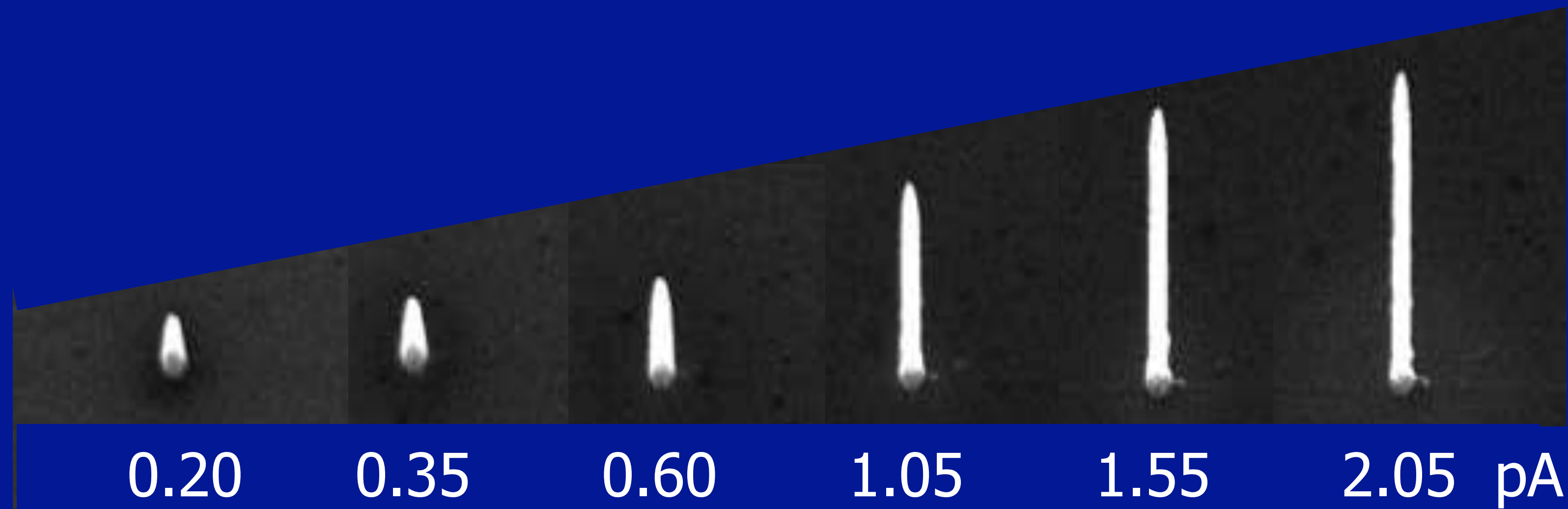
increasing curren



30º tilted view

Variable current

* constant time
* constant Pt-supply



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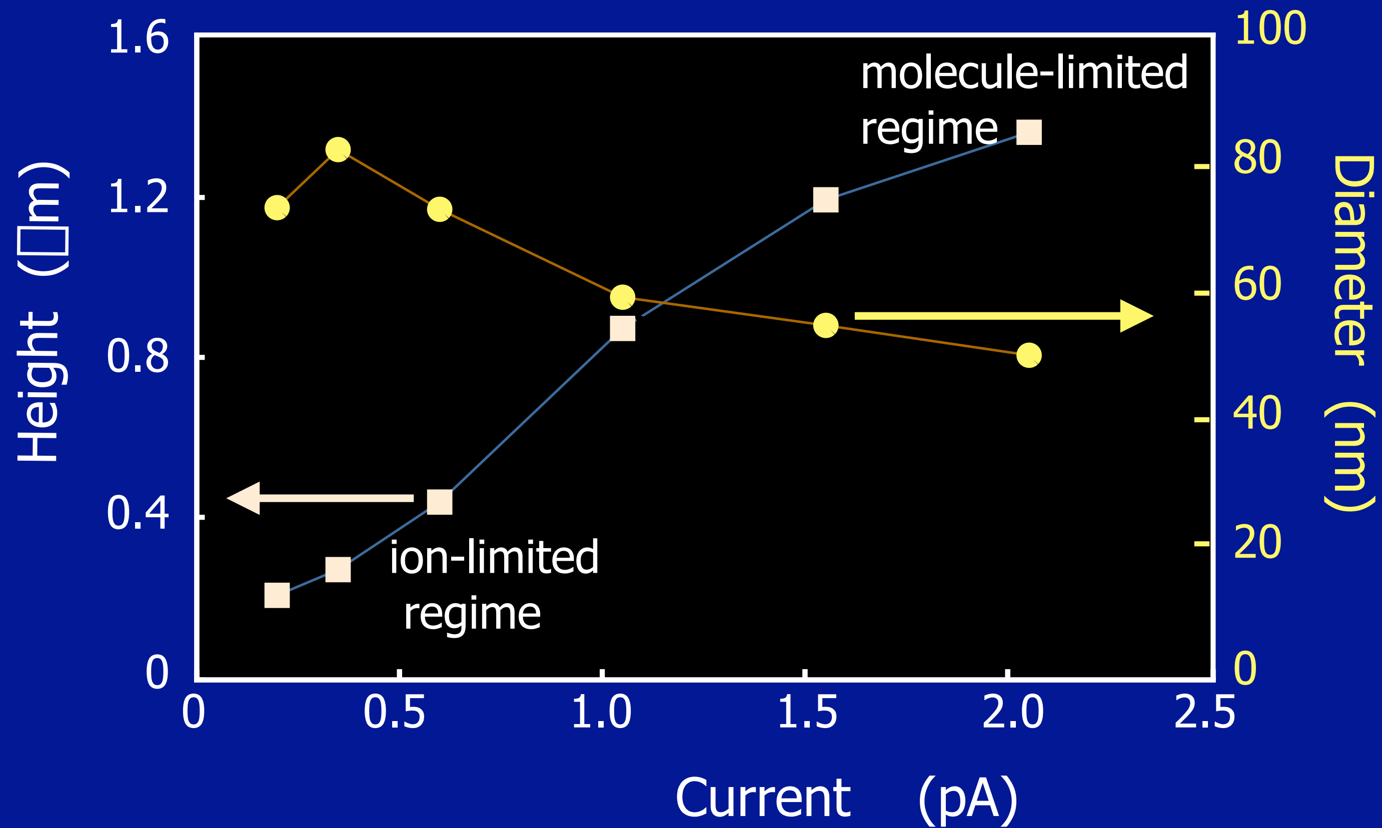
Pillar height & diameter vs. current



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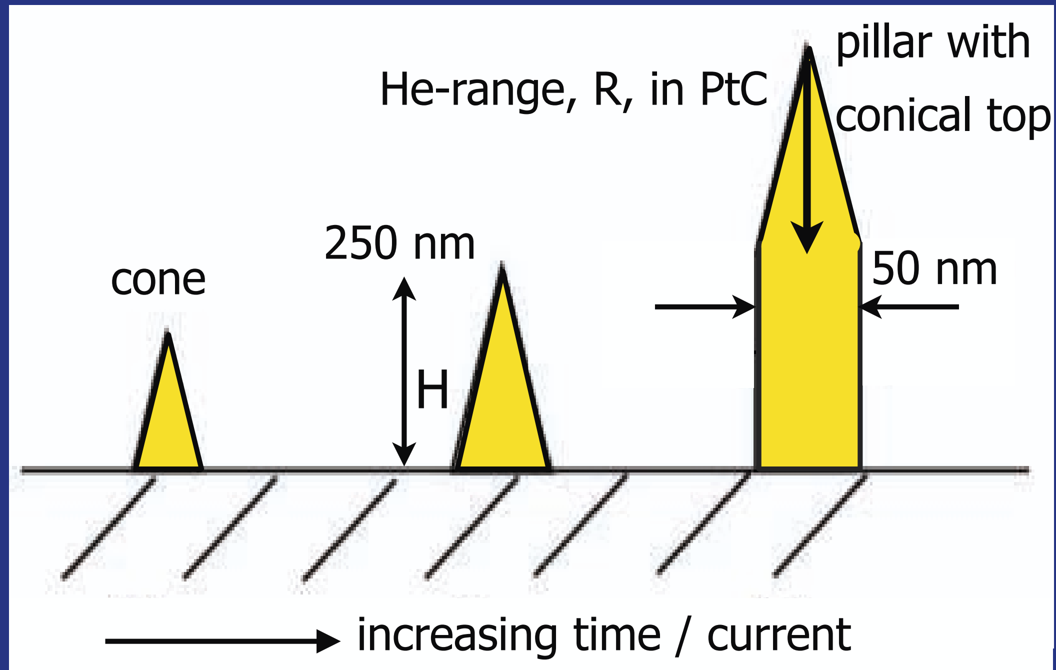
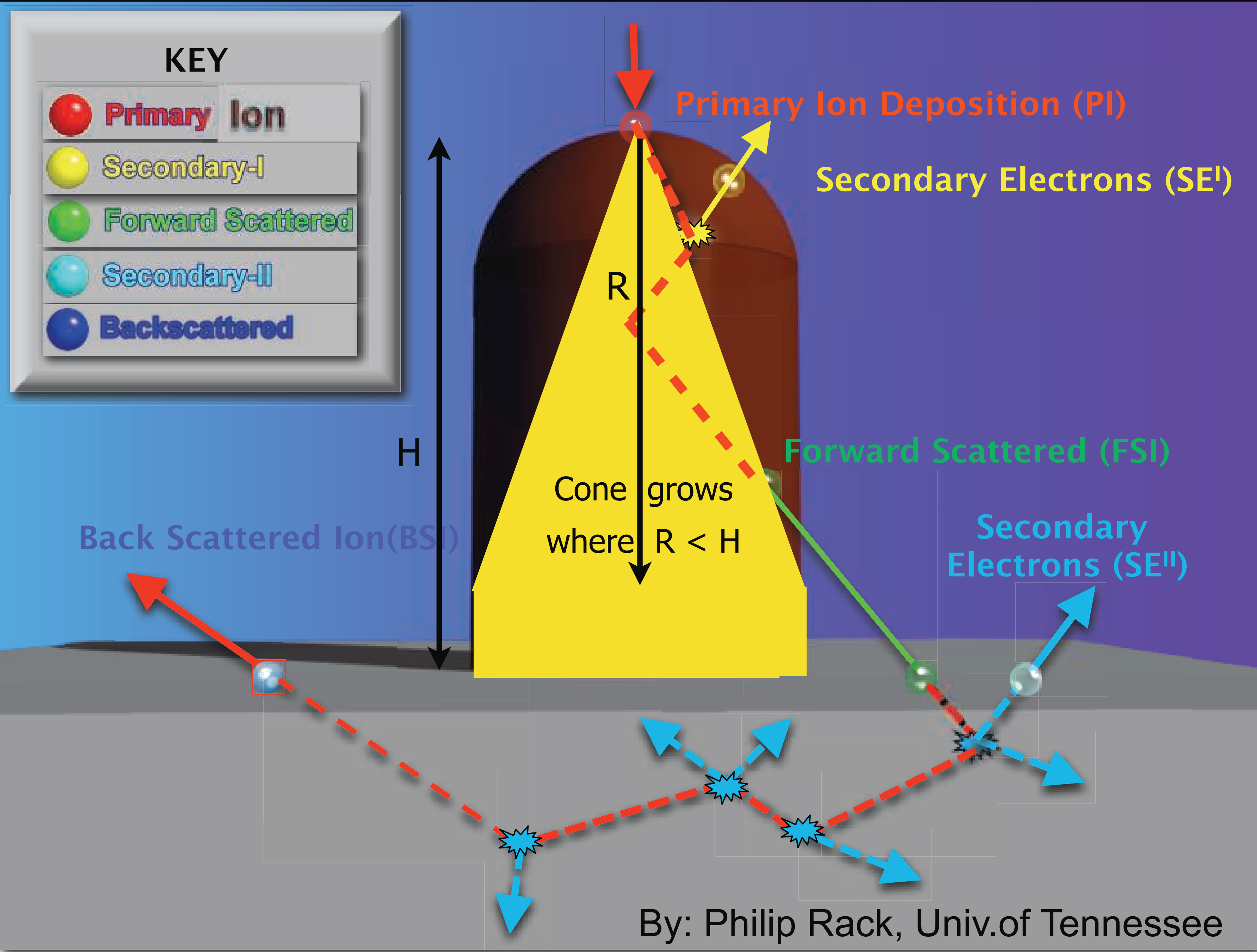
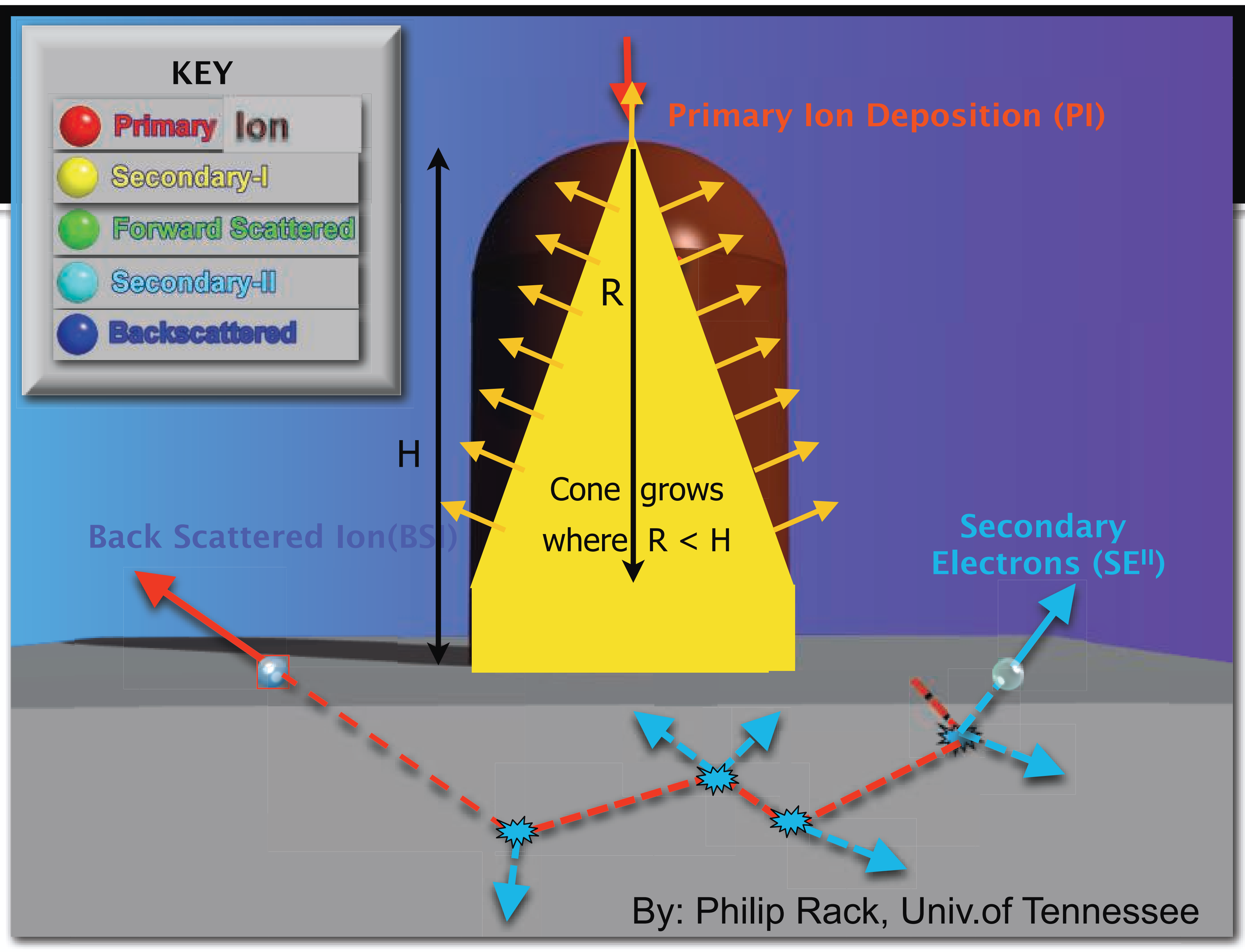
2c. Growth mode & growth mechanism

Pillar shape





KEY
Primary Ion
Secondary-I
Forward Scattered
Secondary-II
Backscattered
Primary Ion Deposition (PI)
Secondary Electrons (SE^I)
R
H
Cone grows where R < H
Forward Scattered (FSI)
Back Scattered Ion(BSI)
Secondary Electrons (SE^II)
By: Philip Rack, Univ.of Tennessee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2c. Proximity effect

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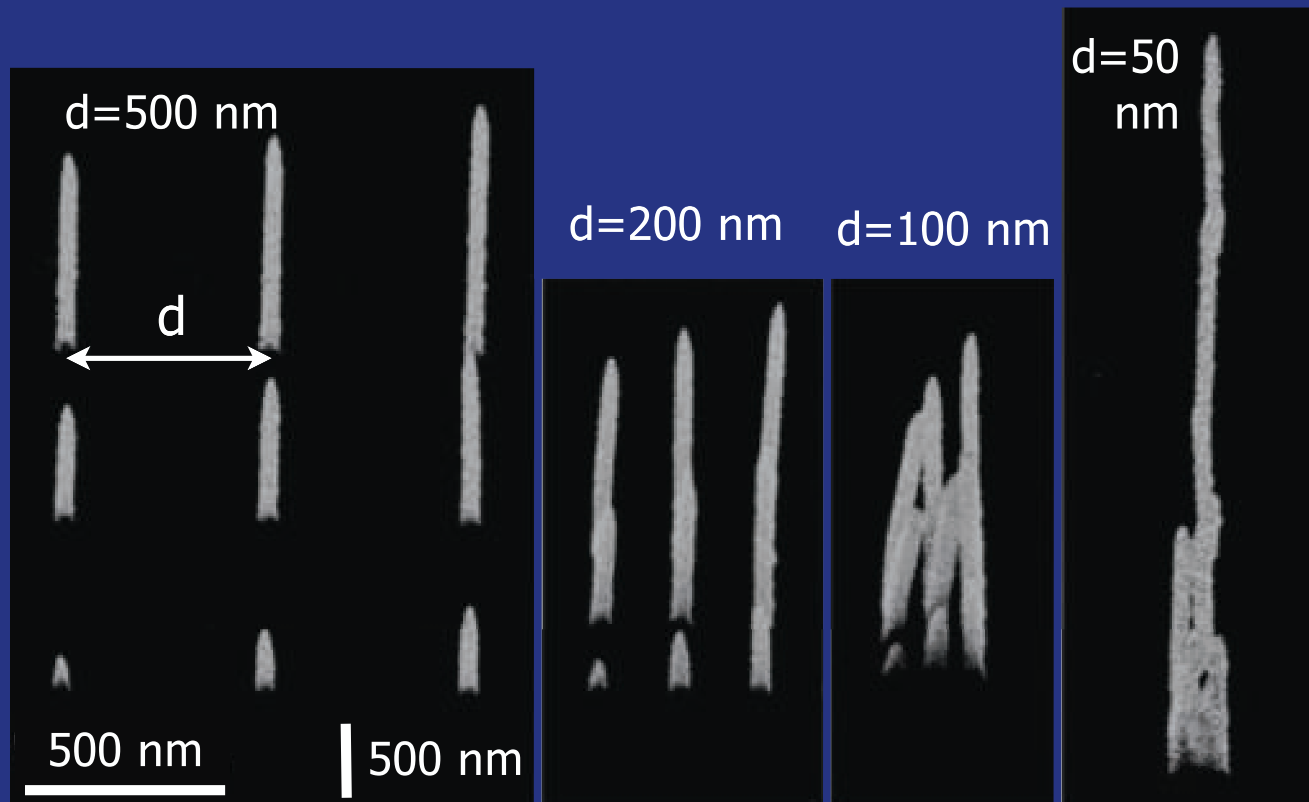
Proximity effect



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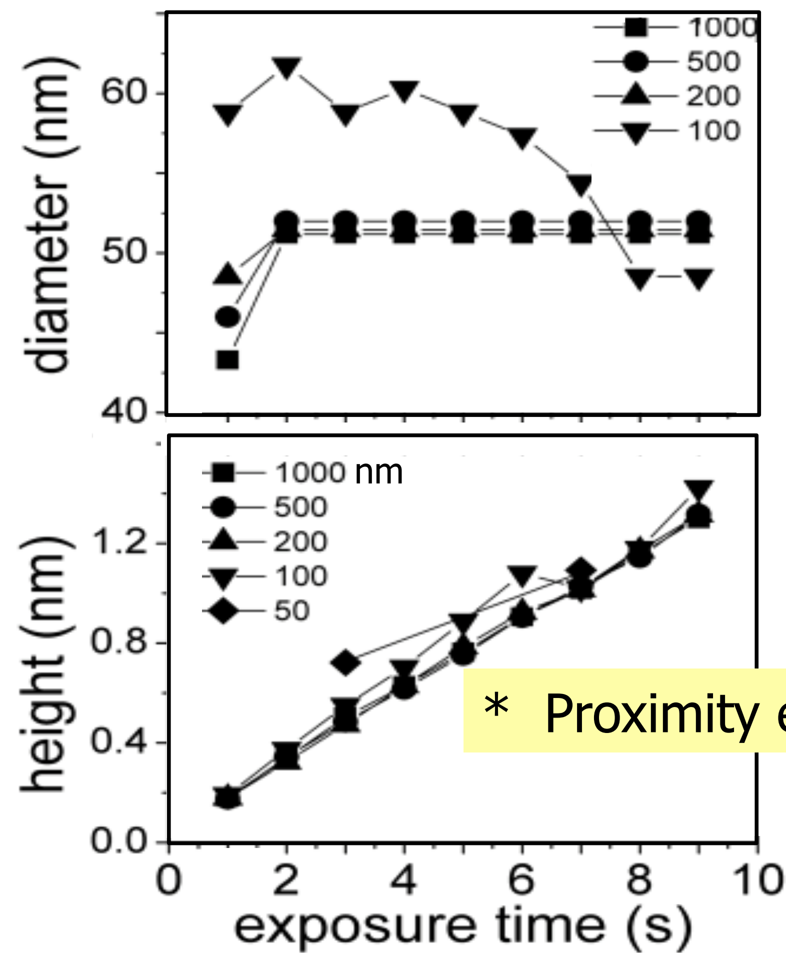
Proximity effect



* Proximity effect if d<200 nm

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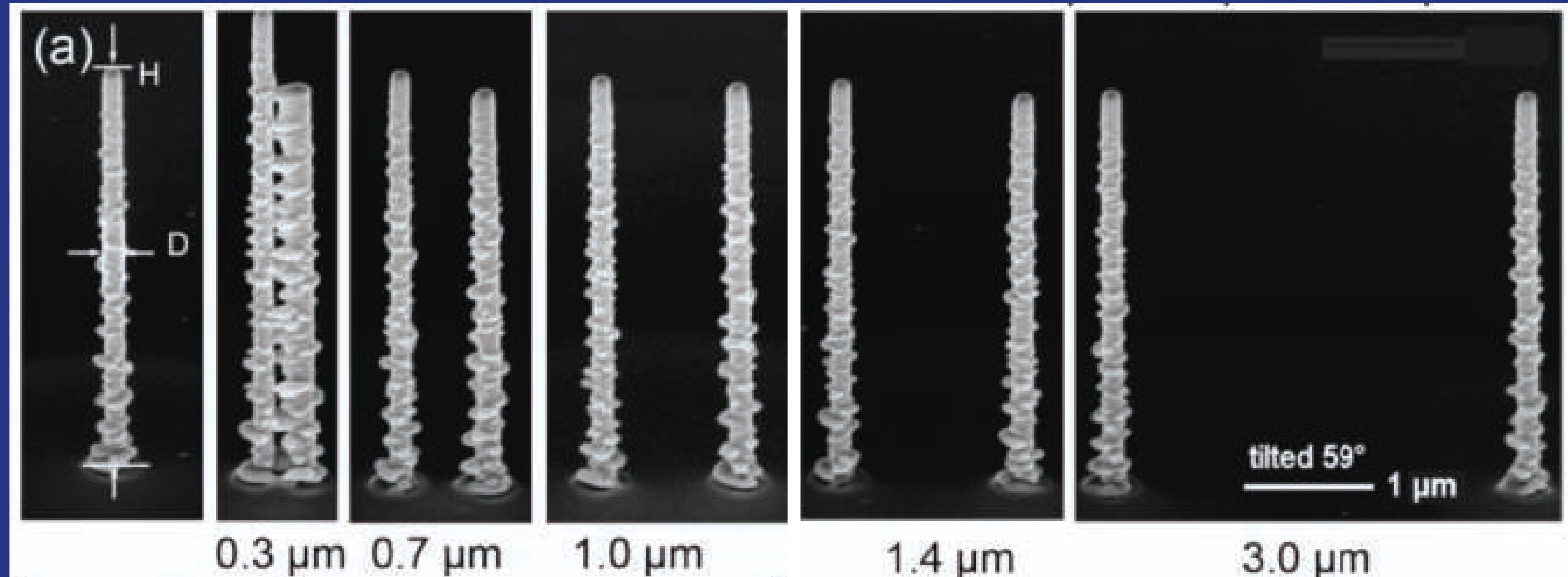
Proximity effect in Ga-IBID pillars



Ping Chen et al., J.Vac.Sci.Technol. B **27** 1838 (2009)

Proximity effect:
- * one is longer
- * the other is broader

Observable if d < ~2.5 μm

Comparison He - Ga IBID

	He	Ga
Vertical growth rate (nm/s)	150	16
Diameter (nm)	50	160
Deposition yield (nm^3/ion)	7.9×10^{-2}	4.5×10^{-2}
Proximity distance (nm)	200	2500

He-IBID looks better than Ga-IBID

Helium lithography vs. electron lithography

1. **HSQ and PMMA: 4 - 40x as sensitive**
2. **Comparable minimal feature size (~6 nm)**
3. **Low proximity effect**
4. **Maximal current 2 pA (200 pA for EBL)**
5. **Non-optimized beam conditions**
6. **Beam damage to specimen**

Helium IBID vs. gallium IBID

1. Comparable sensitivity (for Pt depo)
2. 3x better minimal feature size
3. Minimal sputtering (100x lower)
4. Smoother surfaces ; less proximity effects
5. Lower Pt content
6. Lower beam current

Conclusions (helium beam lithography)

1. **HeBL good candidate:**
   for small-feature & high-density structures
   * 6 nm minimal feature size
   * 14 nm pitch
2. **Room for instrumental improvements**
   beam current & beam shape
3. **Exposure is related to ion's energy loss**

Conclusions (ion beam induced deposition)

1. **He-IBID is feasible**

   * relative high yield

   * low minimal feature size (50 nm / 12 nm)

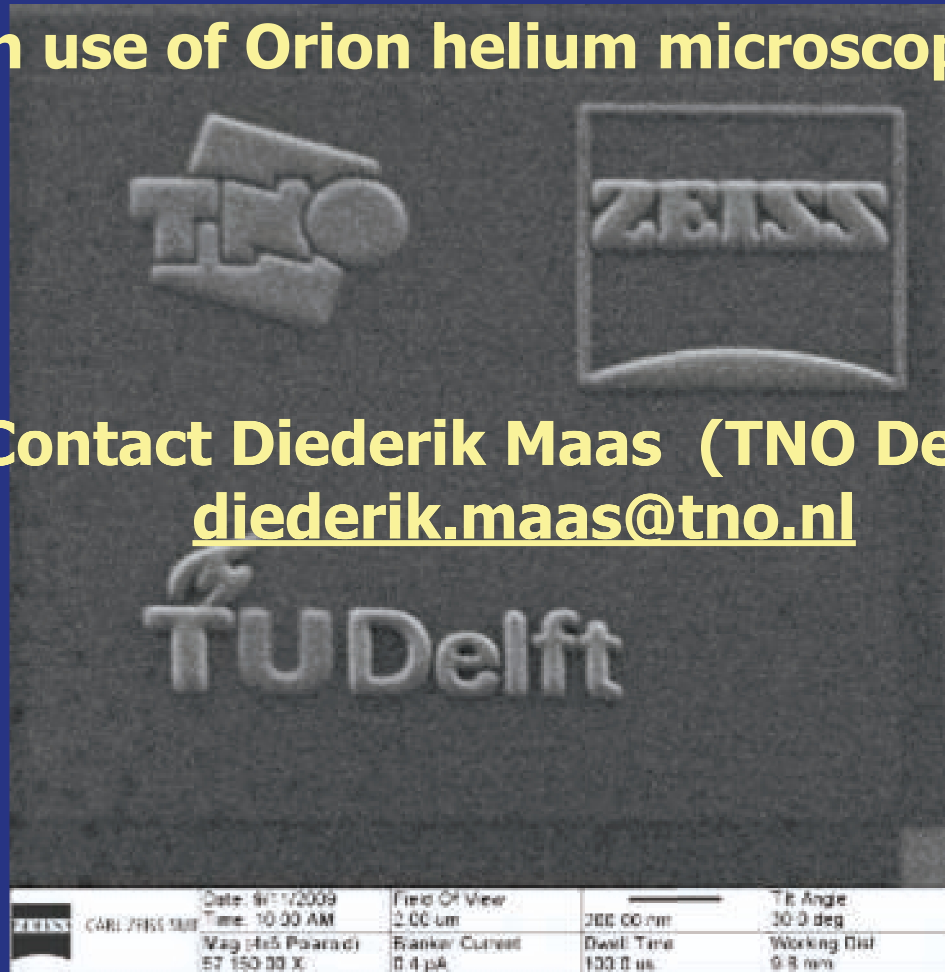
2. **Room for instrumental improvements**

   beam current & beam shape

3. **Deposition is caused to secondary electron emission**

4. **Deposition & observation in one instrument**

Interested in use of Orion helium microscope in Delft?



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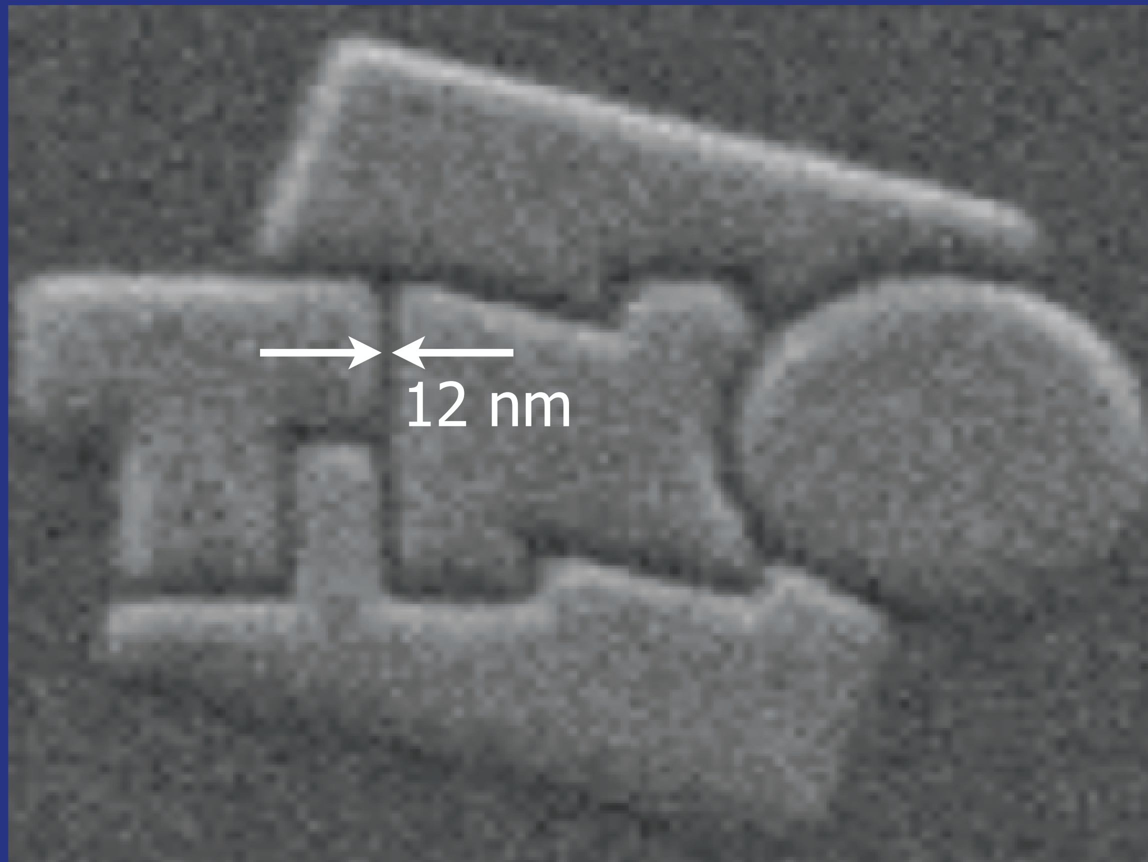

Thank you

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