Lecture 21

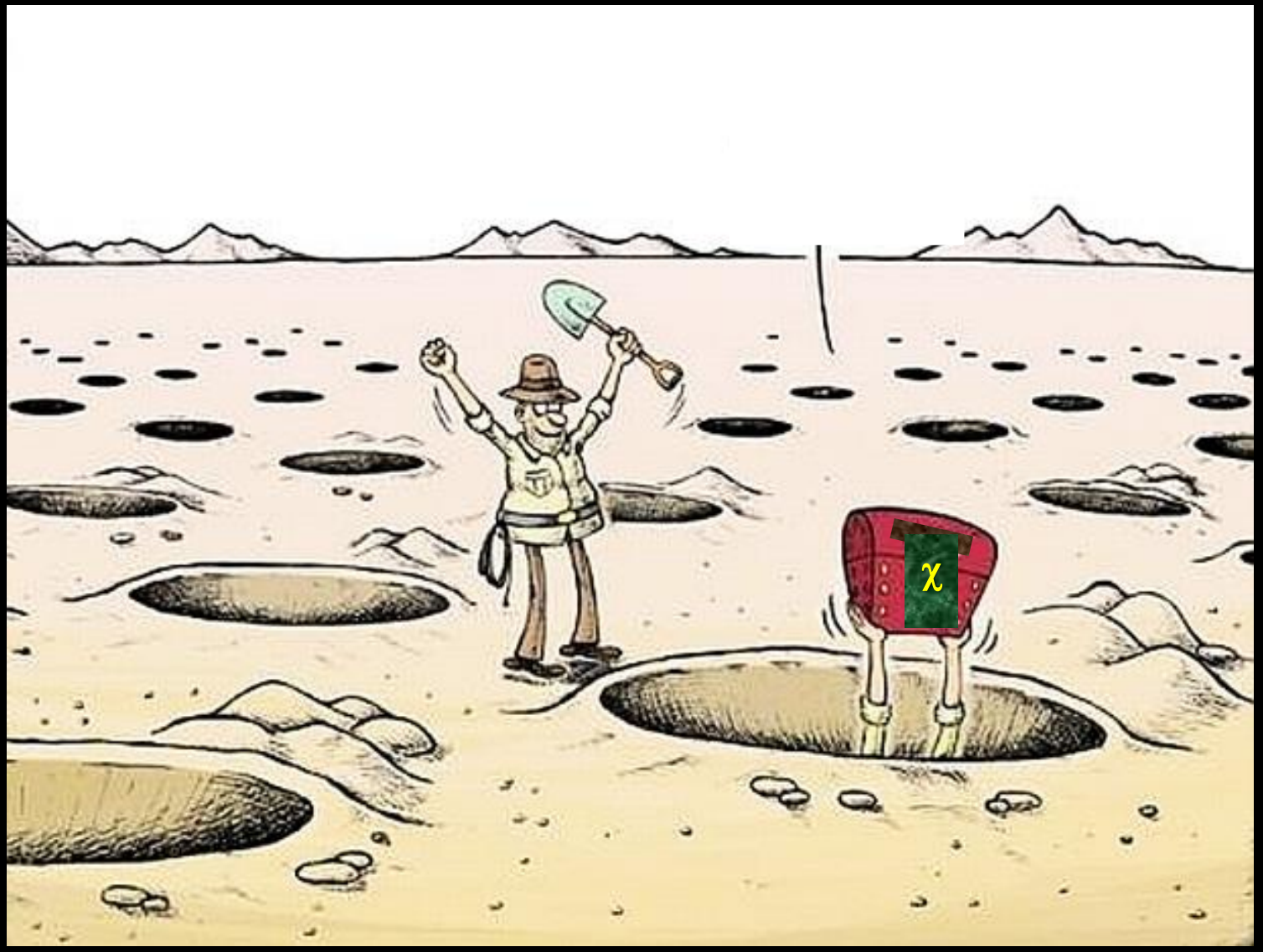
Chemical Engineering for Micro/Nano Fabrication

Final Exam

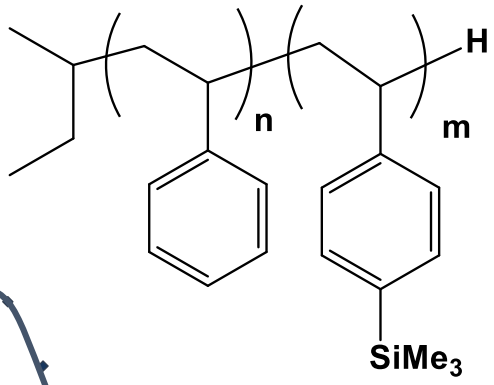
- When: Friday December 15th from 9:00 am – 12 pm
- Where: ETC 2.114
- Bring Pencil, eraser....no calculator.
- Corrected Exams will be available for you in NHB 5.136 after the grades are posted.

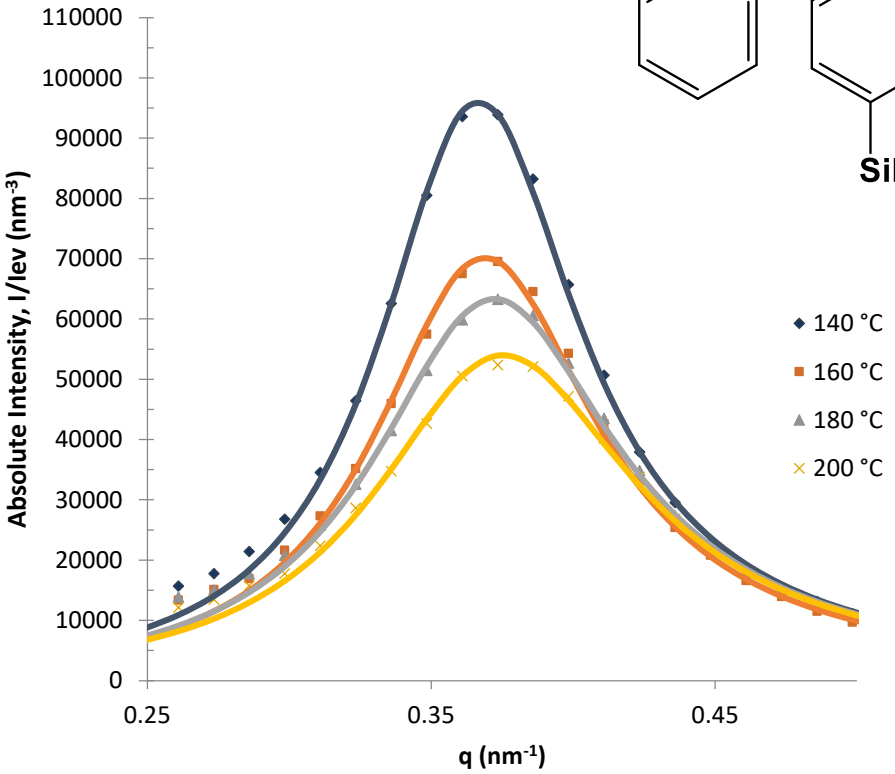
Design Criteria for New BCP

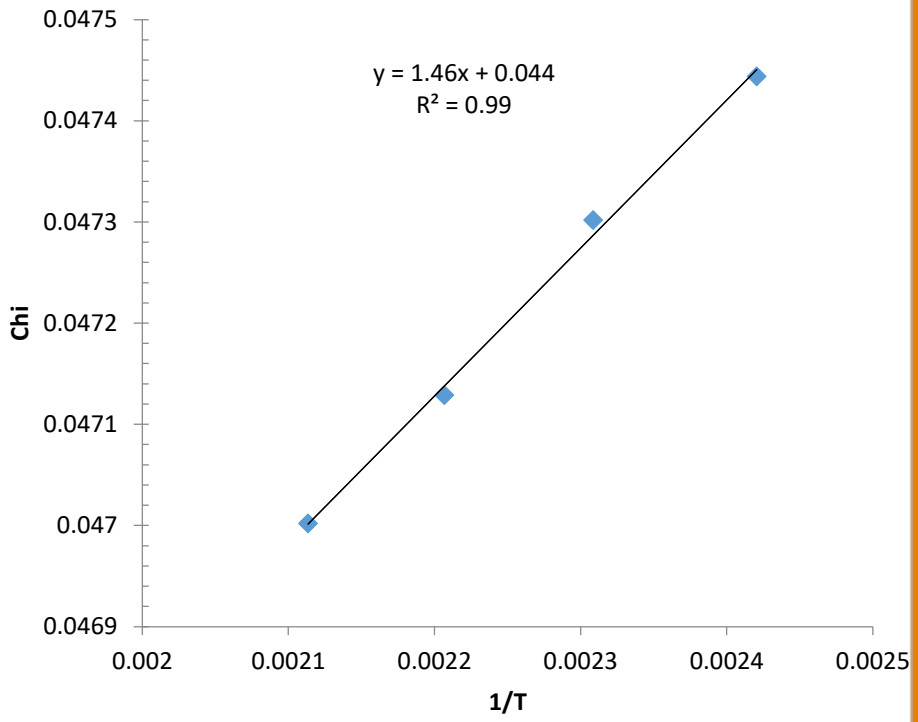
- Incorporate Si in one block….. etch contrast
- High χ ... gives small structures
- Amenable to *orientation* and *alignment*
- *No new unit processes required for mfg*


χ

Determine χ by SAXS







Rheology is also a valuable tool for determination of χ

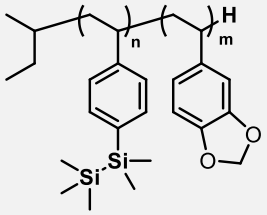
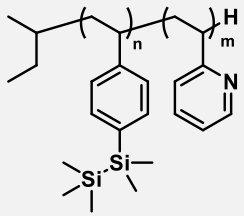
Durand, et. al Journal of Polymer Sci., 2014

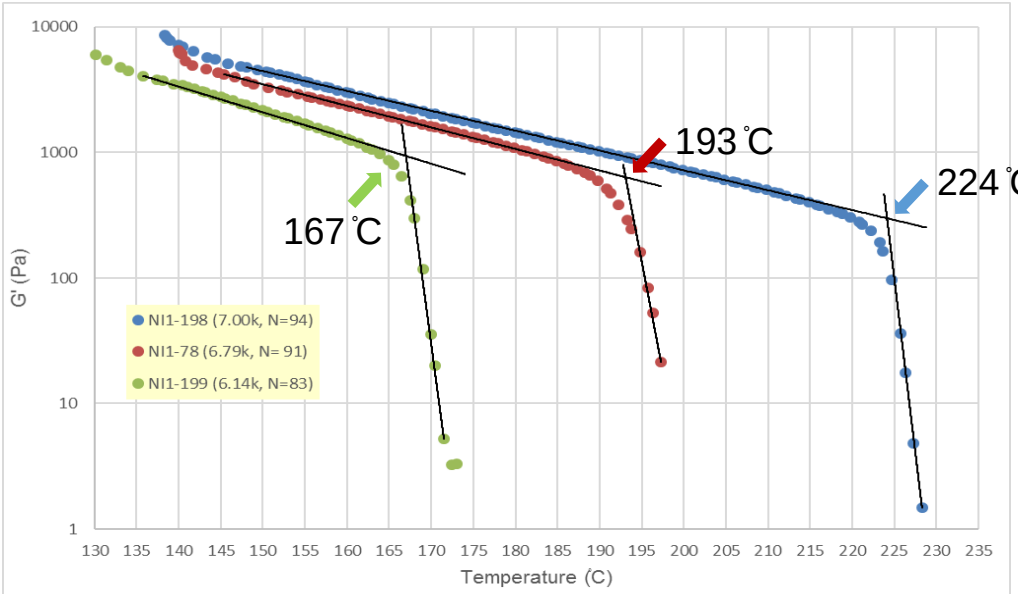
Determine χ by Rheology

$$\chi N_{ODT} = 10.5$$

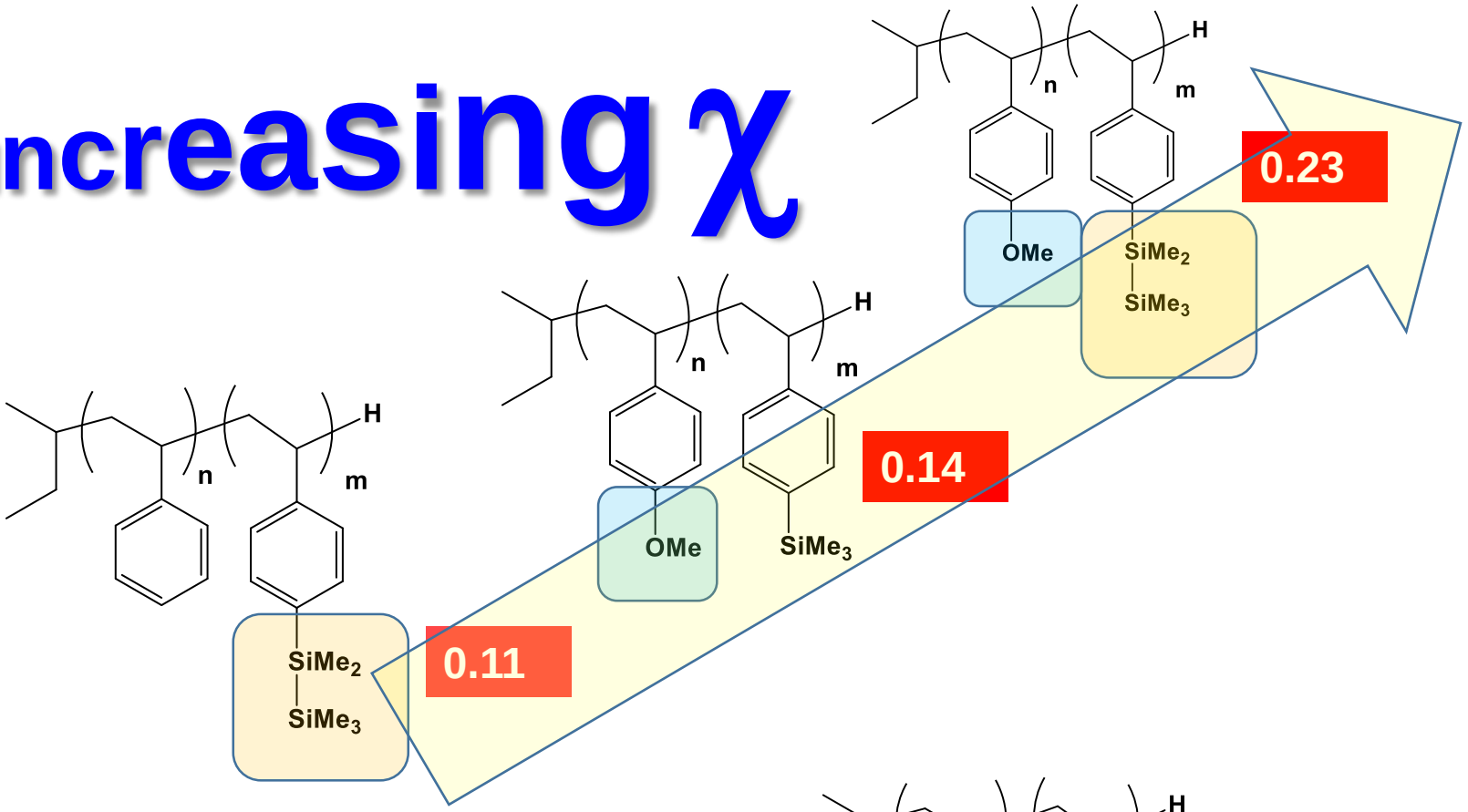
$$\chi(T) = \frac{a}{T} + b$$

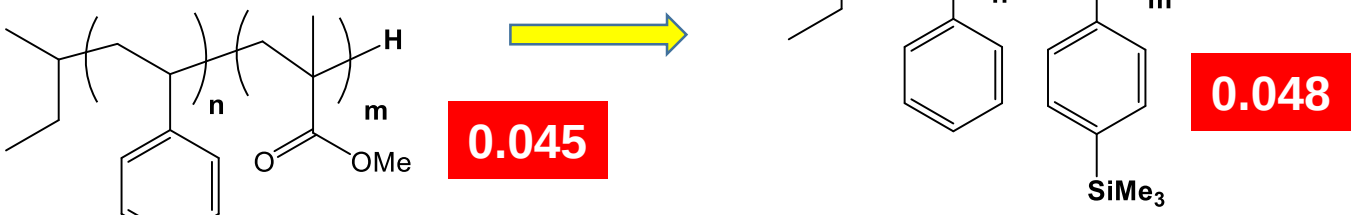
$$\frac{10.5}{N_{ODT}} = \frac{a}{T_{ODT}} + b$$

BCP	 PDSS-PMDOS	 PDSS-b-P2VP
χ (T)	$\frac{49.63}{T} - 0.008$	$\frac{59.78}{T} - 0.009$
χ (180C)	0.102	0.123



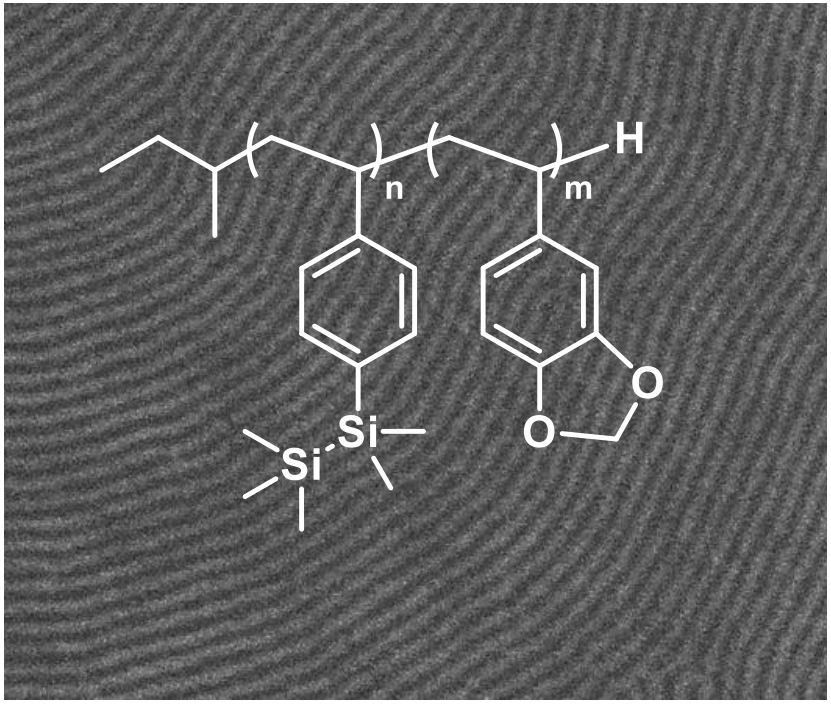
Increasing χ



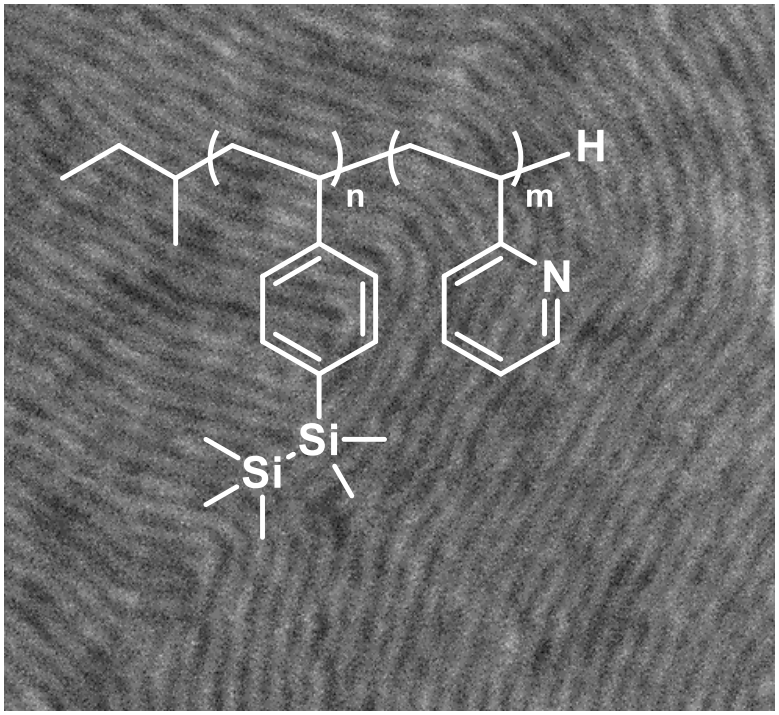


PS-b-PMMA

Oriented high χ block copolymers

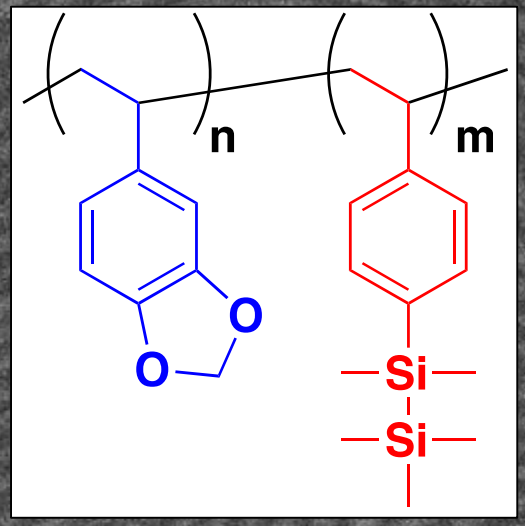


50 Angstrom lines



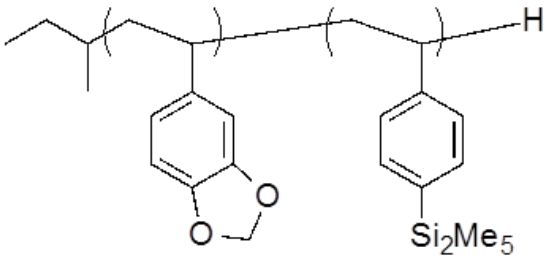
40 Angstrom lines

Small Structure for Bit Patterned Media



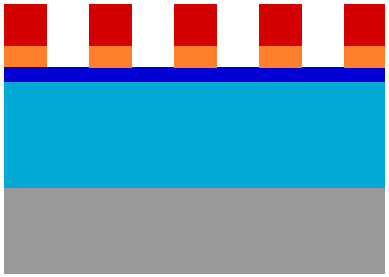
50 Angstrom Lines and Spaces

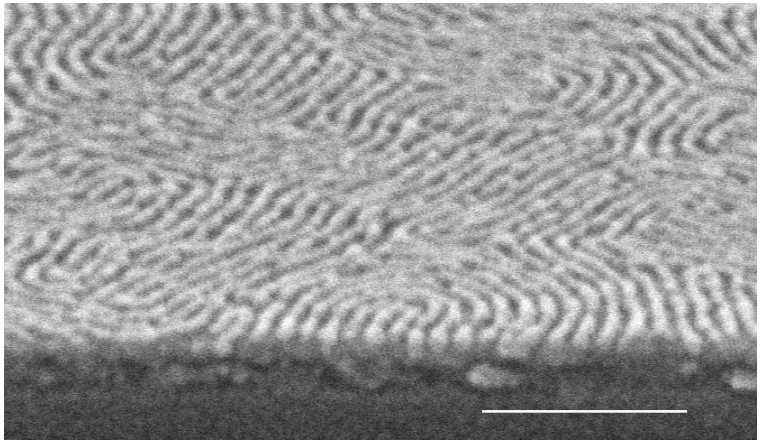
Image Transfer of 50 Å lines and Spaces



BCP etch (CO_2 RIE)

BCP mask + Neutral brush (8 nm)
Chromium (4 nm)
Spin-on carbon (15 nm)
Silicon wafer

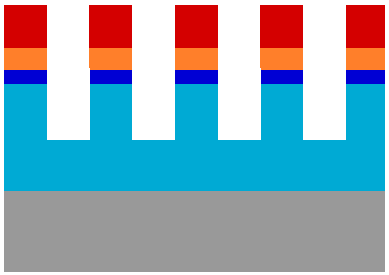


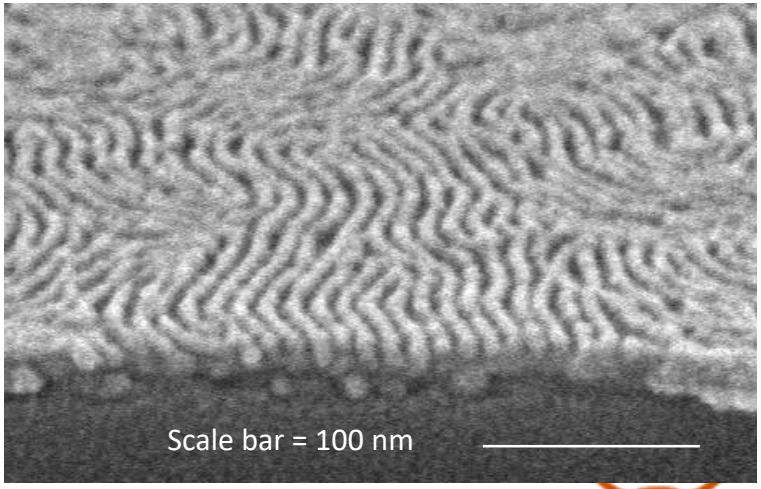


Steve Sirard

Lam RESEARCH

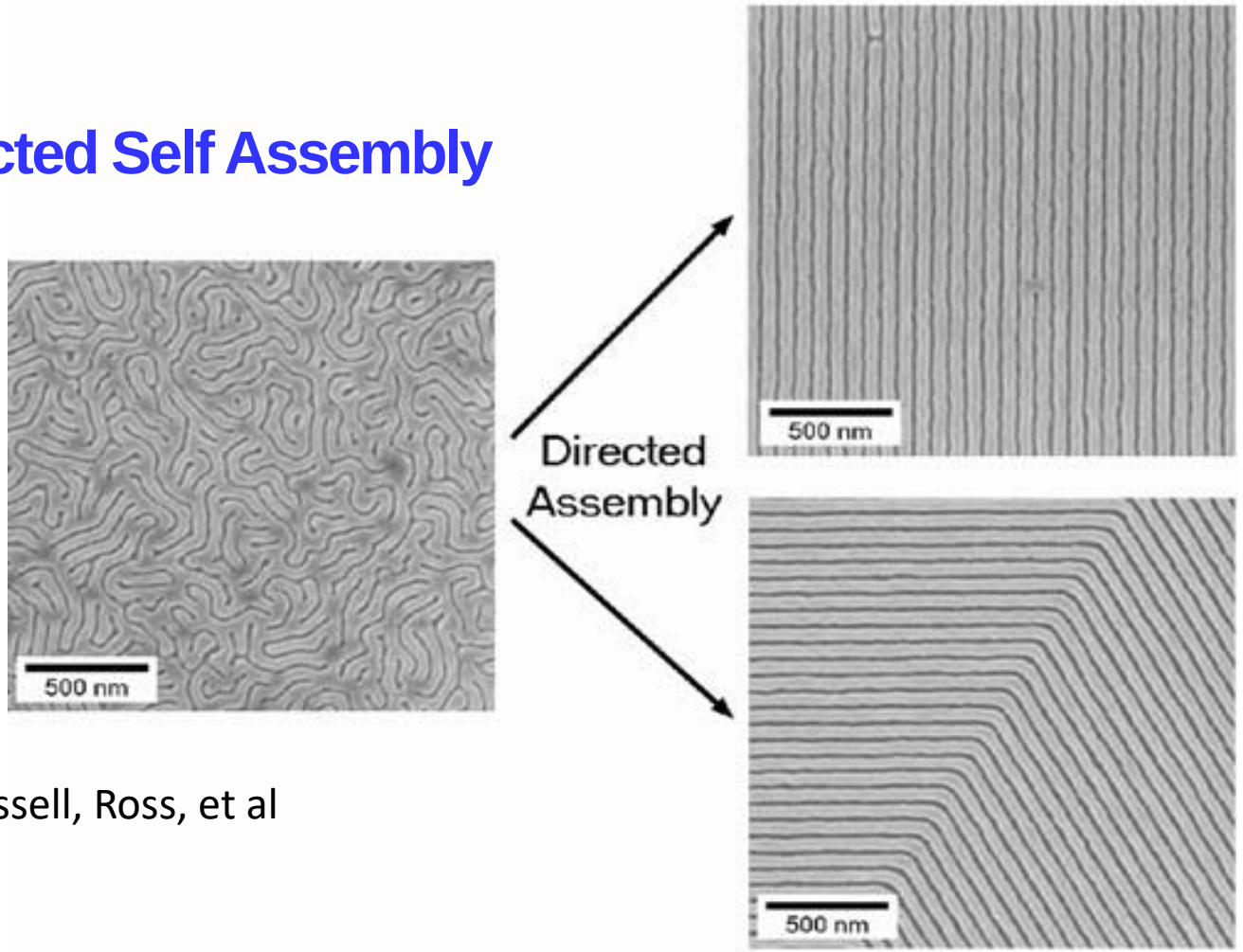
Cr/SOC etch (Cl_2/O_2 RIE)





Now…Alignment Control - DSA

Directed Self Assembly



Nealey, Russell, Ross, et al

Can we align these high χ materials

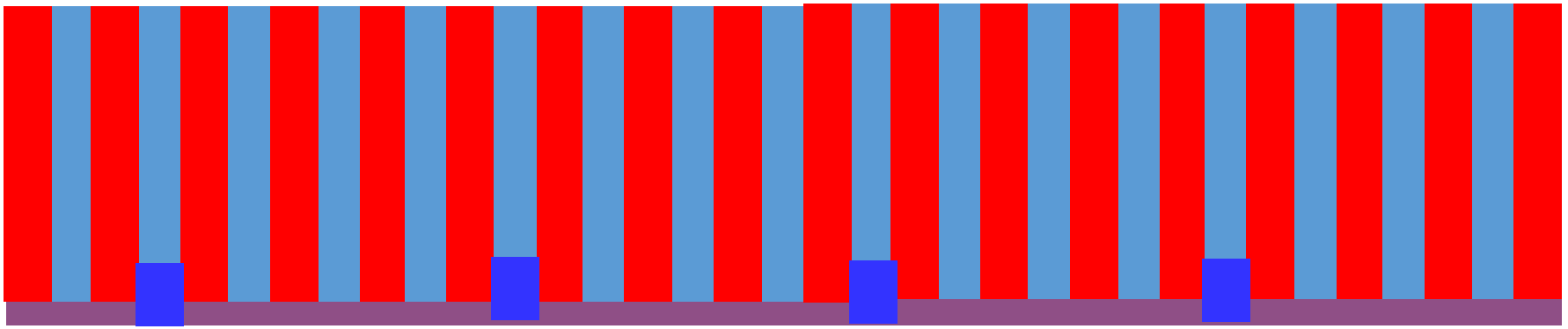
Even Nature struggles with this Challenge

Design for n=4 & 0.5L_o where L_o =20

Challenging Lithography

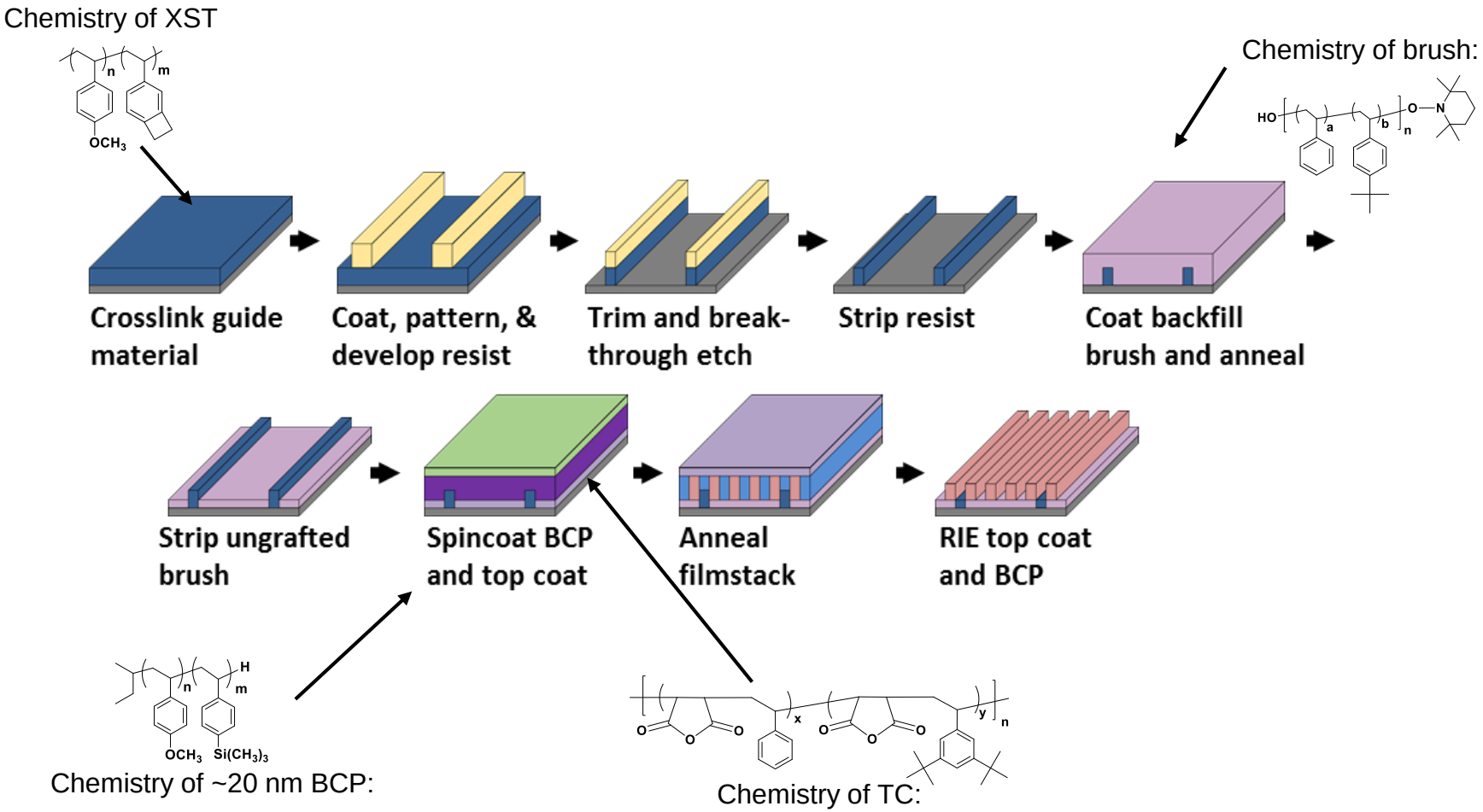
40nm lines and spaces

Line is subsequently “trim etched” to 10nm



- This is the theoretical limit for 193nm immersion litho
- Top coat should be perfectly neutral
- Brush approaches neutral with increasing multiplication
- Guide line should strongly favor one block

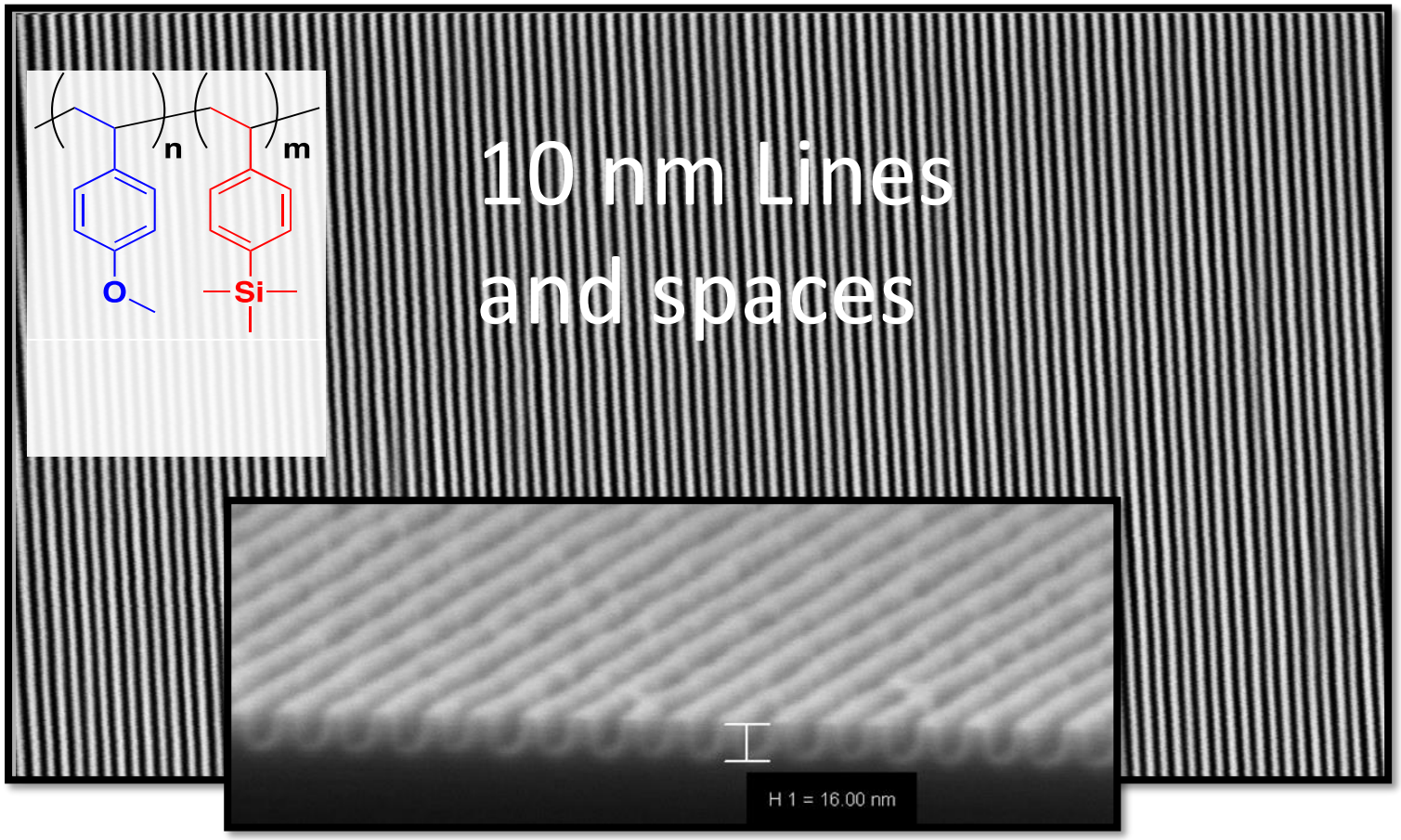
A “Hybrid” process flow created to incorporate top coat and combine chemical and topographic anchoring for DSA



Blachut, G., et al. *Chem. Mater* (2016), **28(24)**, 8951-8961.

Directed Assembly at HGST

Electron Beam written Guide patterns



Julie

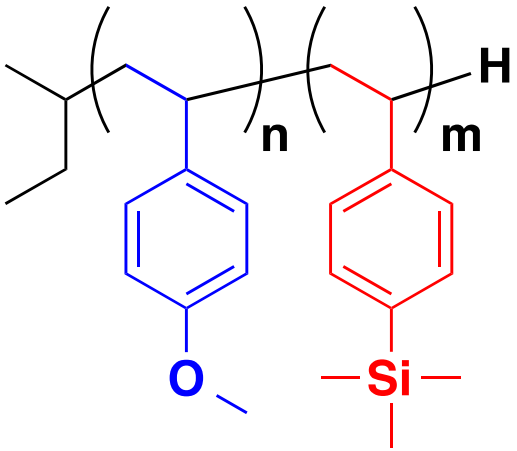
Ricardo

ACS Appl. Mater. Interfaces ***2015****, 7, 13476*

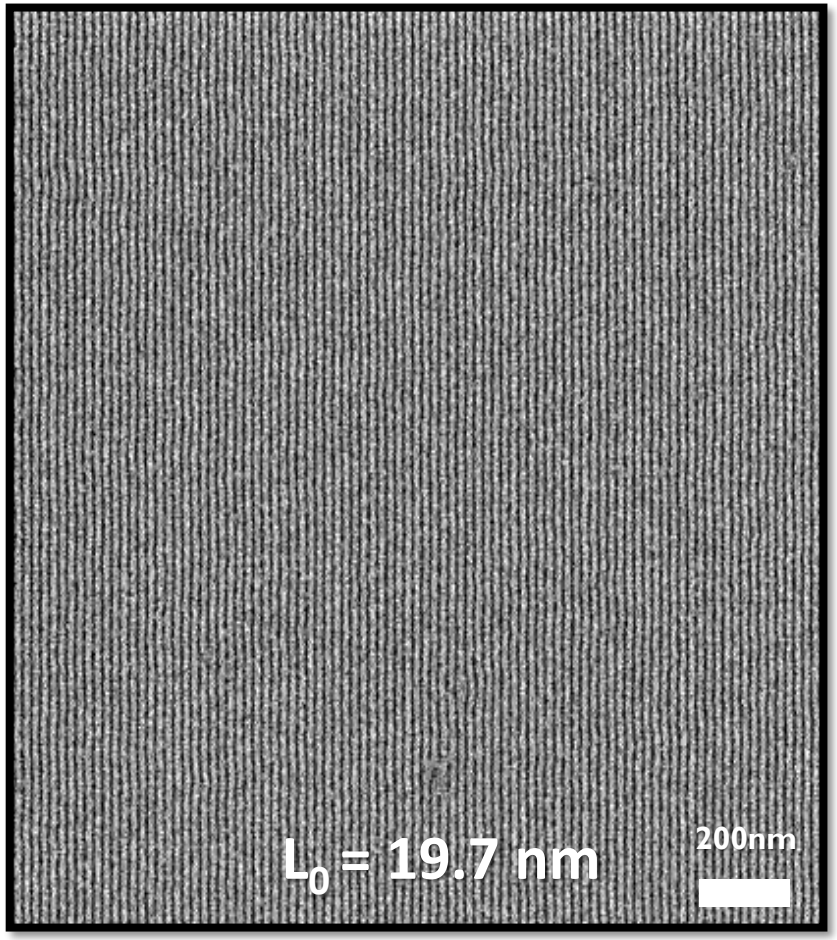
Greg in Belgium!

Gregory Blachut

imec



PMOST-PTMSS



Chem. Mater **28(24)**8951-8961 (2016)

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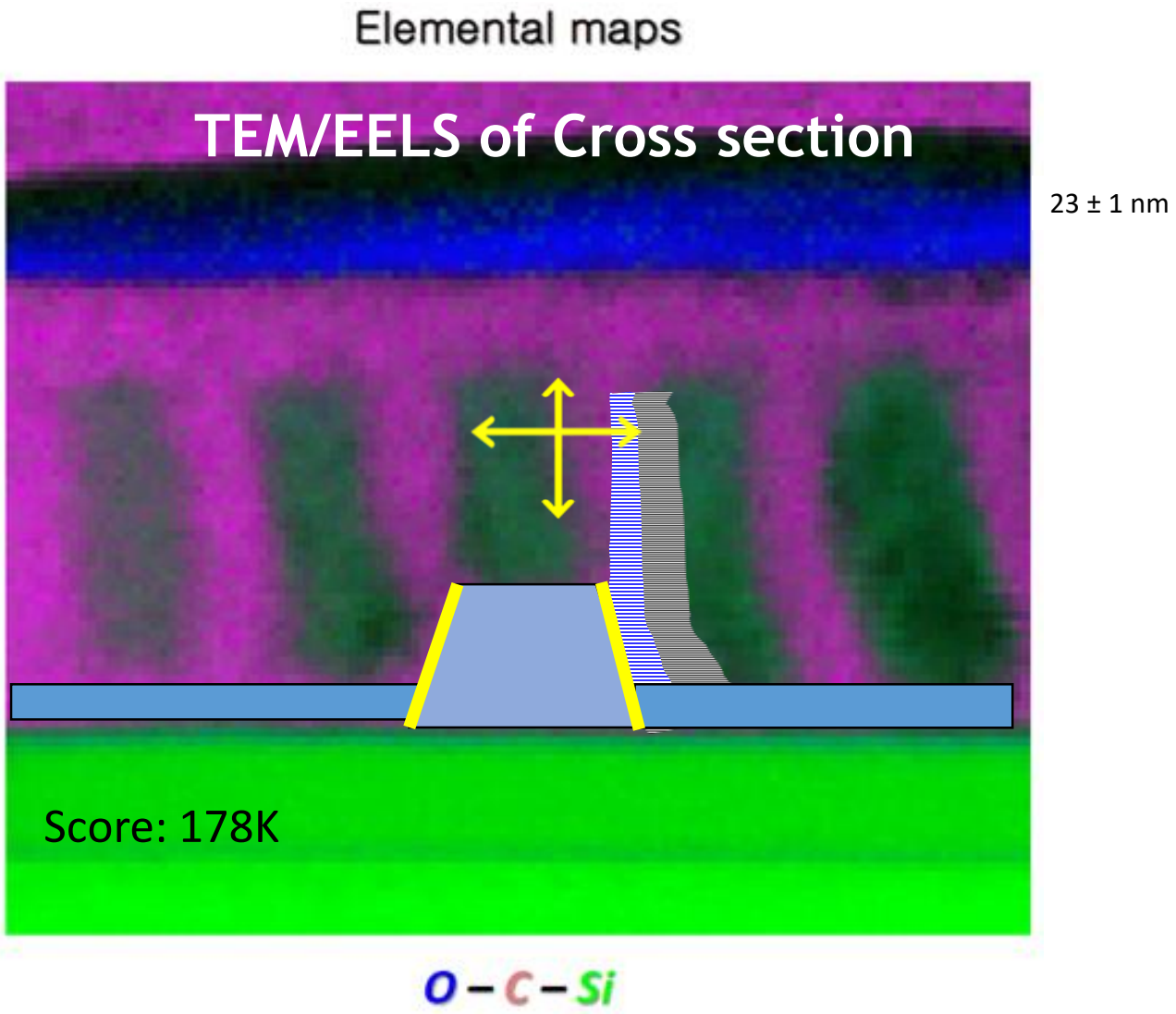
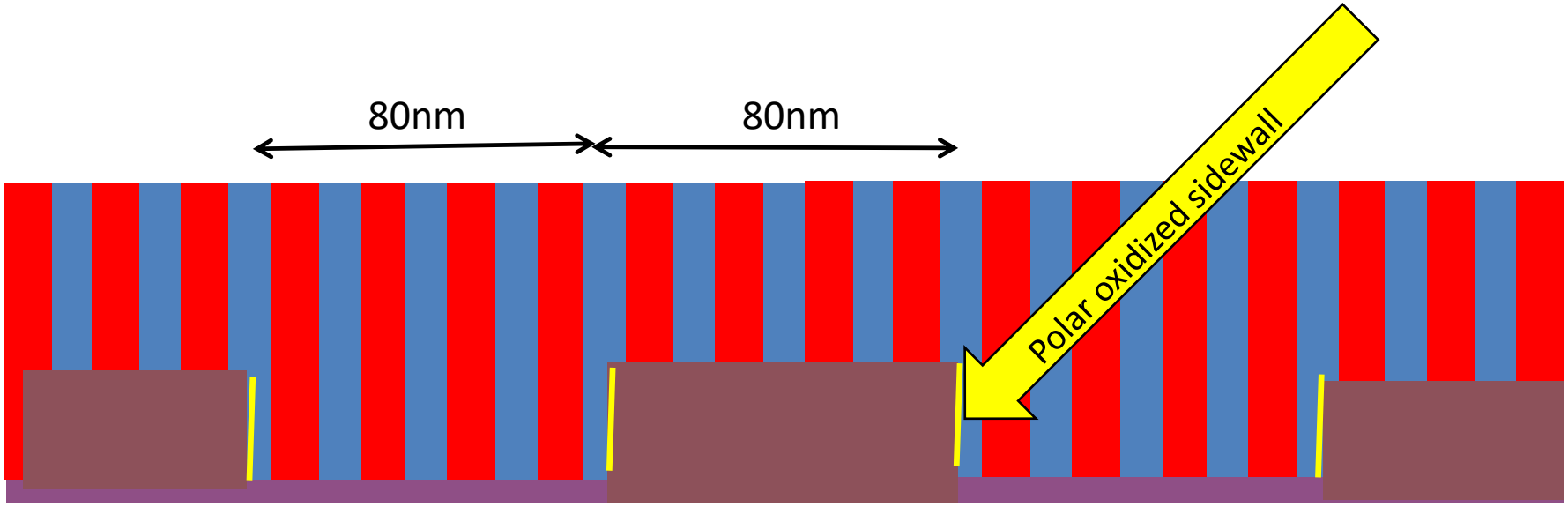
Possible Interpretation of Imec Cross sections



Relaxed Optical Litho Proposal

Design for n=4, L_o = 20

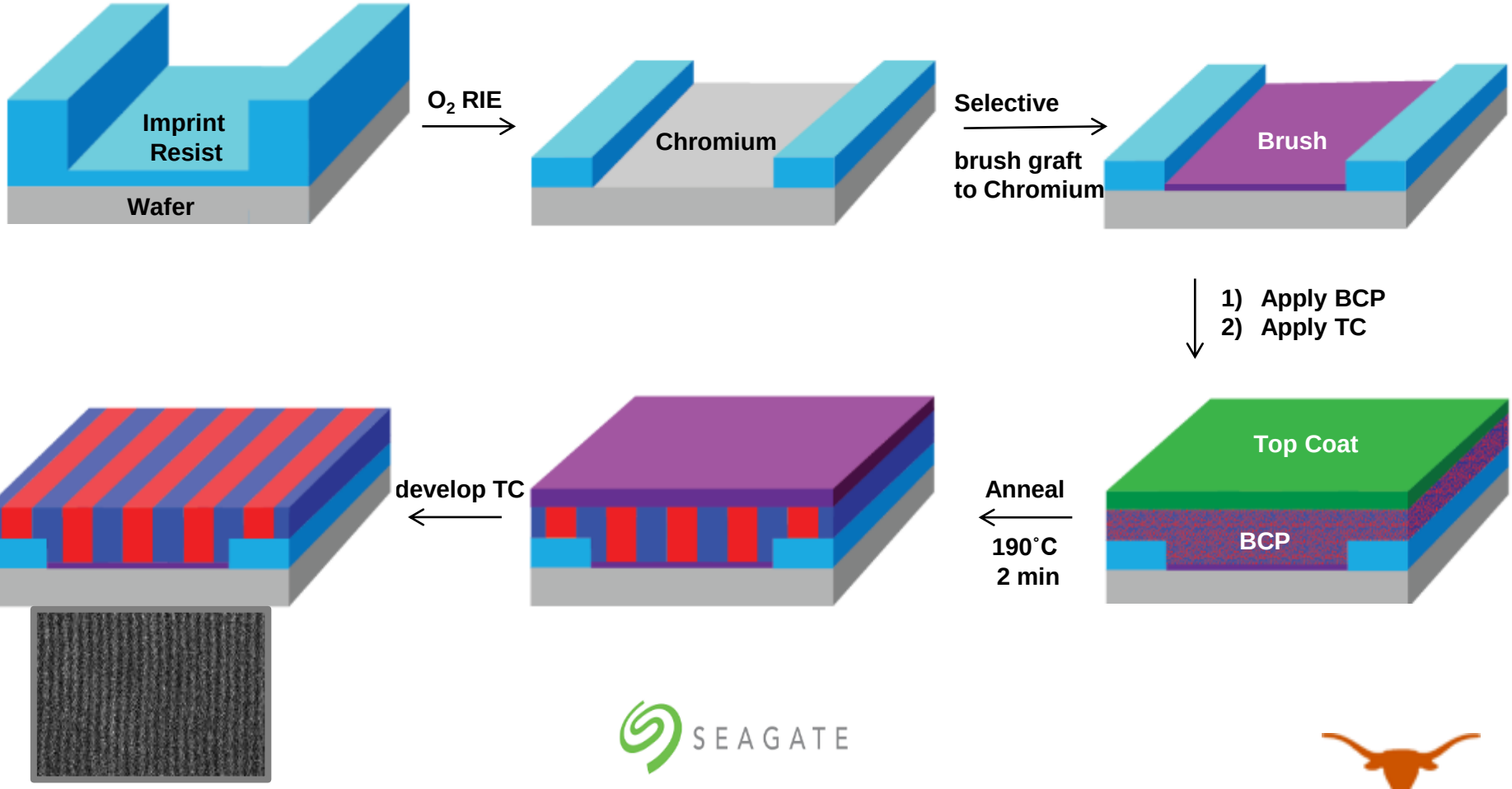


Top coat and XST should be perfectly neutral for all n

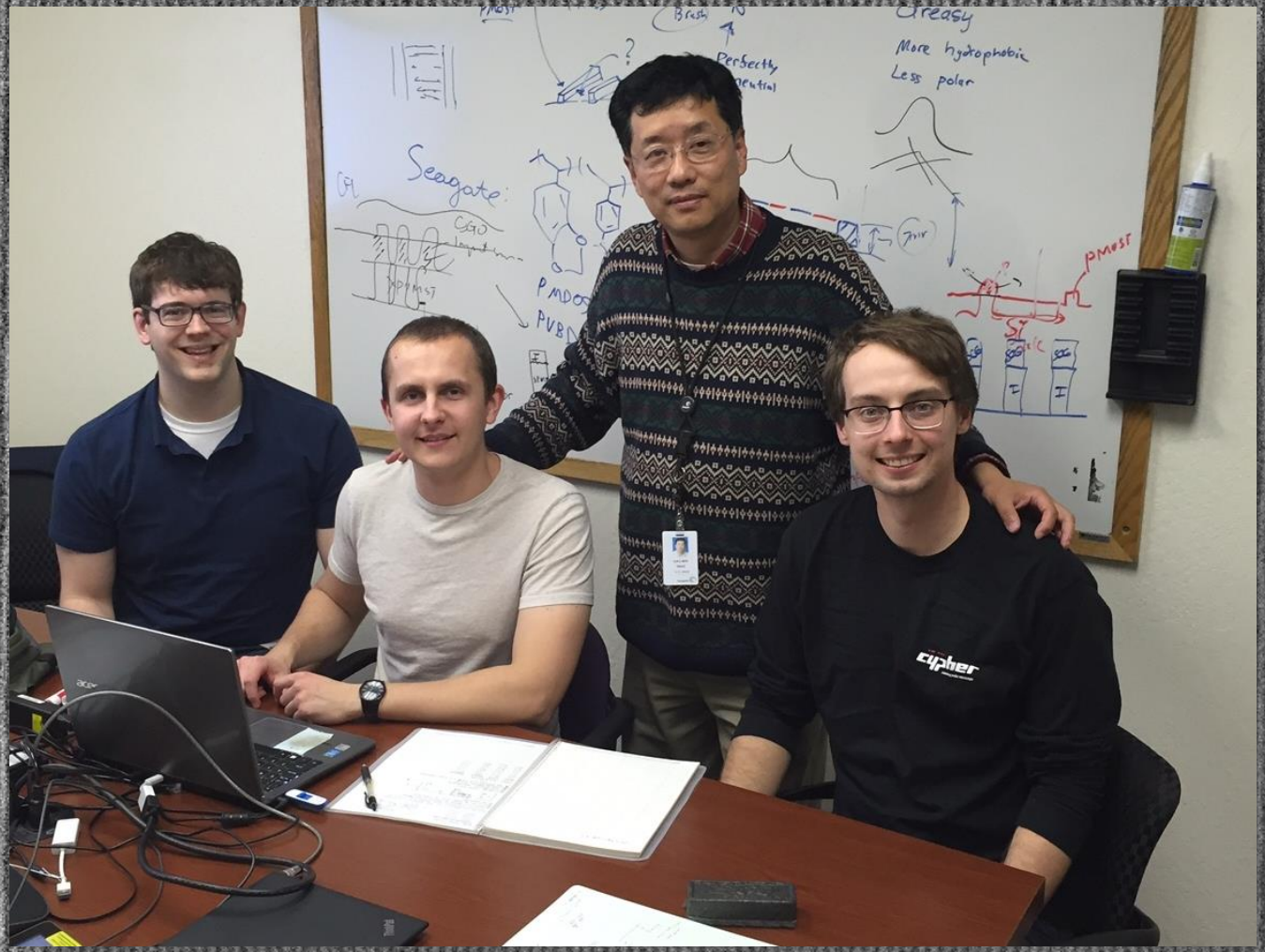
Requires selective reaction of the brush with substrate not sidewall !!

Now being tested at imec with Geert Vandenberghe & Dustin Janes

5 nm DSA using Imprint Lithography



SEAGATE



50 Å lines and spaces

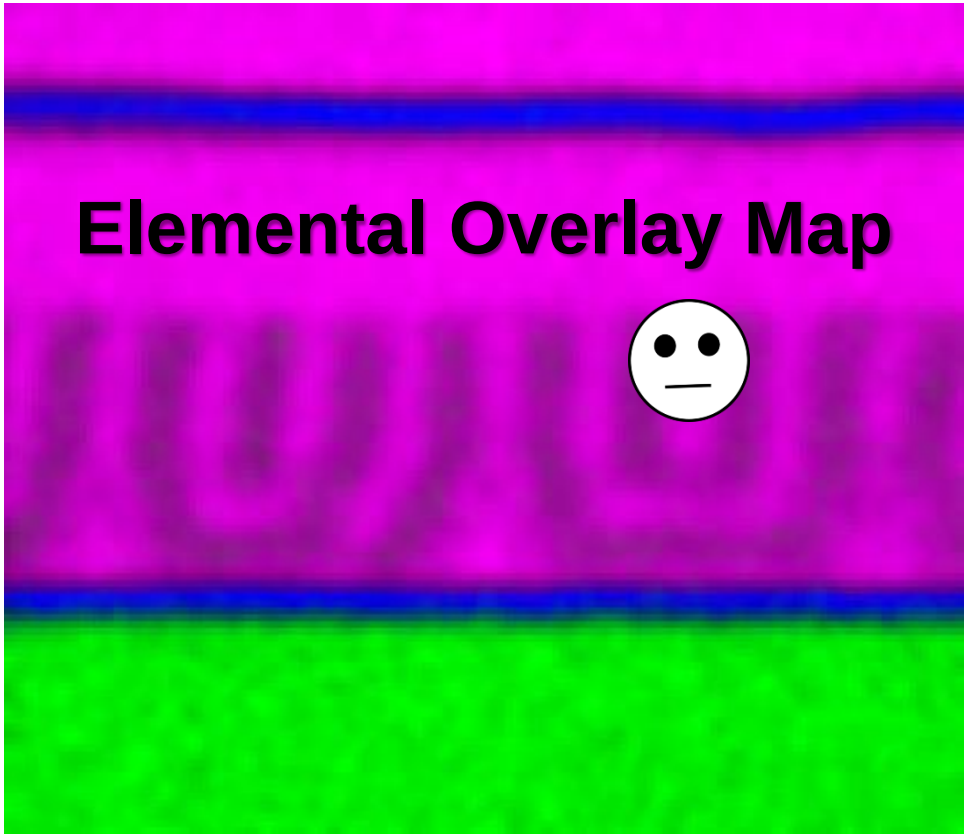
SEAGATE

200 nm

Mag = 75.00 K X
InLens

WD = 5.8 mm
EHT = 10.00 kV

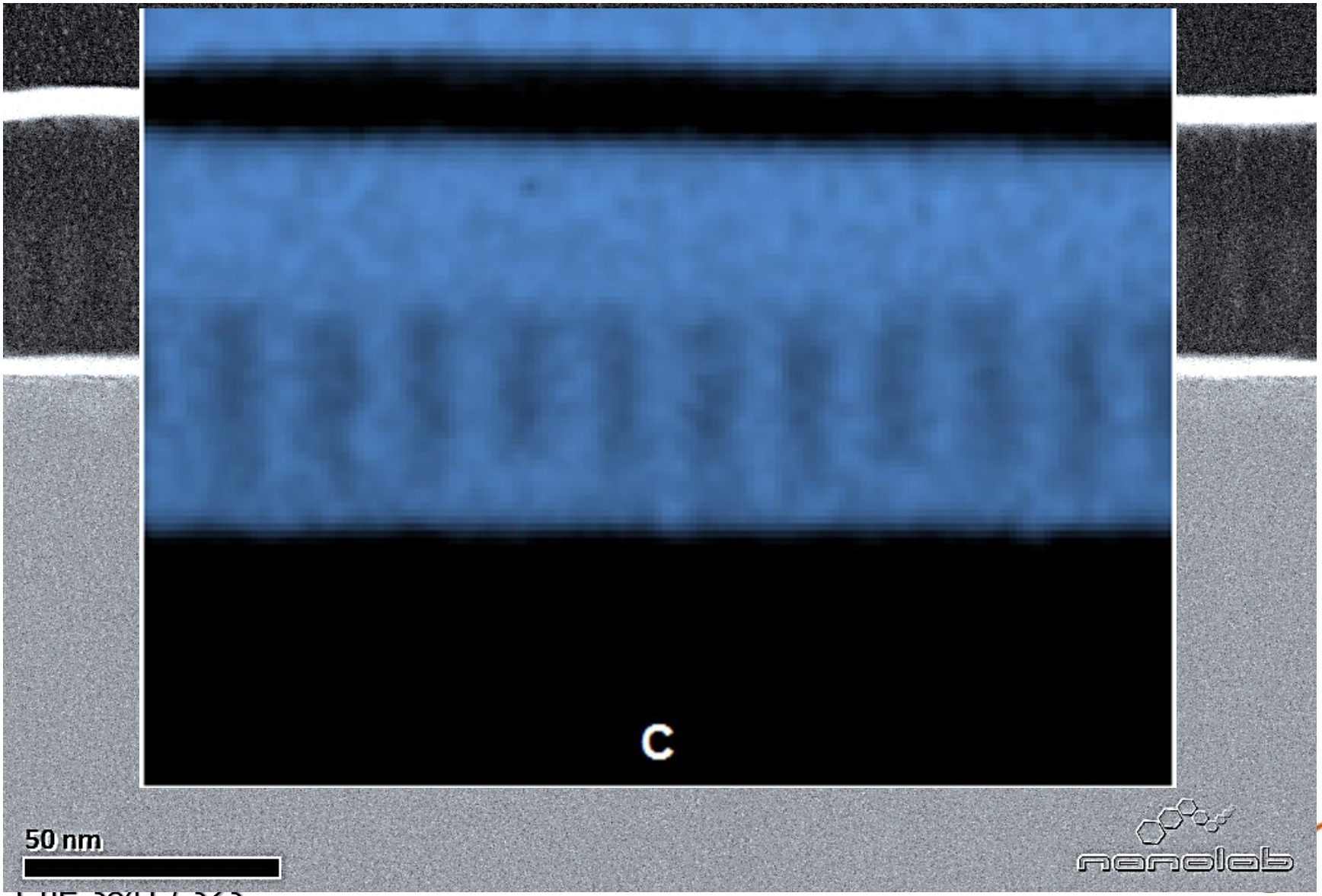
Second try

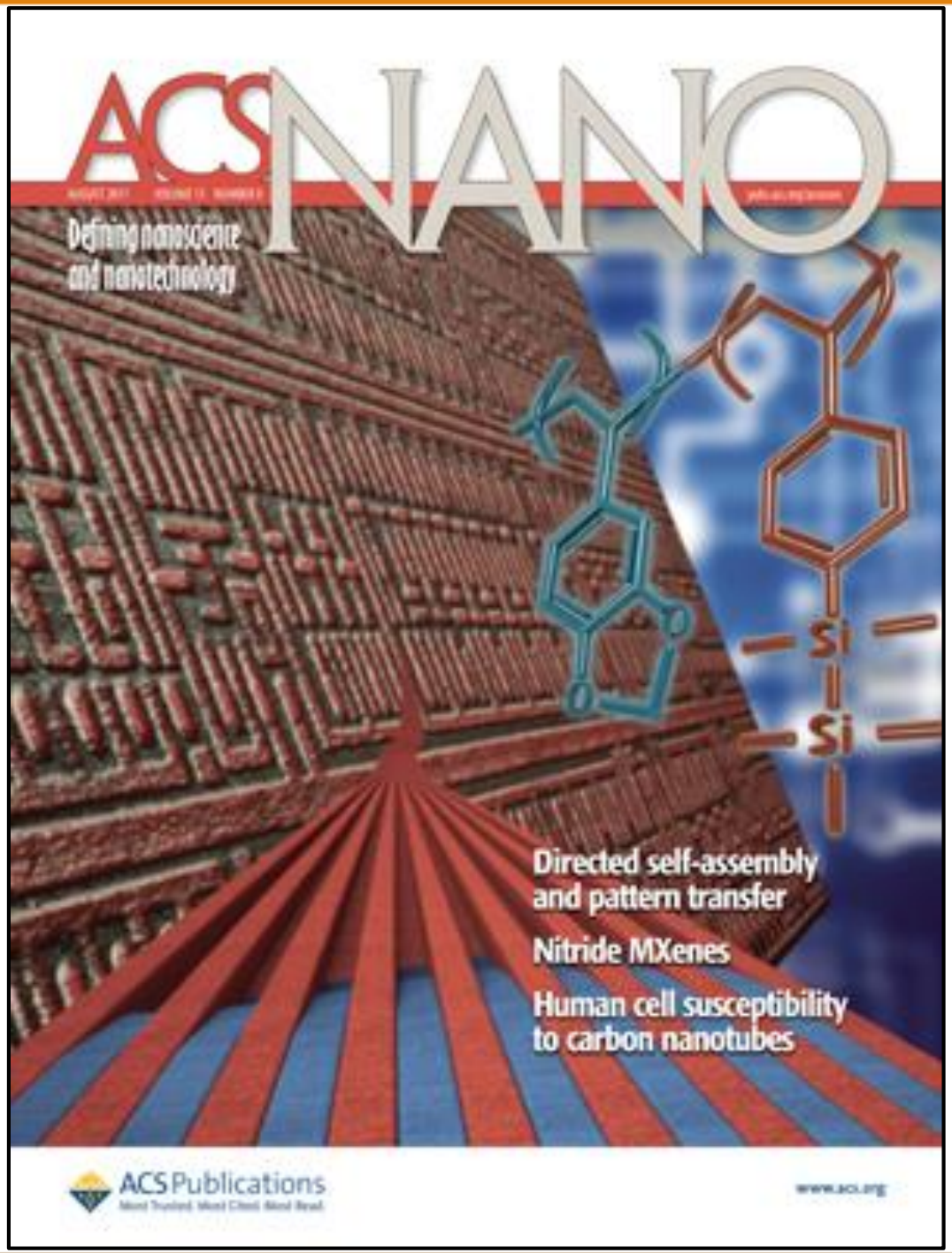


C-Si-Cr

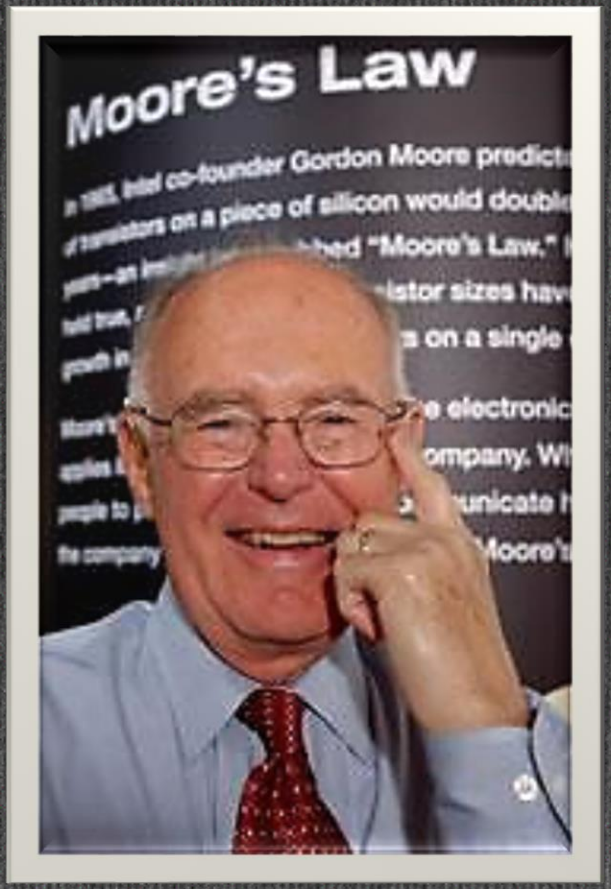
(Map contrasts are optimized to show element distributions, they are not directly proportional to actual abundances)b

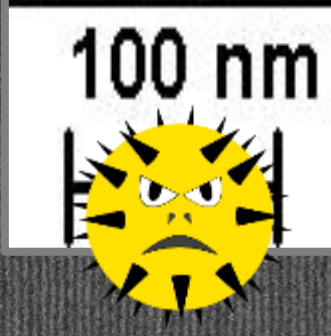
STEM Cross sections of Latest 5nm Process




ACS NANO
Defining nanoscience and nanotechnology
Directed self-assembly and pattern transfer
Nitride MXenes
Human cell susceptibility to carbon nanotubes
ACS Publications
www.acs.org

Etch developed 50 Å lines and spaces





collaboration with

SEAGATE

Thank You!!