XFLASH® 7 DETECTOR WEBINAR SERIES PART II

Achieving sub-10 nm EDS spatial resolution on bulk specimen in SEM

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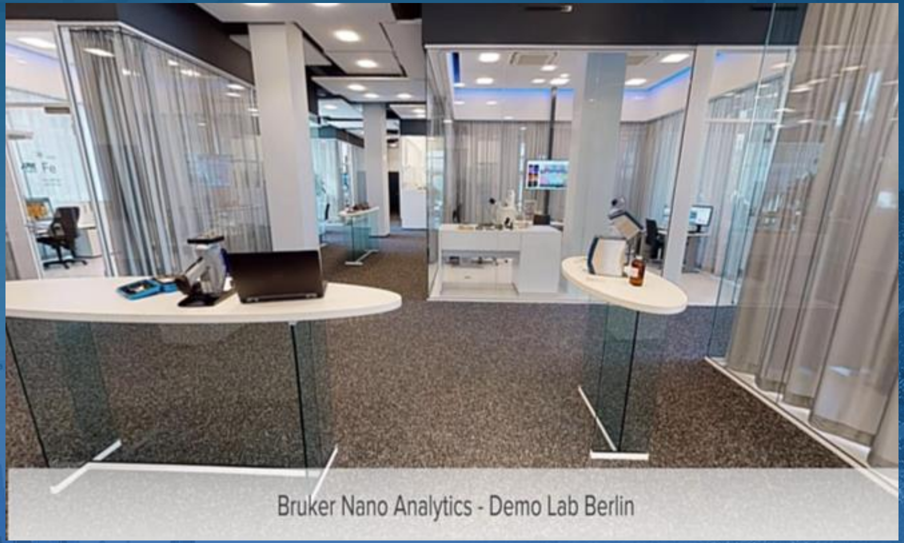

Presenters

Dr. Igor Németh
Application Scientist, Bruker Nano Analytics

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Application Scientist, Bruker Nano Analytics

Outline

- Introduction XFlash® 7 for SEM
  - Fast signal processing
  - Data/spectrum quality at high speeds
  - Esprit LiveMap: real time chemical imaging

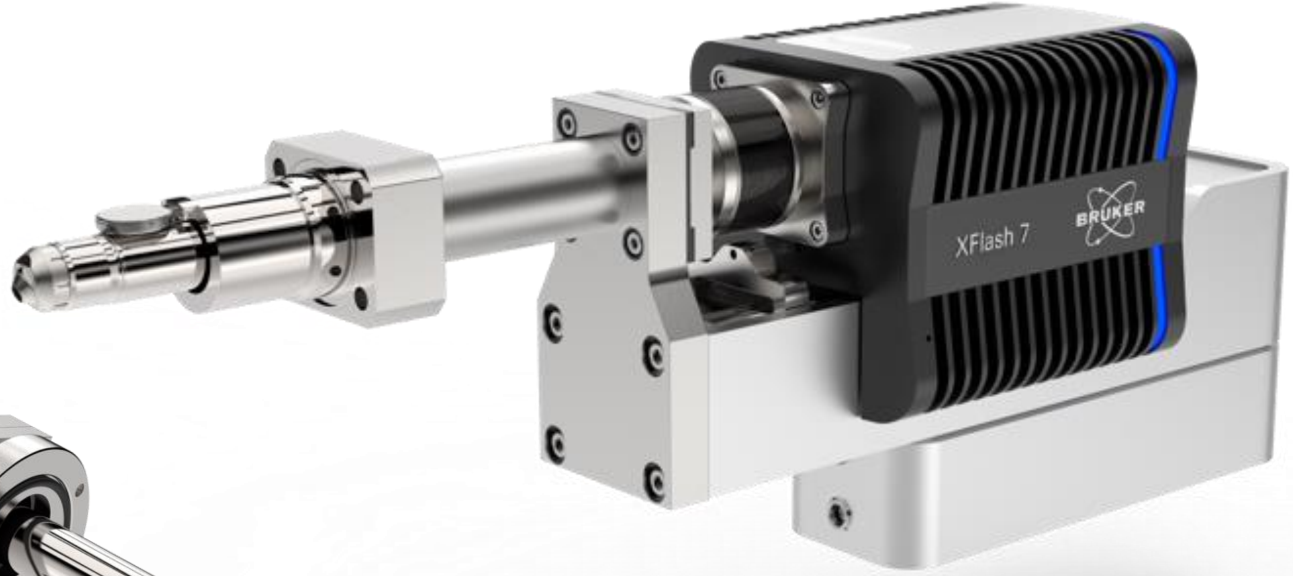
XFLASH® 7 DETECTOR WEBINAR SERIES PART I
Improving Efficiency with the XFlash® 7 EDS Detector Family
On-demand session downloadable from
www.bruker.com

- Achieving sub-10 nm EDS spatial resolution on bulk specimen in SEM
  - Spatial resolution in SEM: Influencing factors, beam diameter, kV, optimal pixel size
  - Optimal mapping settings for high resolution measurement. What to consider?
  - Application examples:
    - semiconductor structures (FinFET)
    - Ni-based single crystal superalloy

XFlash® 7

Fast. Precise. Reliable.

XFlash® 7 - the detector
for SEM and FIB-SEM



XFlash® 7T - the detector
for TEM and STEM

XFlash® 7 – Be faster!

With up to 1,000,000 cps the XFlash® 7 offers the highest real analytical throughput on the market for EDS detectors, meaning:

- Get best results in the shortest time
  - Fast survey maps
  - Fast particle analysis
- No risk of signal loss caused by slow read-out electronics
- Maximize your sample throughput without compromising quality
- ESPRIT LiveMap for real-time chemical imaging: use chemical information instead of BSE image signal to navigate on your sample

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Achieving sub-10 nm EDS spatial resolution on bulk specimen in SEM

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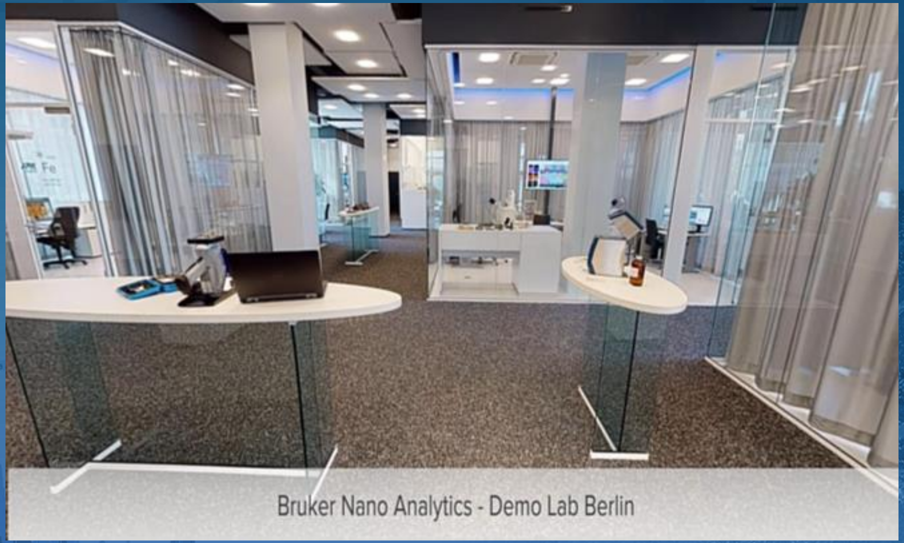
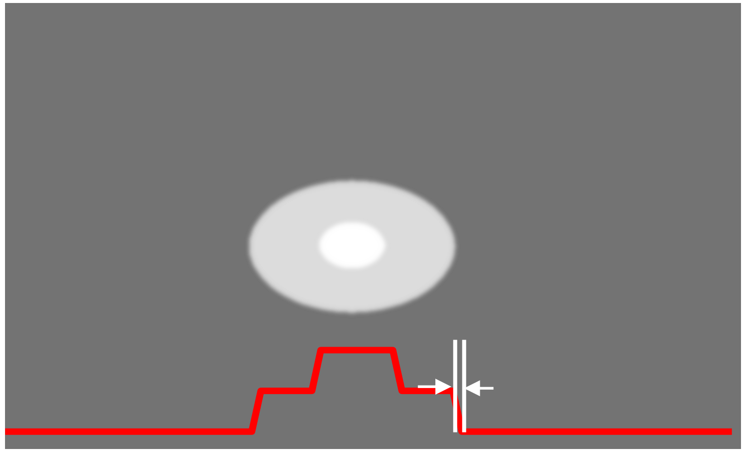
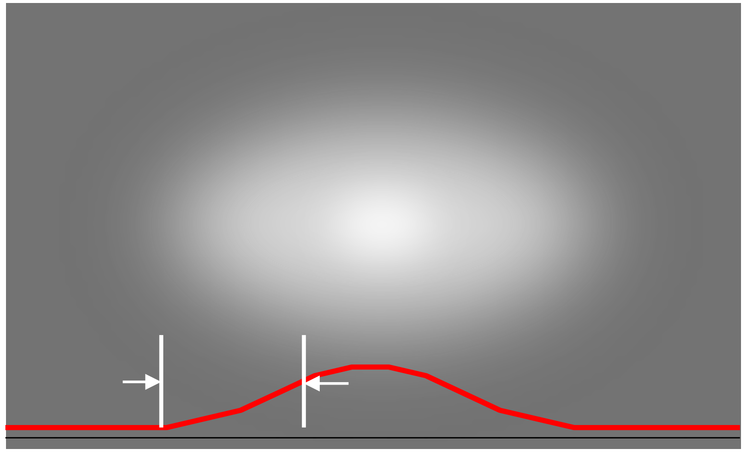


Spatial resolution

- Discern or separate distinct two features -> Spatial resolution
- Separate fine scale features -> High spatial resolution
- Fine scale/High magnification? -> Application

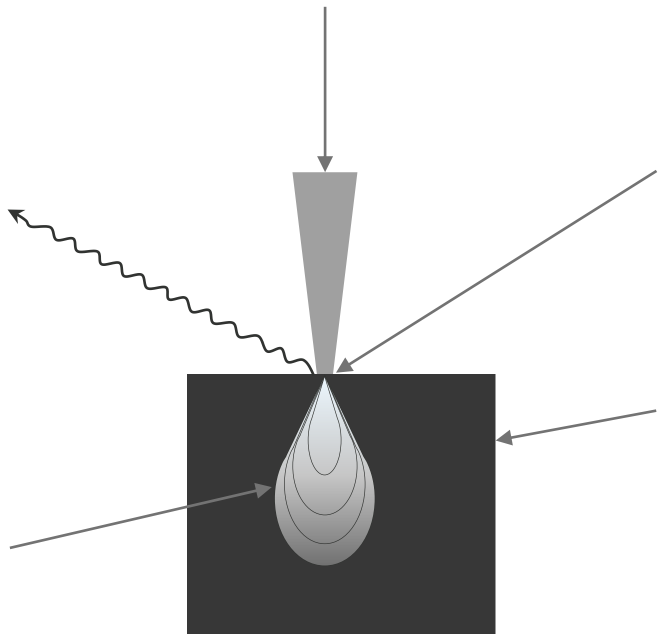


Sharp features – good spatial resolution

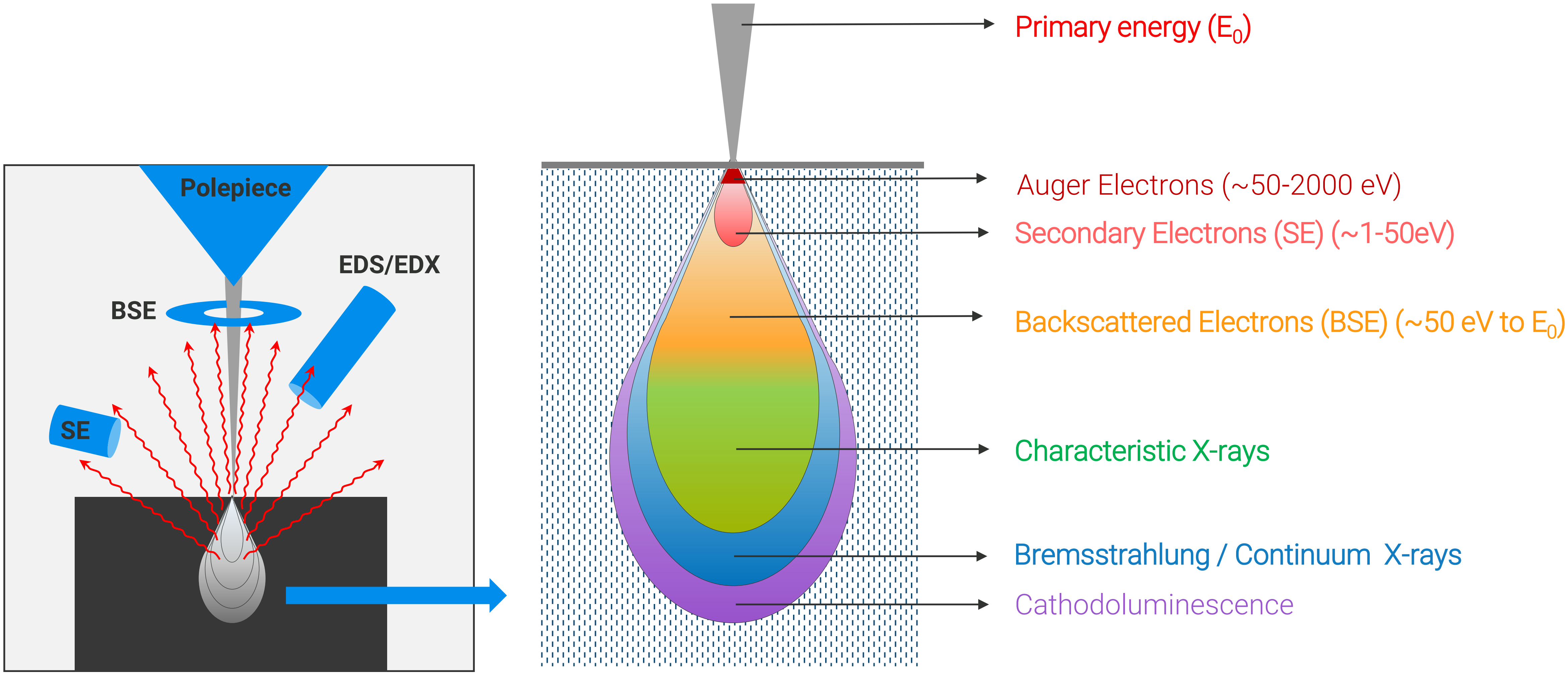


Blurred features – bad spatial resolution

Spatial resolution in SEM



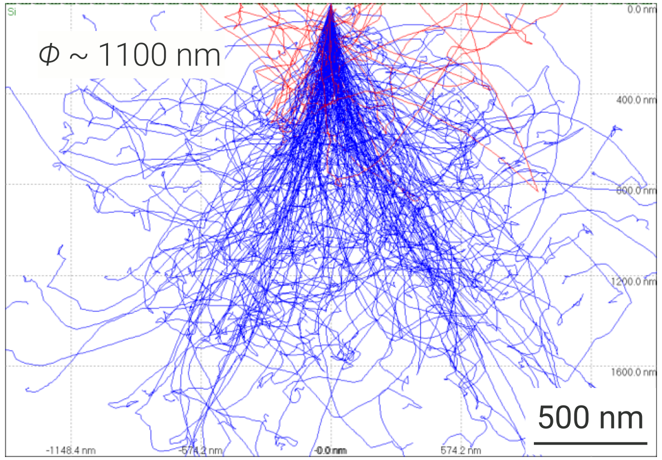
Interaction volume – signal generation



Interaction volume – different materials

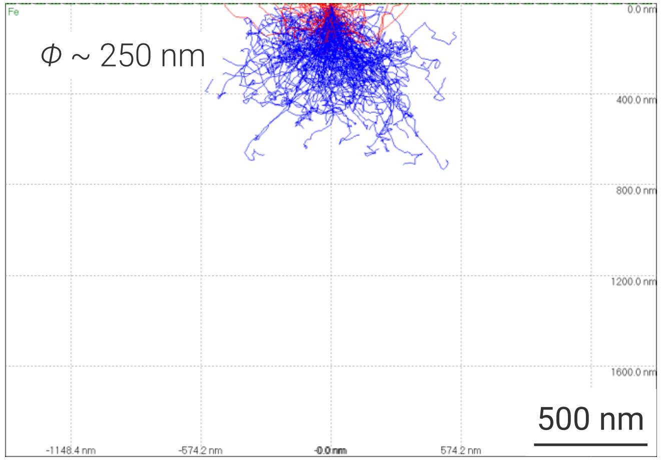
- Signal generation depth (interaction volume) at 15 kV for different materials

Si - 15 kV



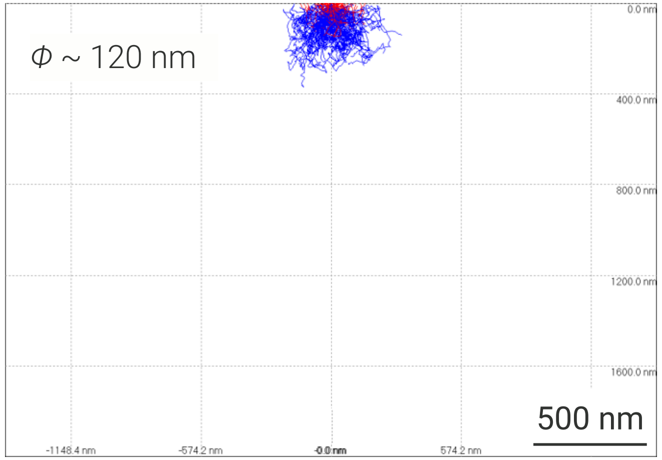
Z = 14 ρ = 2.33 g/cm^3 Kα = 1.74 keV

Fe - 15 kV



Z = 26 ρ = 7.86 g/cm^3 Kα = 6.40 keV

W - 15 kV

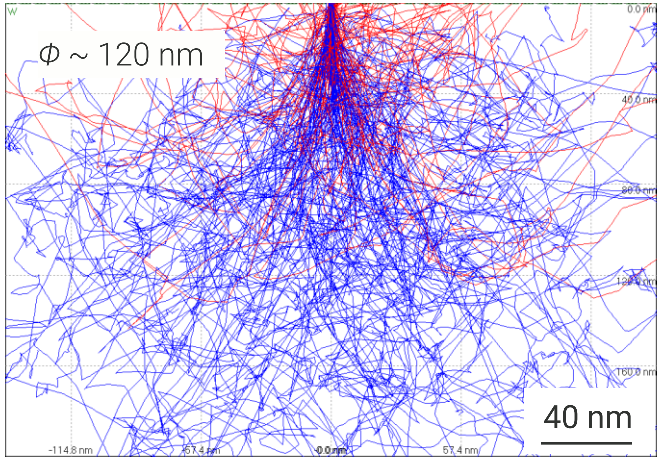


Z = 79 ρ = 19.3 g/cm^3 Lα = 9.70 keV

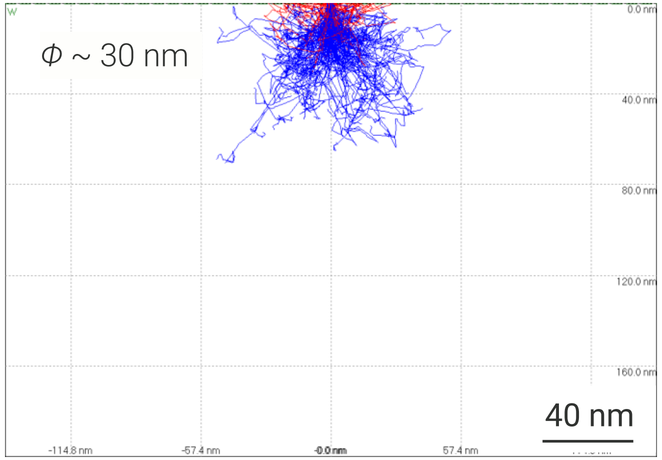
Interaction volume – different kVs

- Signal generation depth (interaction volume) for W at different primary energies

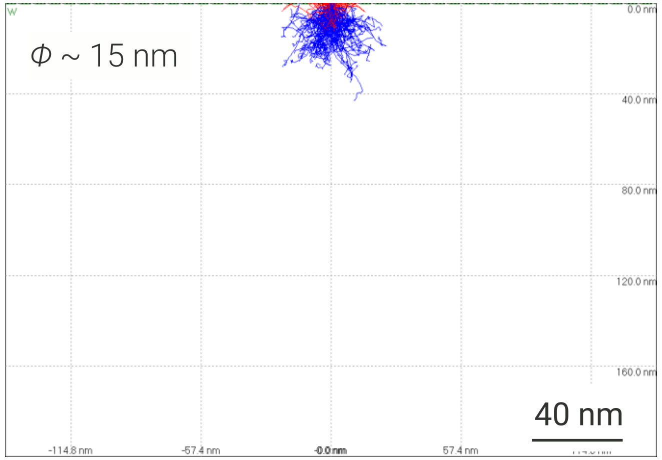
W - 15 kV



W - 5 kV



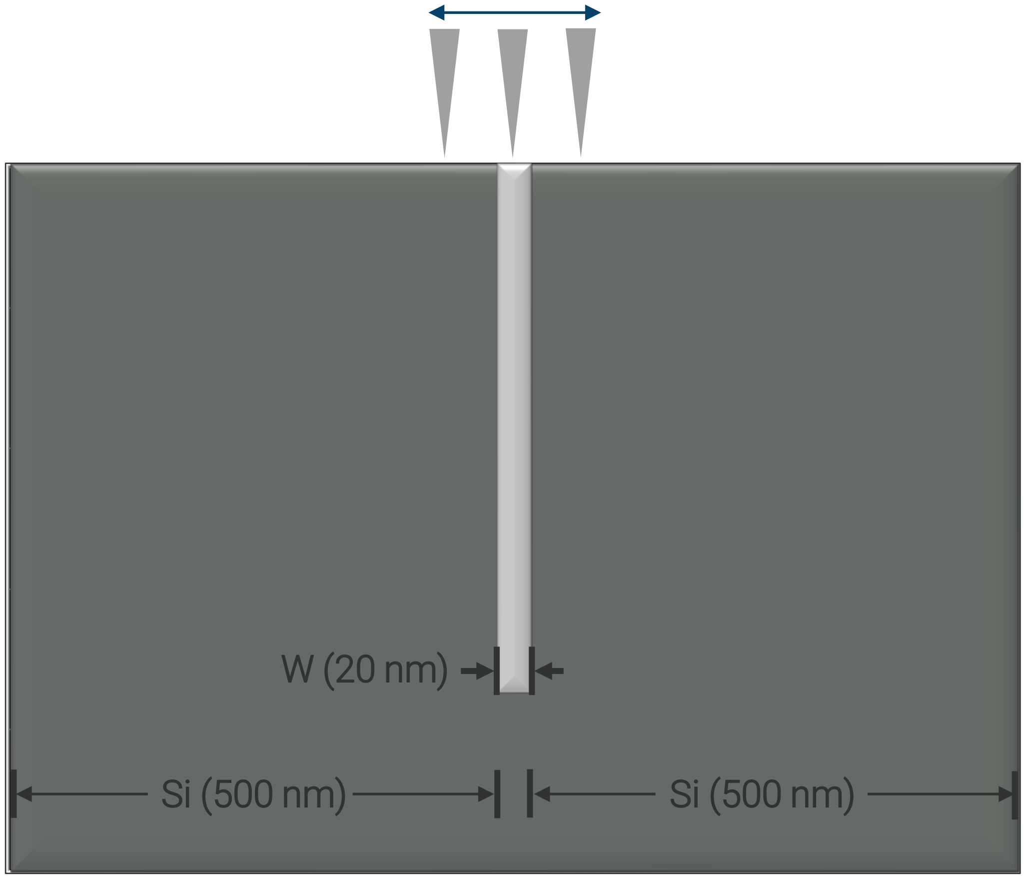
W - 3 kV



Z = 74 ρ = 19.3 g/cm^3 Lα = 8.39 keV

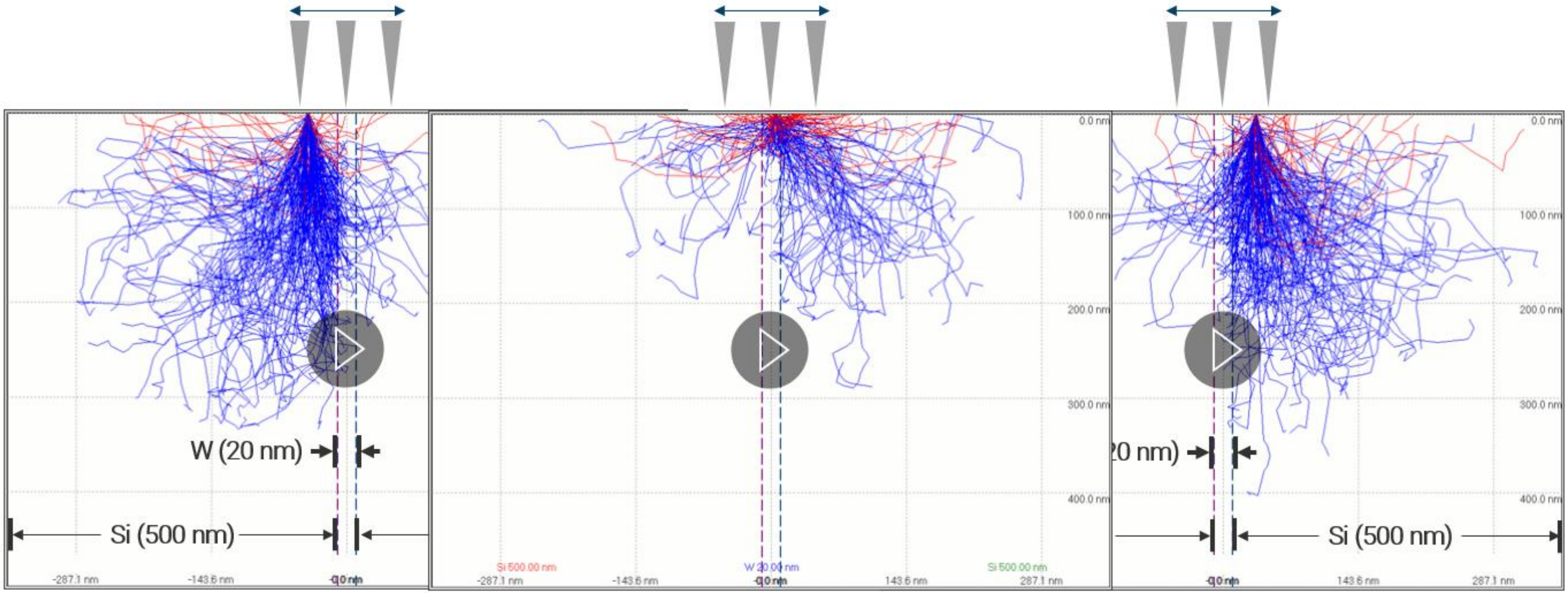
Interaction volume generation Si – W – Si

- 5 kV beam scanning across a 20 nm tungsten (W) layer in Silicon (Si)



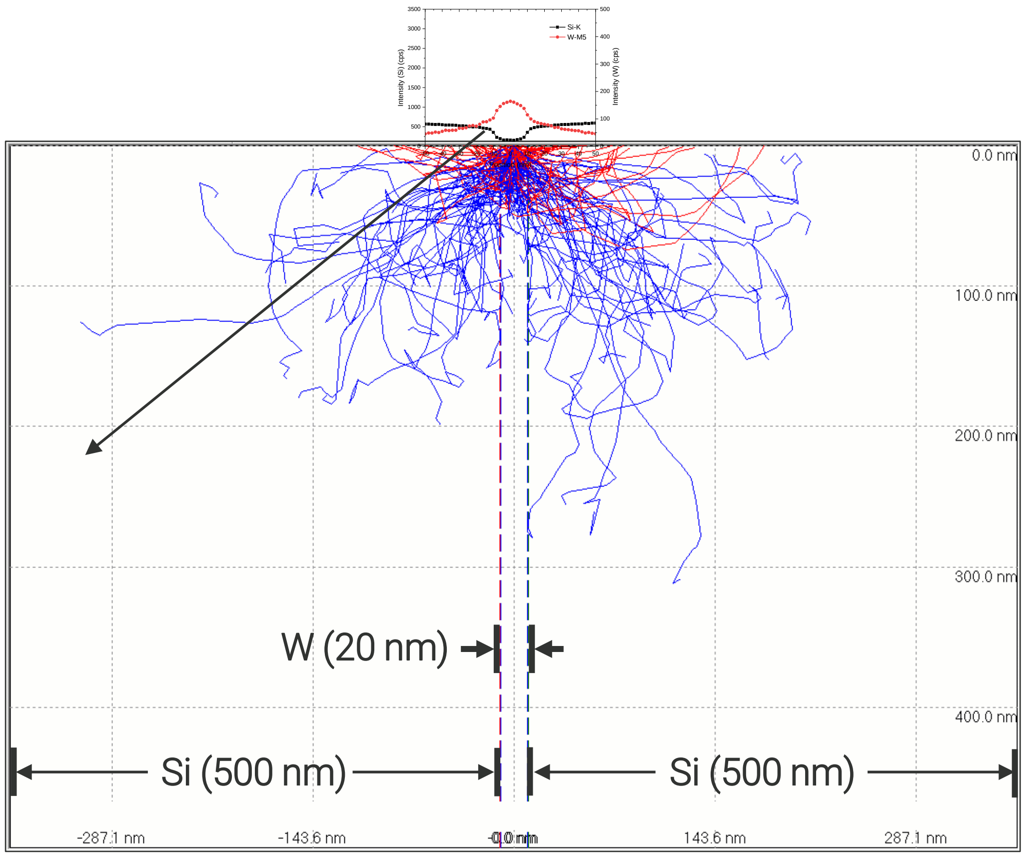
Interaction volume generation Si – W – Si

- 5 kV beam scanning across a 20 nm tungsten (W) layer in Silicon (Si)

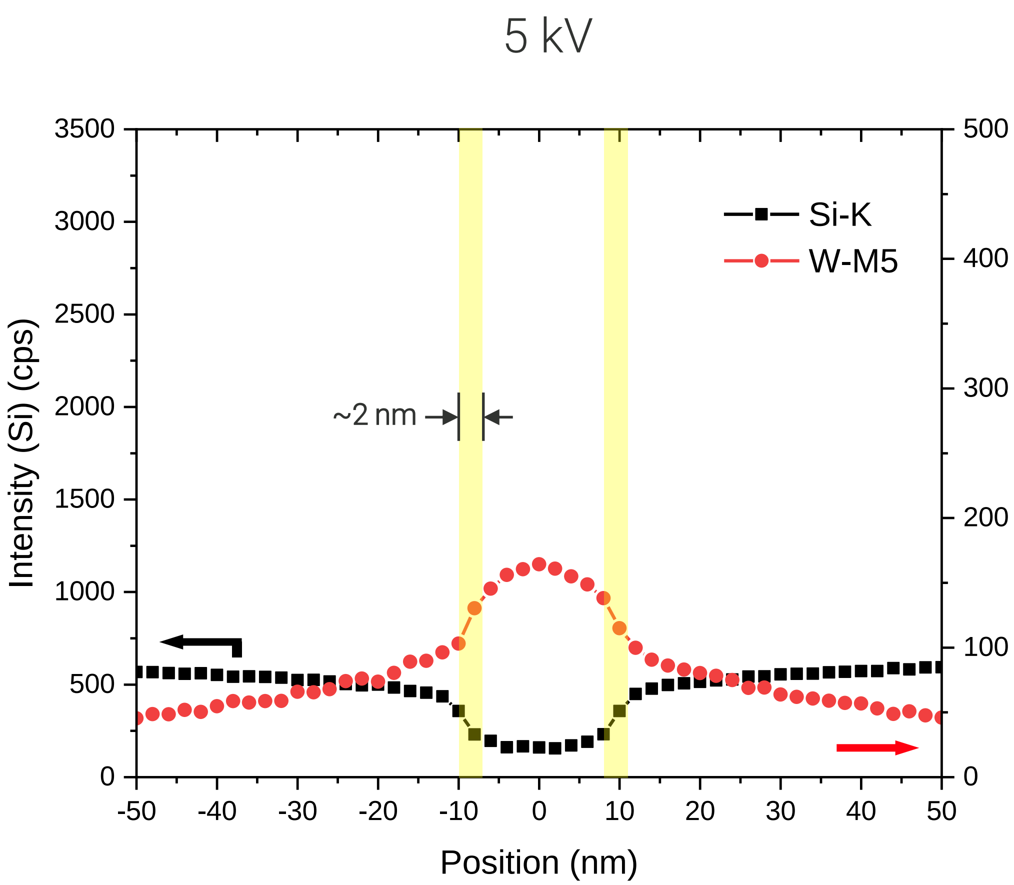


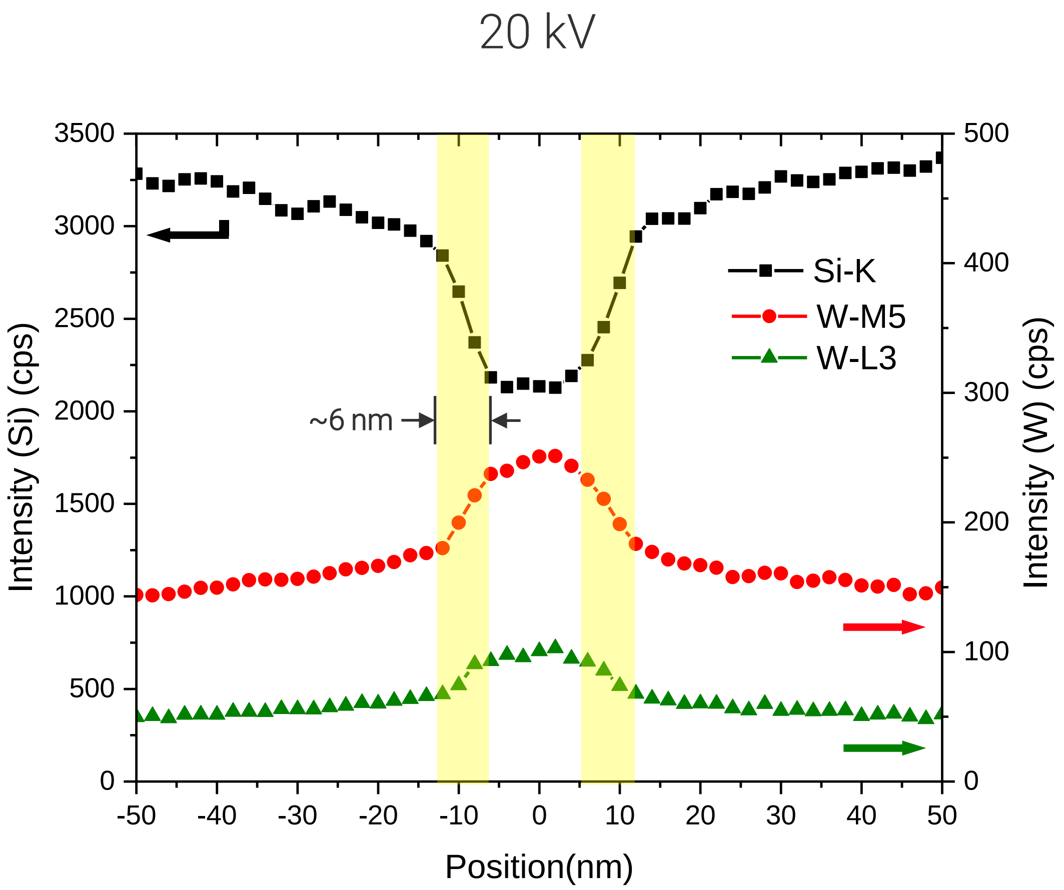
Intensity of X rays generated across Si – W – Si

- 5 kV beam scanning across a 20 nm tungsten (W) layer in Silicon (Si)



Intensity of X rays generated across Si – W – Si



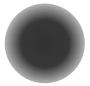


Radial distribution of x-ray intensity vs. Beam diameter

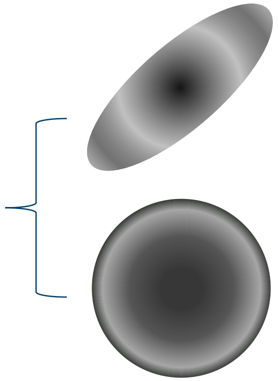
Importance of beam focusing

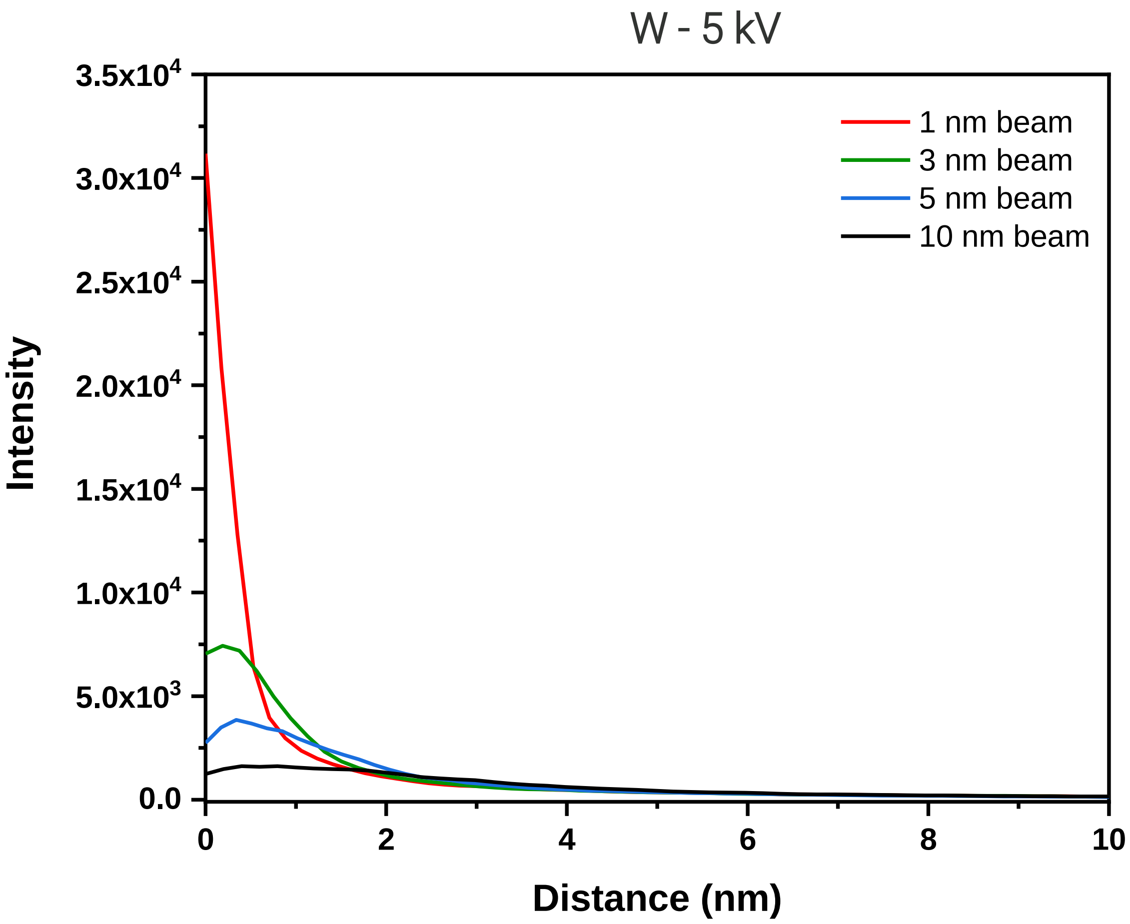
- Intensity of generated x rays is higher for smaller beam diameter – lower noise around signal

Well focused beam – Sharp interfaces



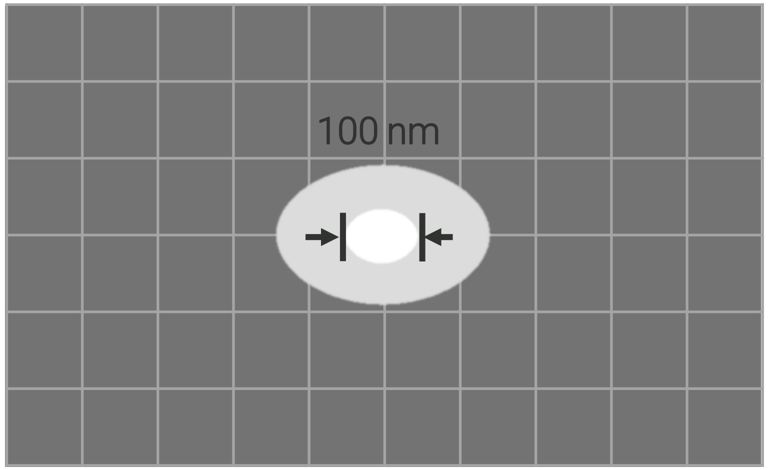
Distorted beam – more noise in map





Pixel size

Image res: 10 × 6 pixels, pixel size = 100 nm

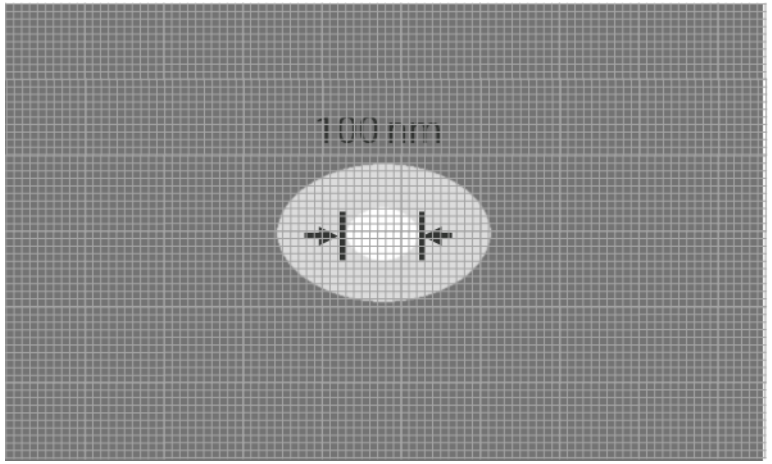


Map = 60 pixels (Under sampling)

Map counts = 200,000

Mean = 3333 counts/pixel

Image res: 200 × 120 pixels, pixel size = 5 nm

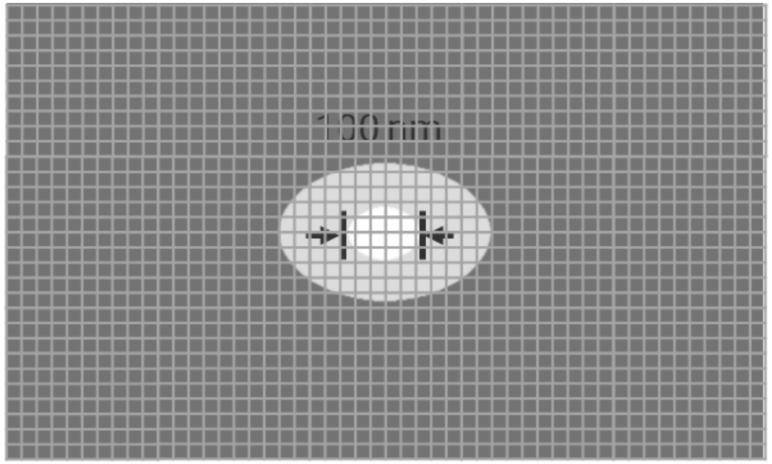


Map = 24000 pixels (Oversampling)

Map counts = 200,000

Mean = 8.33 counts/pixel

Image res: 50 × 30 pixels, pixel size = 20 nm



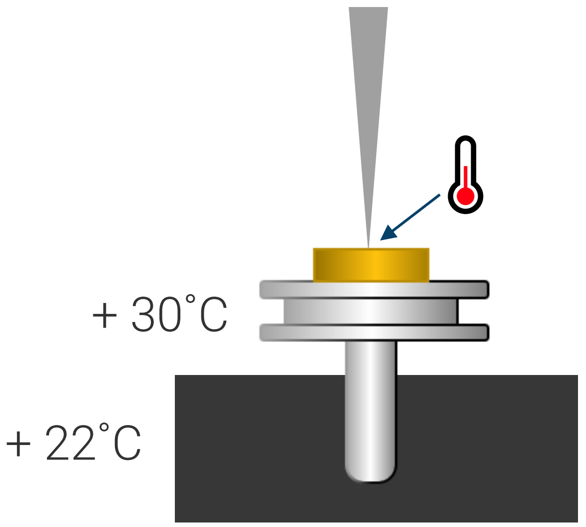
Map = 1500 pixels (reasonable sampling)

Map counts = 200,000

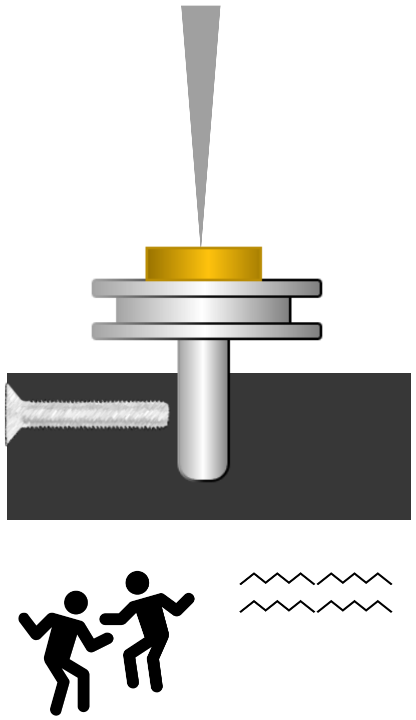
Mean = 200 counts/pixel

Image drift in SEM – Types

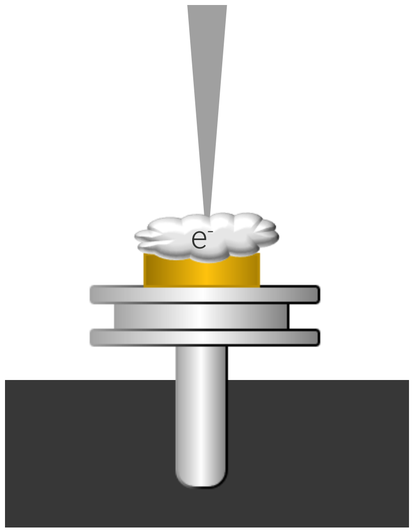
Thermal drift



Mechanical drift

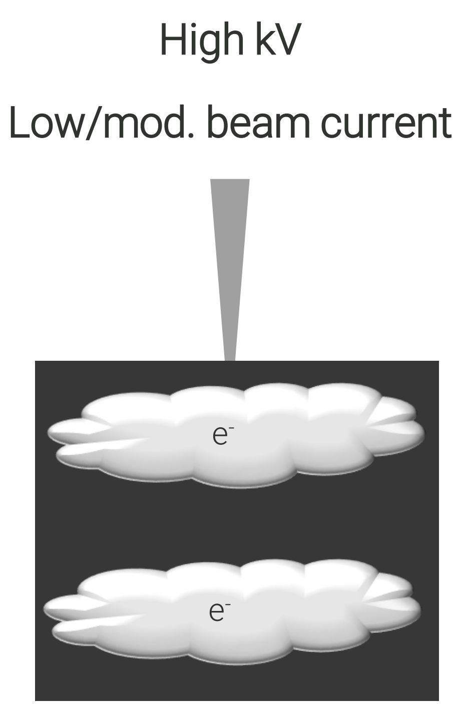


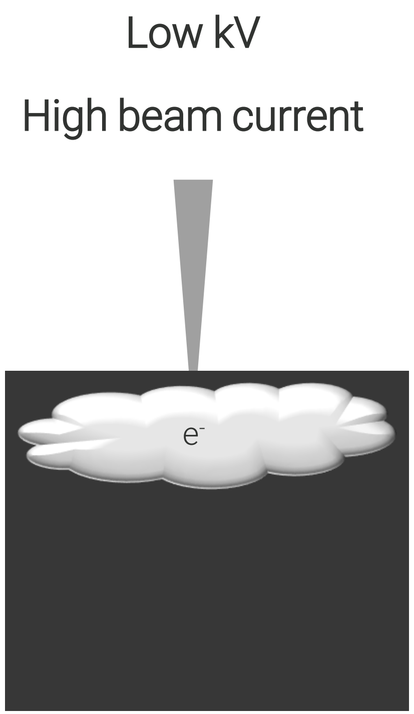
Charge accumulation drift

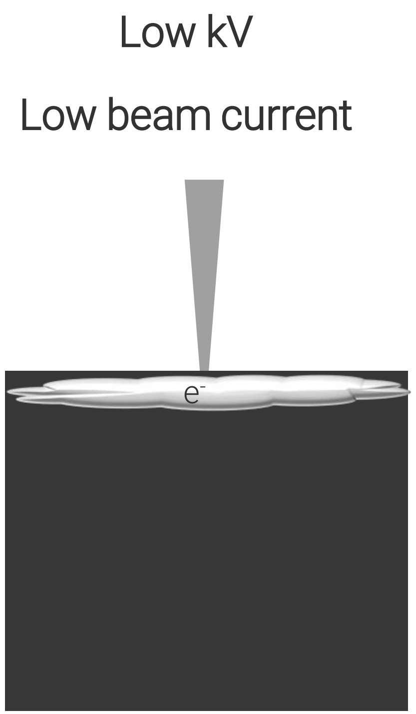


- Beam conditions
- Pixel dwell time

Charge accumulation drift – Beam conditions

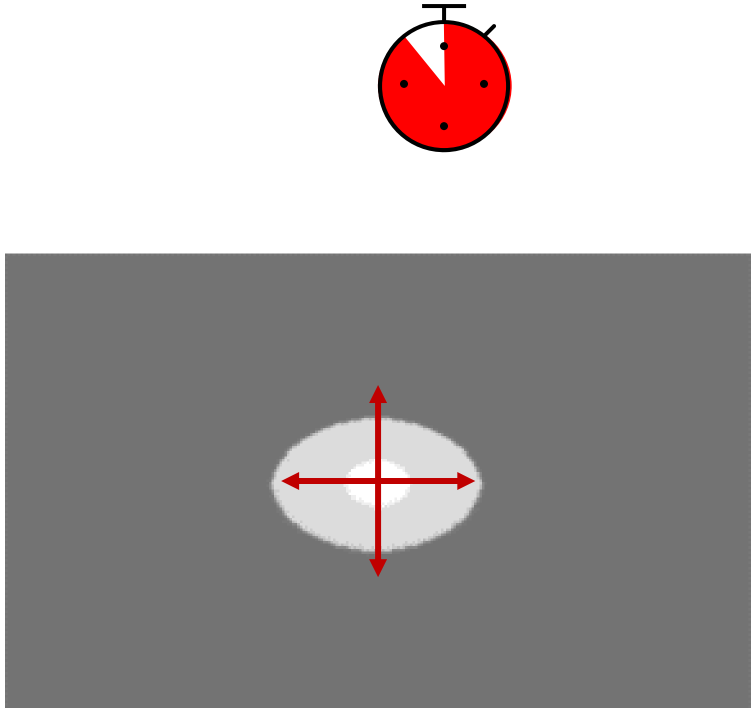




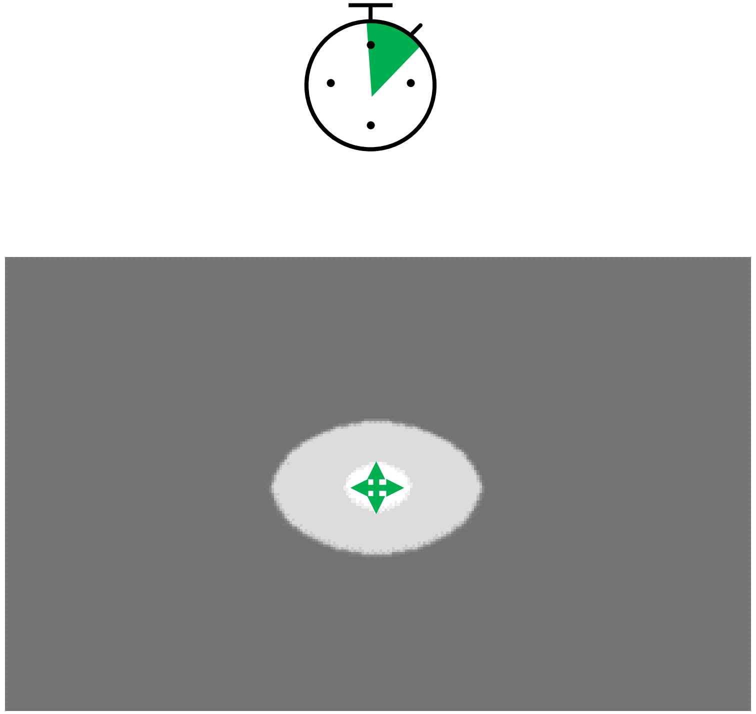


Charge accumulation drift – Pixel dwell time/scan speed

- Longer dwell time (Higher charge accumulation)
- Shorter dwell time (Lower charge accumulation)



more sample drift

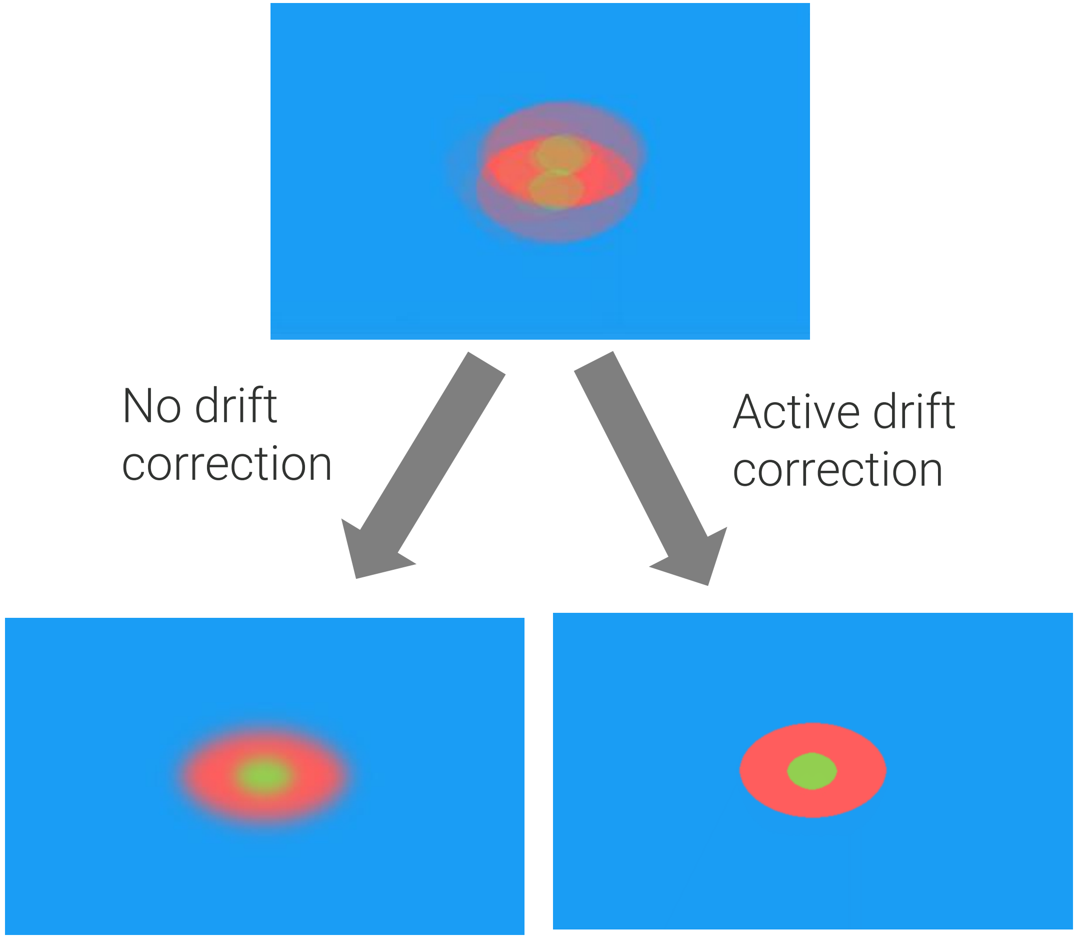


less sample drift

Drift Co. – a must!

Drift compensation and SEM image shift

- Image drift is corrected using the SEM image overlay compensation.
- Pixel XY position retained on a feature or interface
- In-lens detector input can also be used (SE contrast is too low)
- Reduced area mapping – better drift correction range



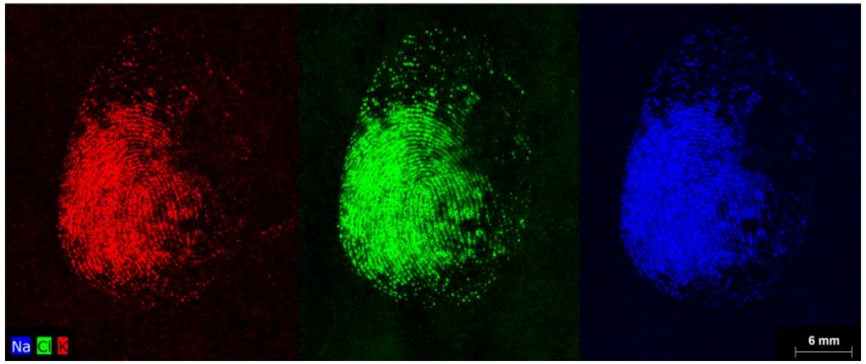
Additional precautions

- Sample mounting must be strong/stiff/steady
- Let stage and beam stabilize for 20 min
- Vibration damping system
- Evening measurements (low disturbance)
- C coating (~10 nm) for charging samples

High spatial resolution EDS measurements - Checklist

- Diameter of primary electron beam
- Pixel and map size – avoiding oversampling
- Charging samples – Starting with low kV and low beam current settings
- Drift correction

- **Clean sample, holders and stage**

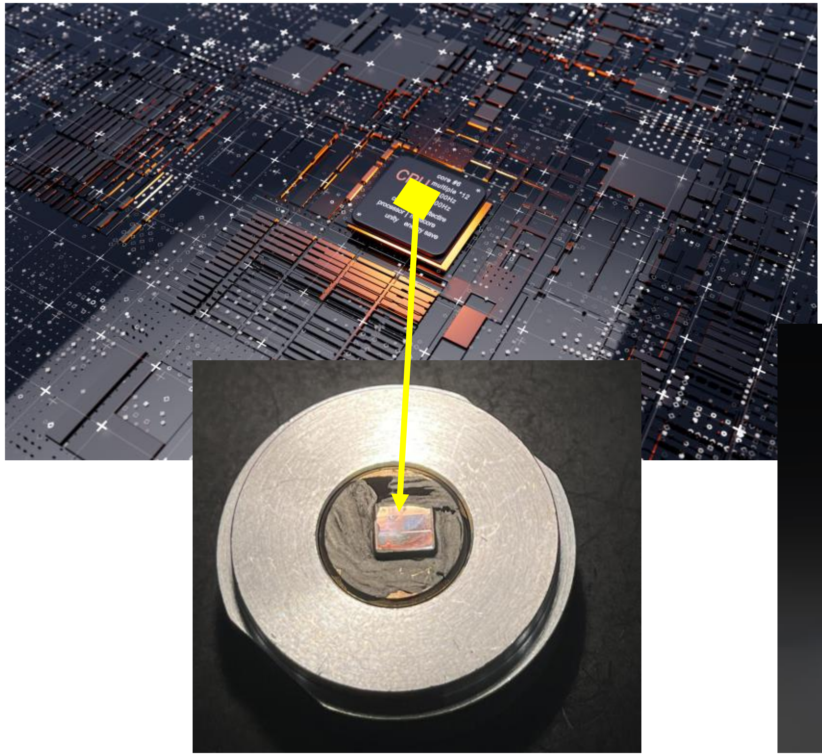


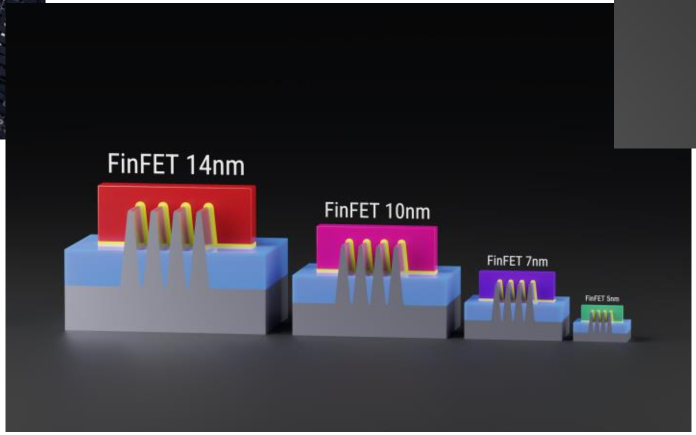
micro-XRF map of a fingerprint

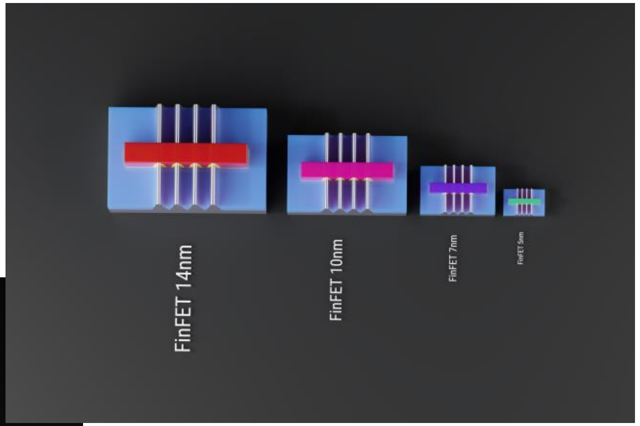
Minimize beam/carbon contamination on the samples!!

Application examples

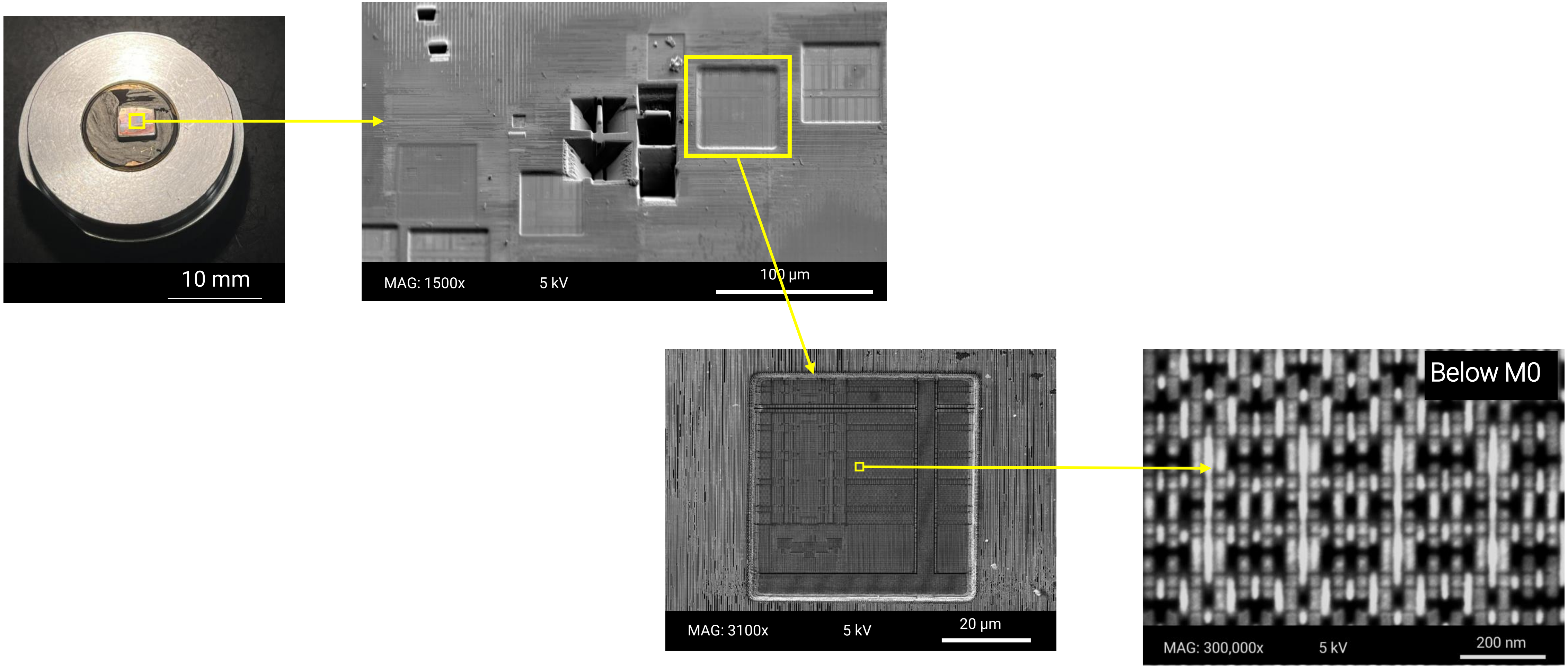
1. CPU (FinFET)





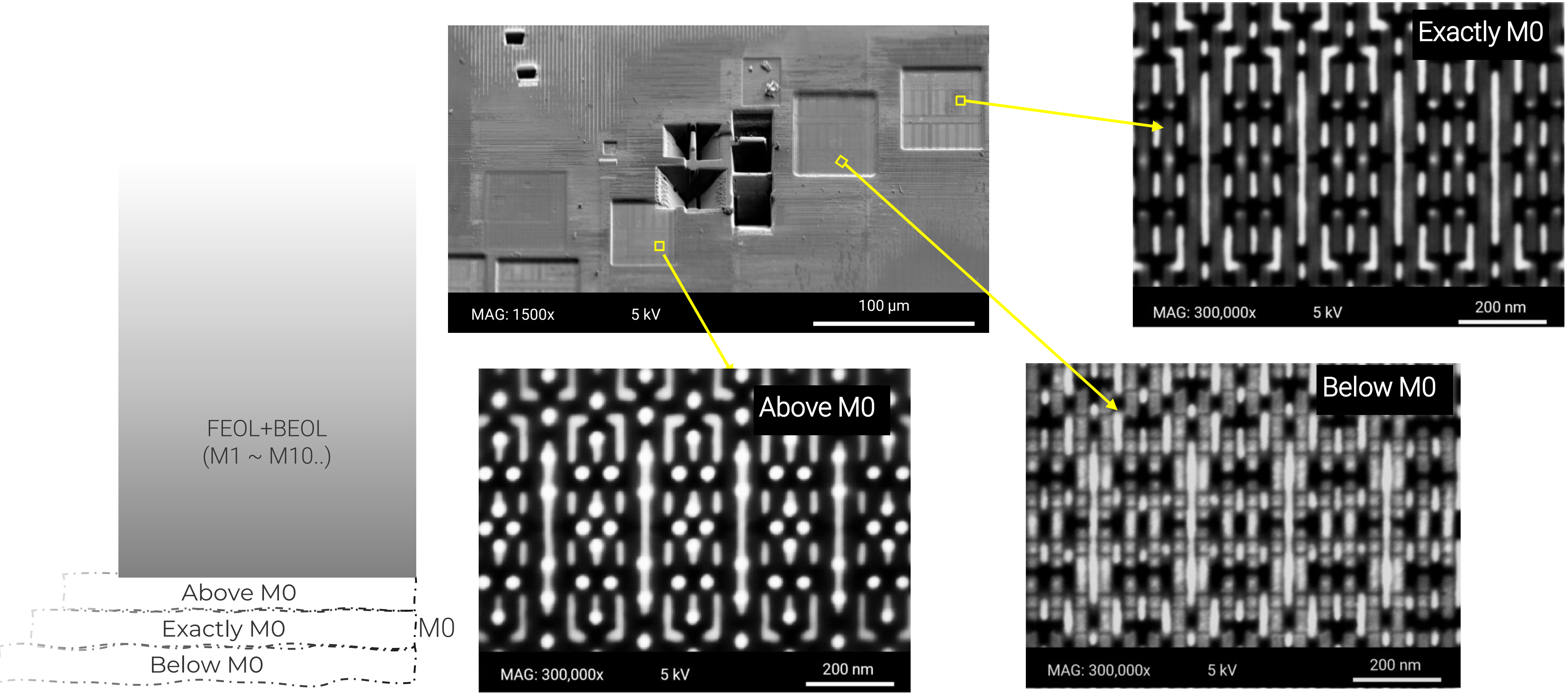


Deprocessed CPU (FinFET) – PFIB delayering



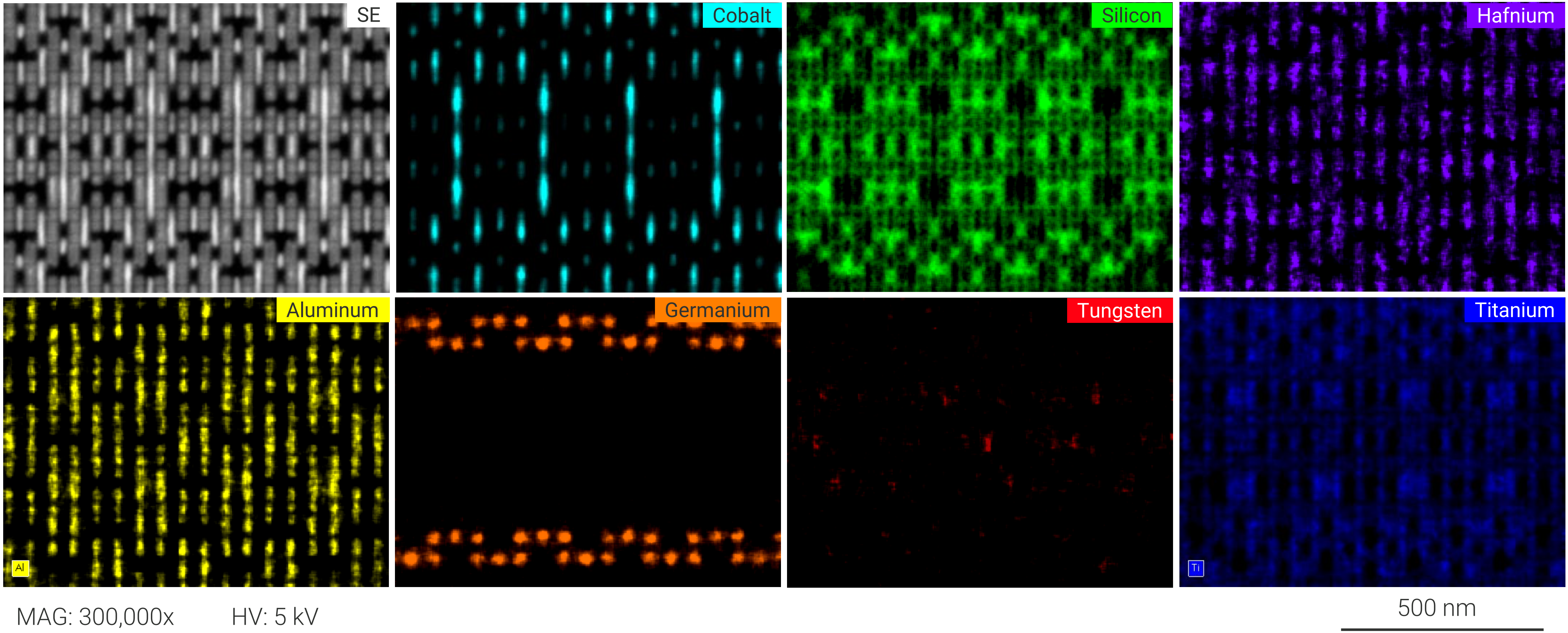
Sample courtesy: Dr. Andrey Denisyuk, TESCAN ORSAY HOLDING, a.s, Brno, CZ

Deprocessed CPU (FinFET) – PFIB delayering

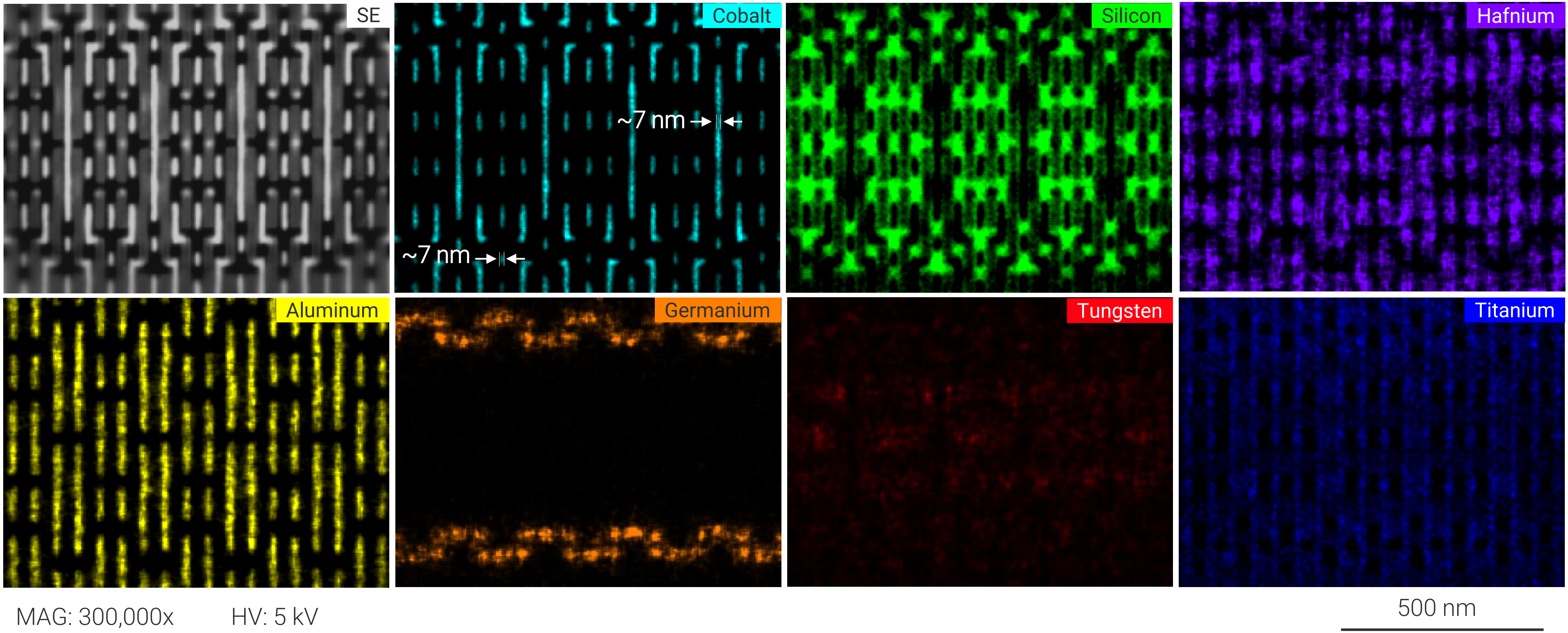


Sample courtesy: Dr. Andrey Denisyuk, TESCAN ORSAY HOLDING, a.s, Brno, CZ

5 kV, 300kx MAG, Below M0

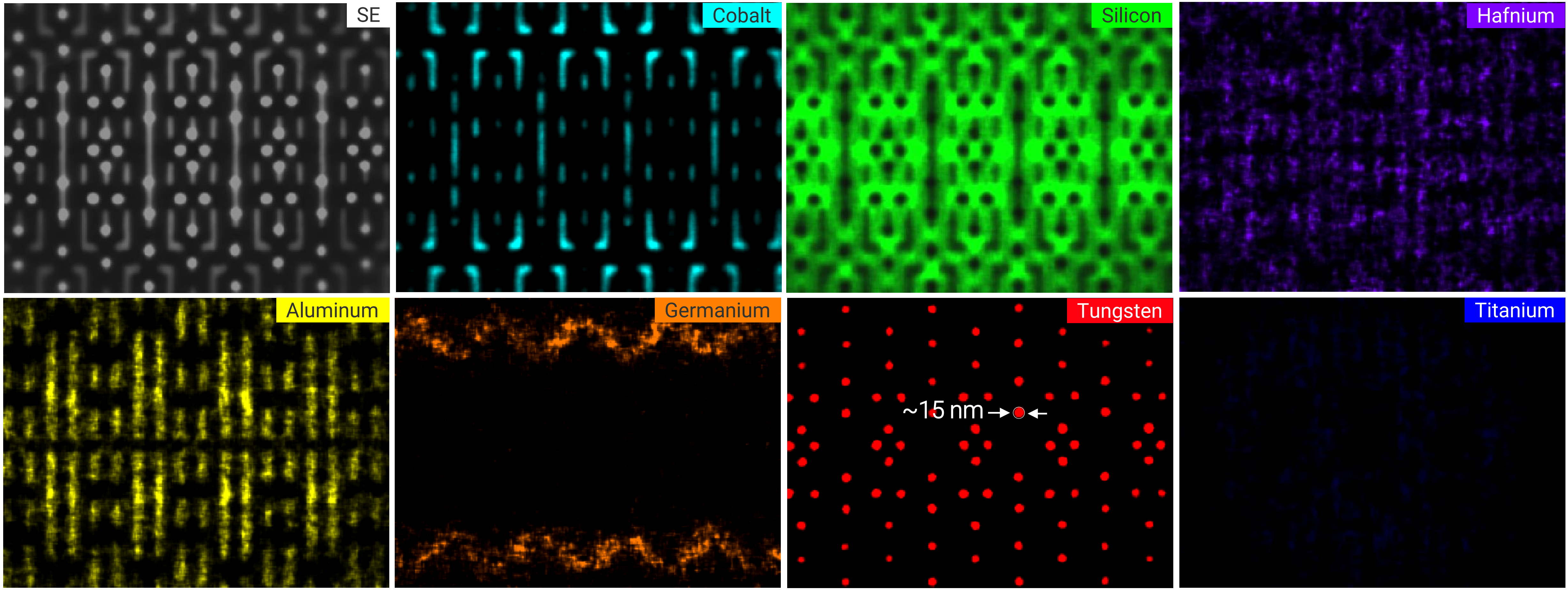


5 kV, 300kx MAG, Exactly M0



MAG: 300,000x HV: 5 kV

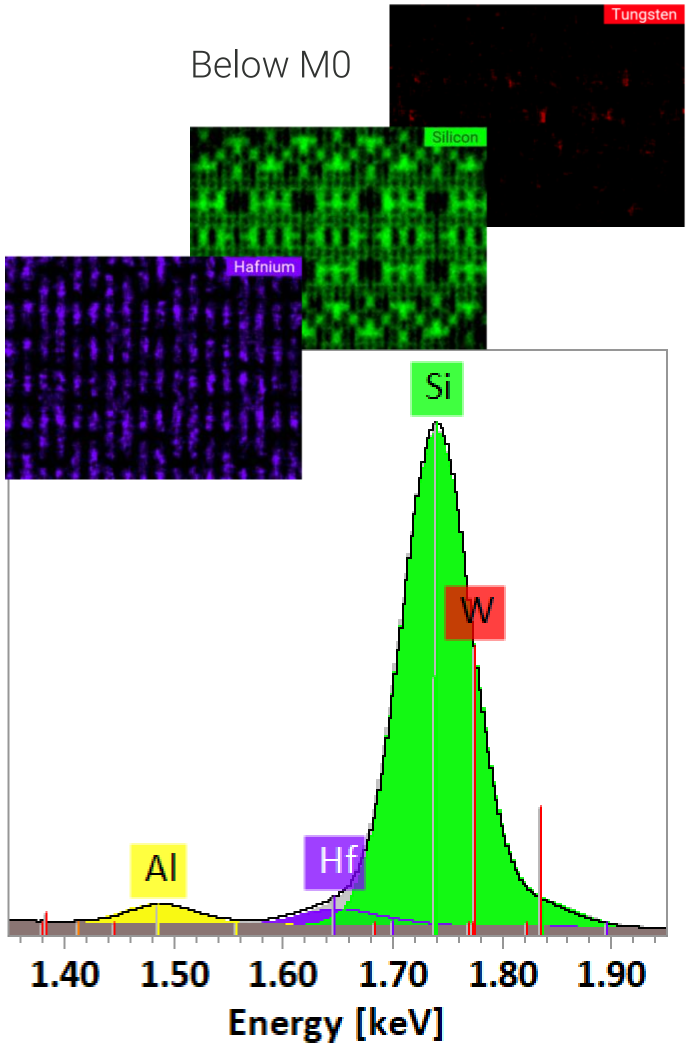
5 kV, 300kx MAG, Above M0

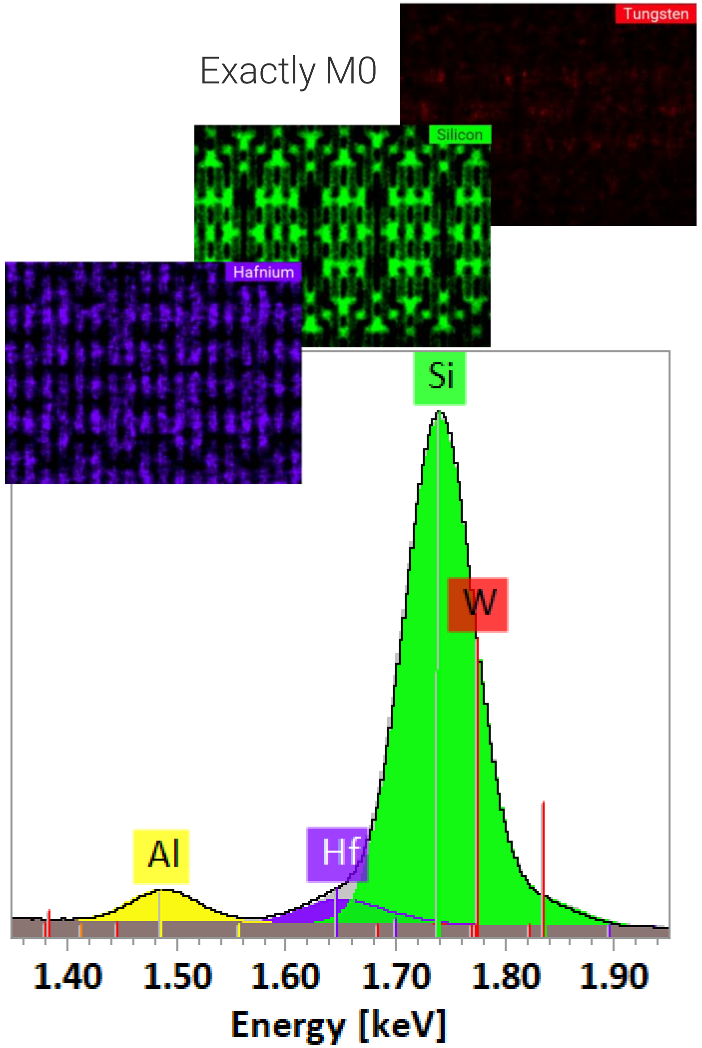


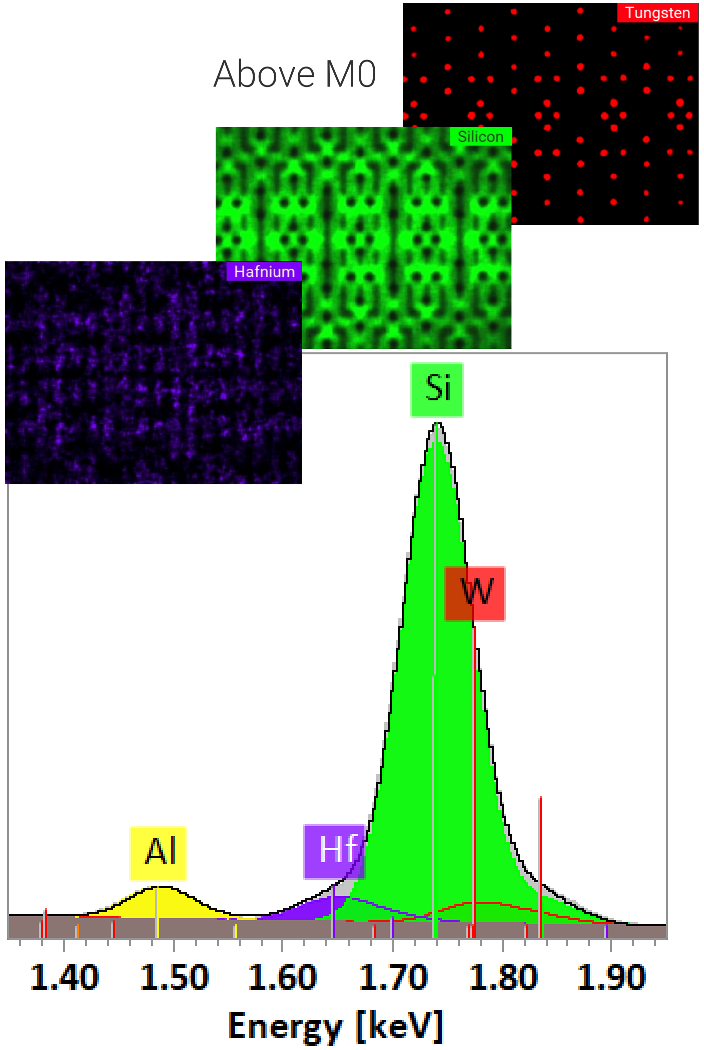
MAG: 300,000x HV: 5 kV

500 nm

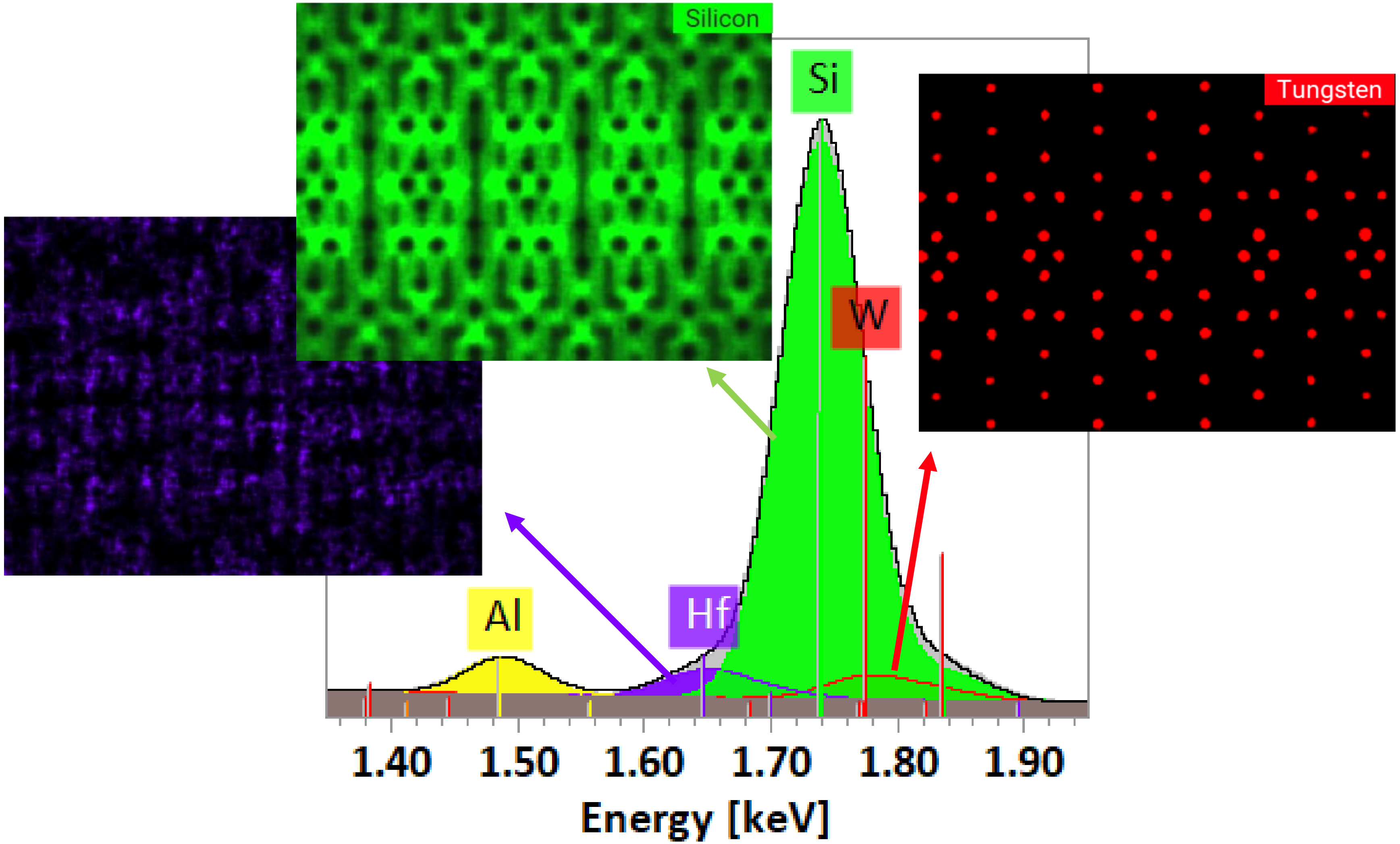
Automatic peak deconvolution







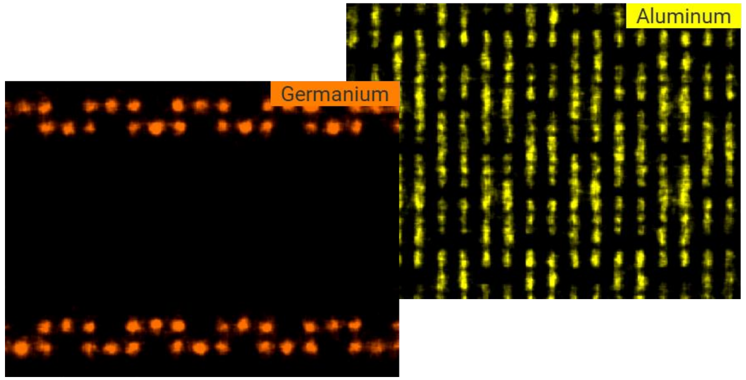
Automatic peak deconvolution – Above M0



Measurement parameters

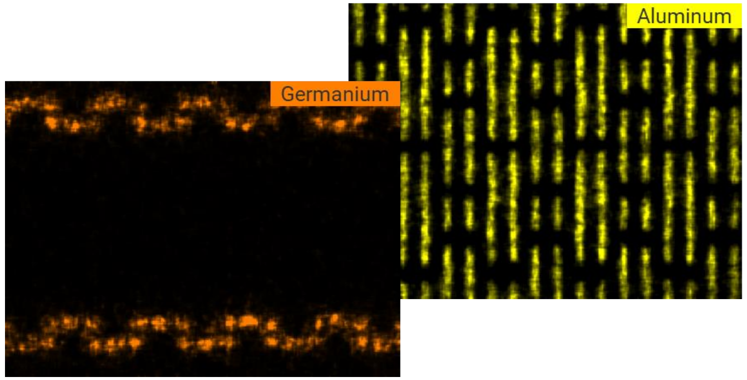
Below M0

EDS MEASUREMENT PARAMETERS	
Measurement time	60 min
Count rate	15500 cps
Probe current	380 pA
Dead time	18%
Total counts	4.6E+7 (46M)
H-FOV	1000 nm
Map size	300 x 225 px



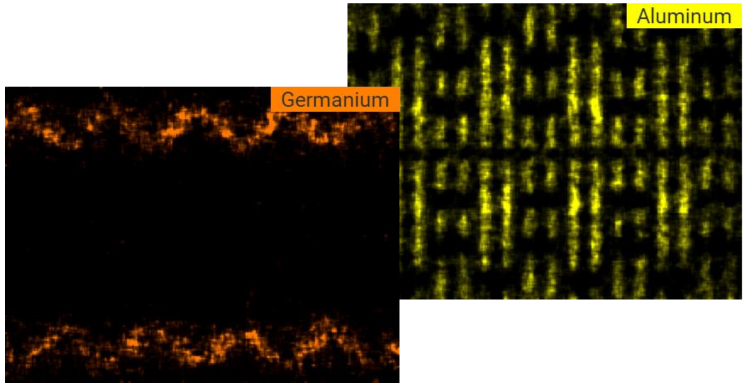
Exactly M0

EDS MEASUREMENT PARAMETERS	
Measurement time	55 min
Count rate	15200 cps
Probe current	350 pA
Dead time	17%
Total counts	4.2E+7 (42M)
H-FOV	1000 nm
Map size	300 x 225 px

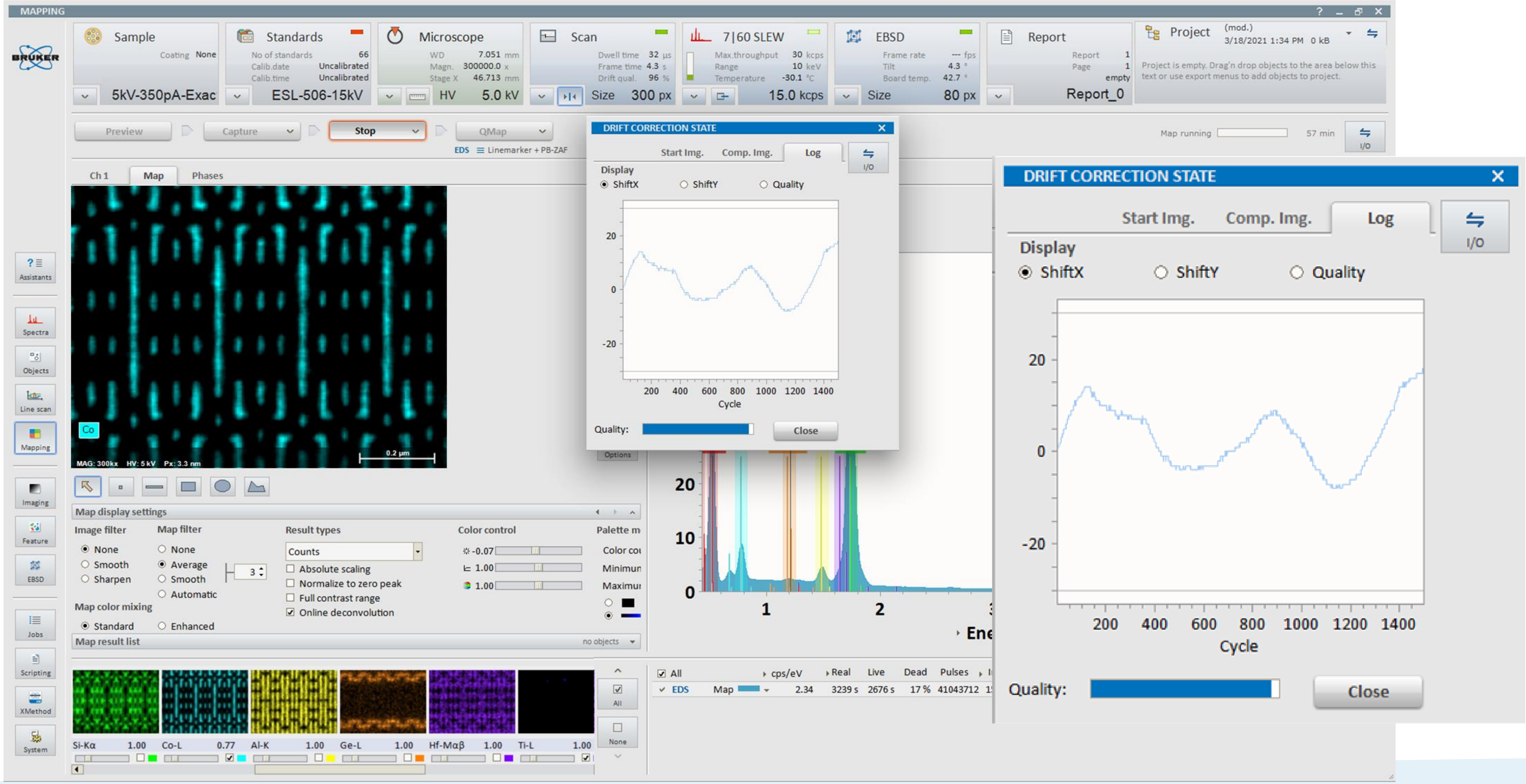


Above M0

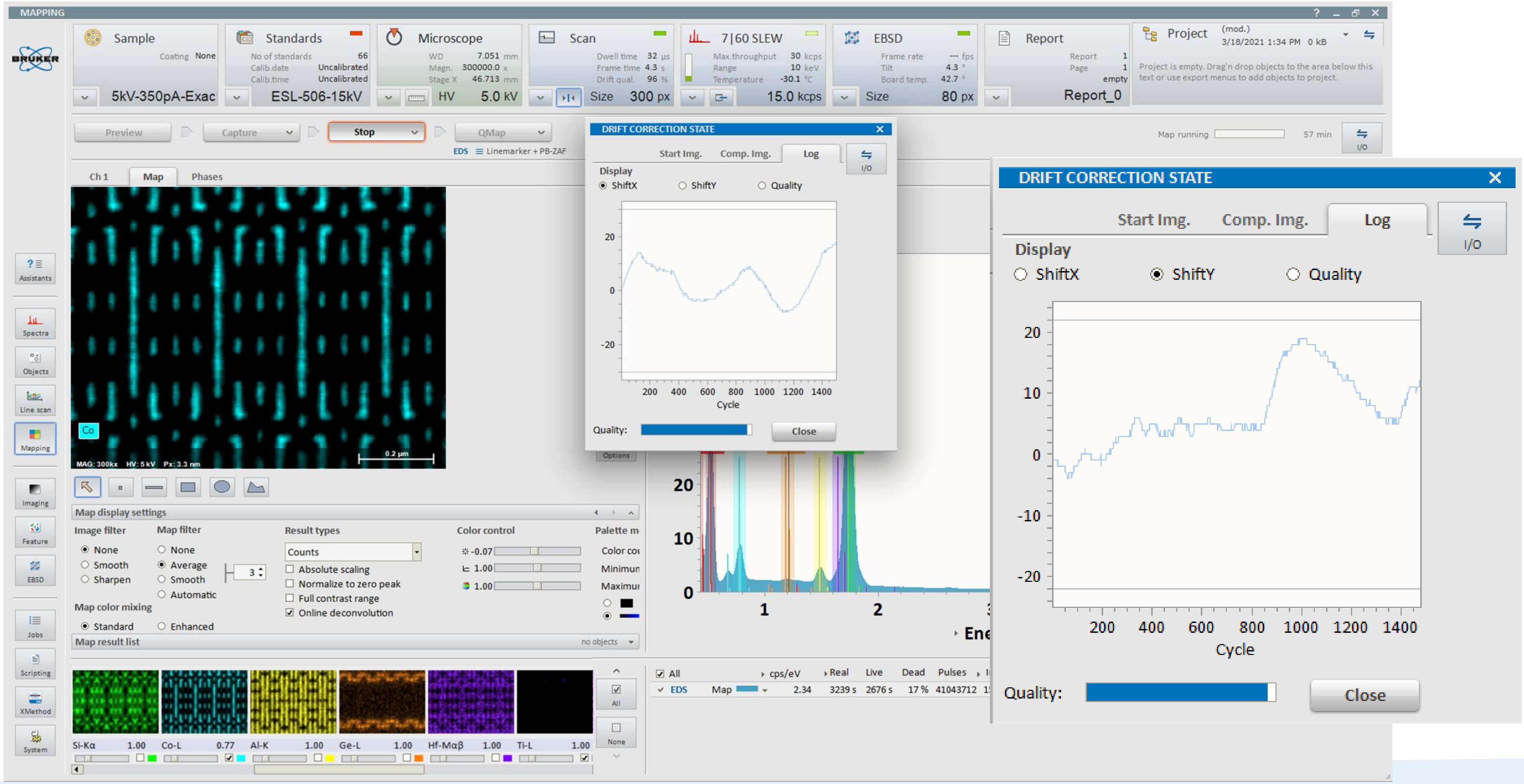
EDS MEASUREMENT PARAMETERS	
Measurement time	60 min
Count rate	15600 cps
Probe current	390 pA
Dead time	18%
Total counts	4.6E+7 (46M)
H-FOV	1000 nm
Map size	300 x 225 px



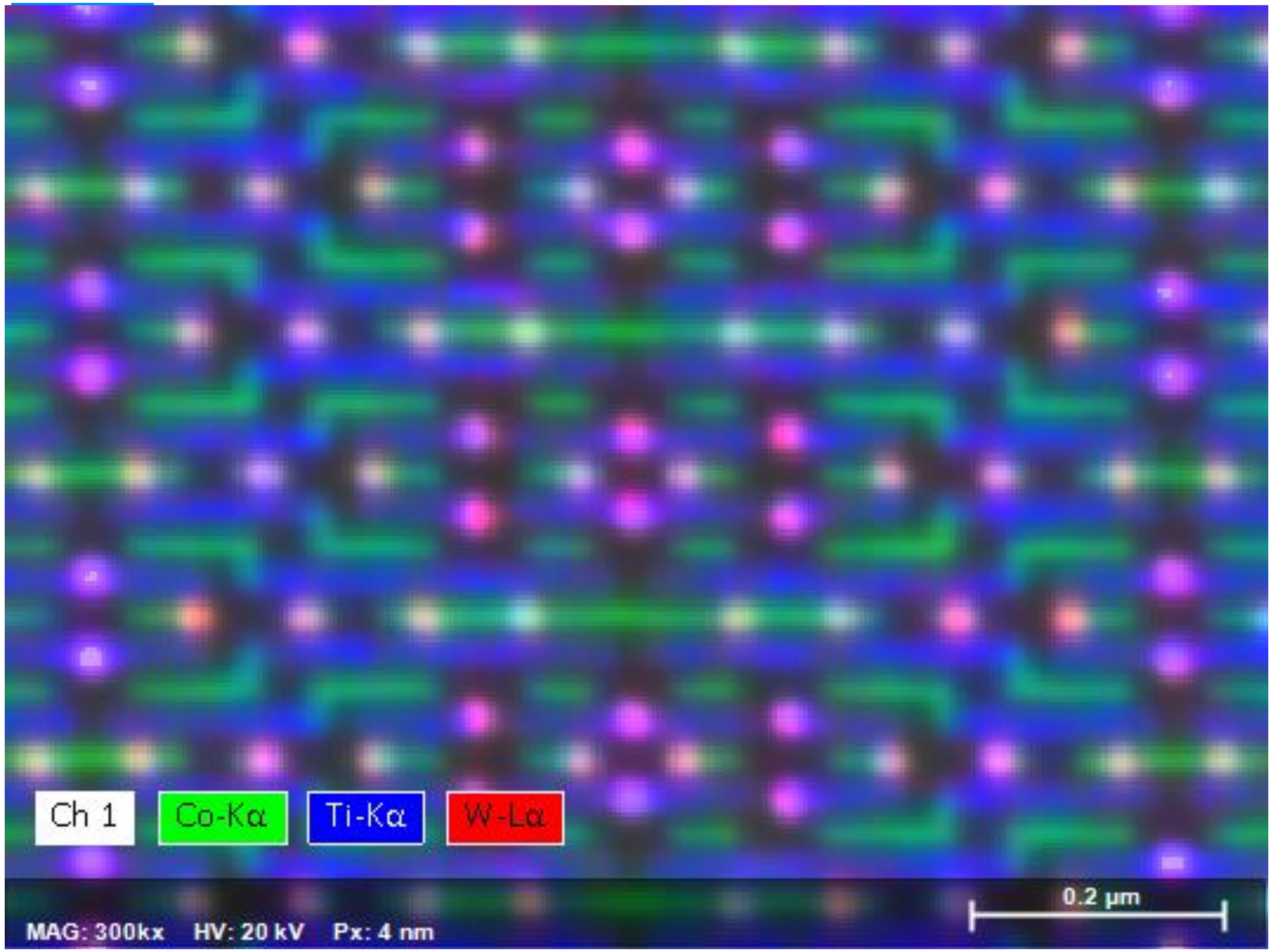
Drift correction



Drift correction



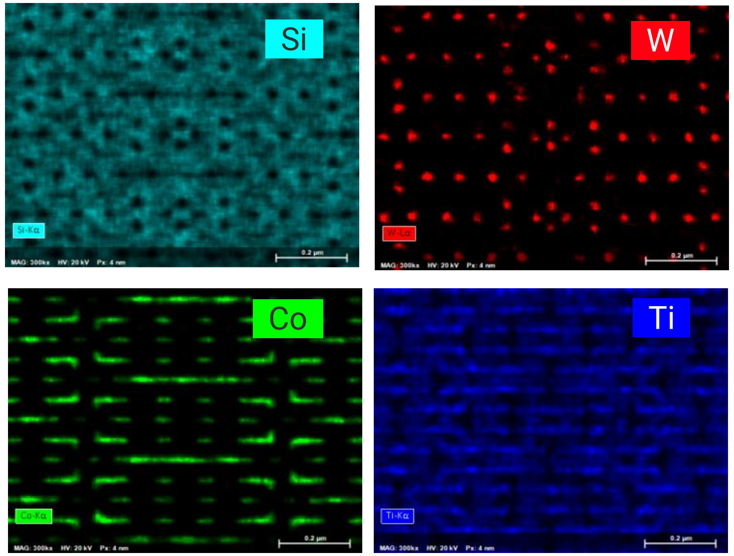
20 kV, 300kx MAG, Above M0



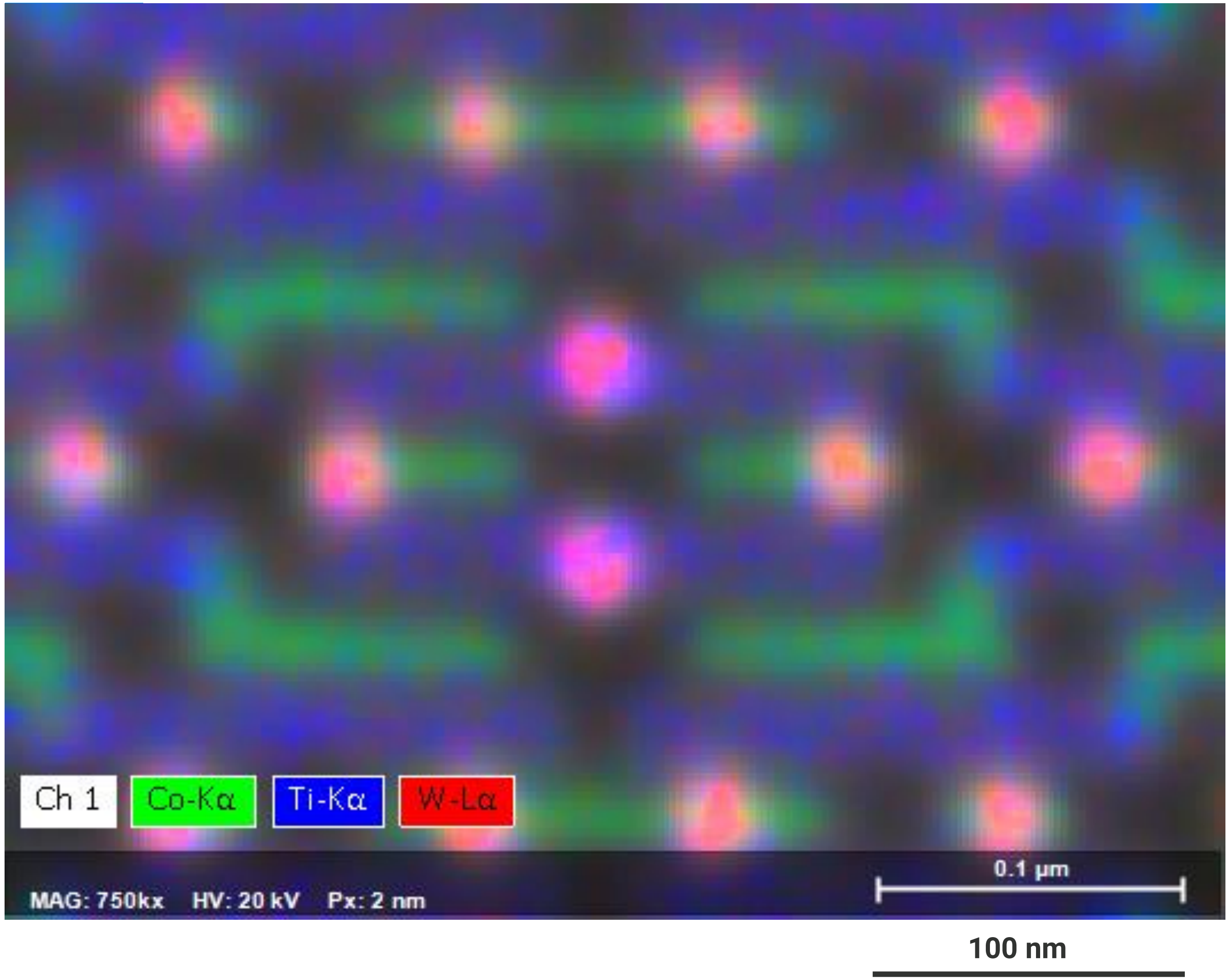
200 nm

EDS MEASUREMENT PARAMETERS

Measurement time	30 min
Count rate	50700 cps
Probe current	290 pA
Dead time	27%
Total counts	6.6E+7 (66M)
H-FOV	1000 nm
Map size	250 x 187 px

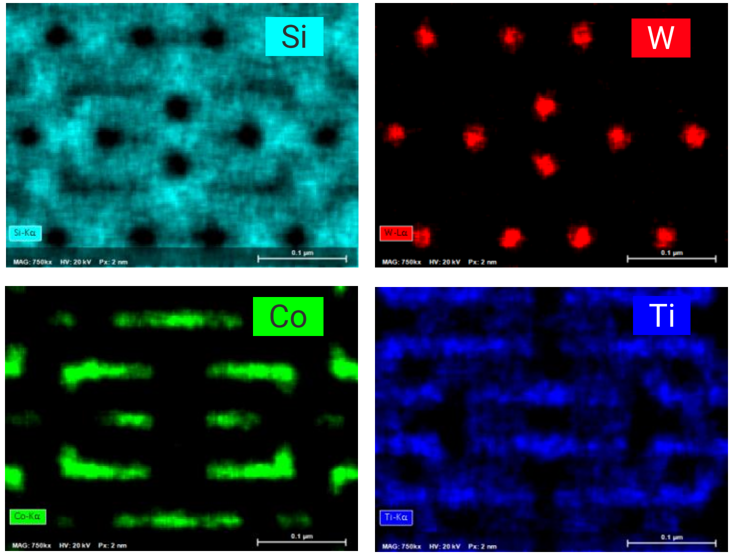


20 kV, 750kx MAG, Above M0

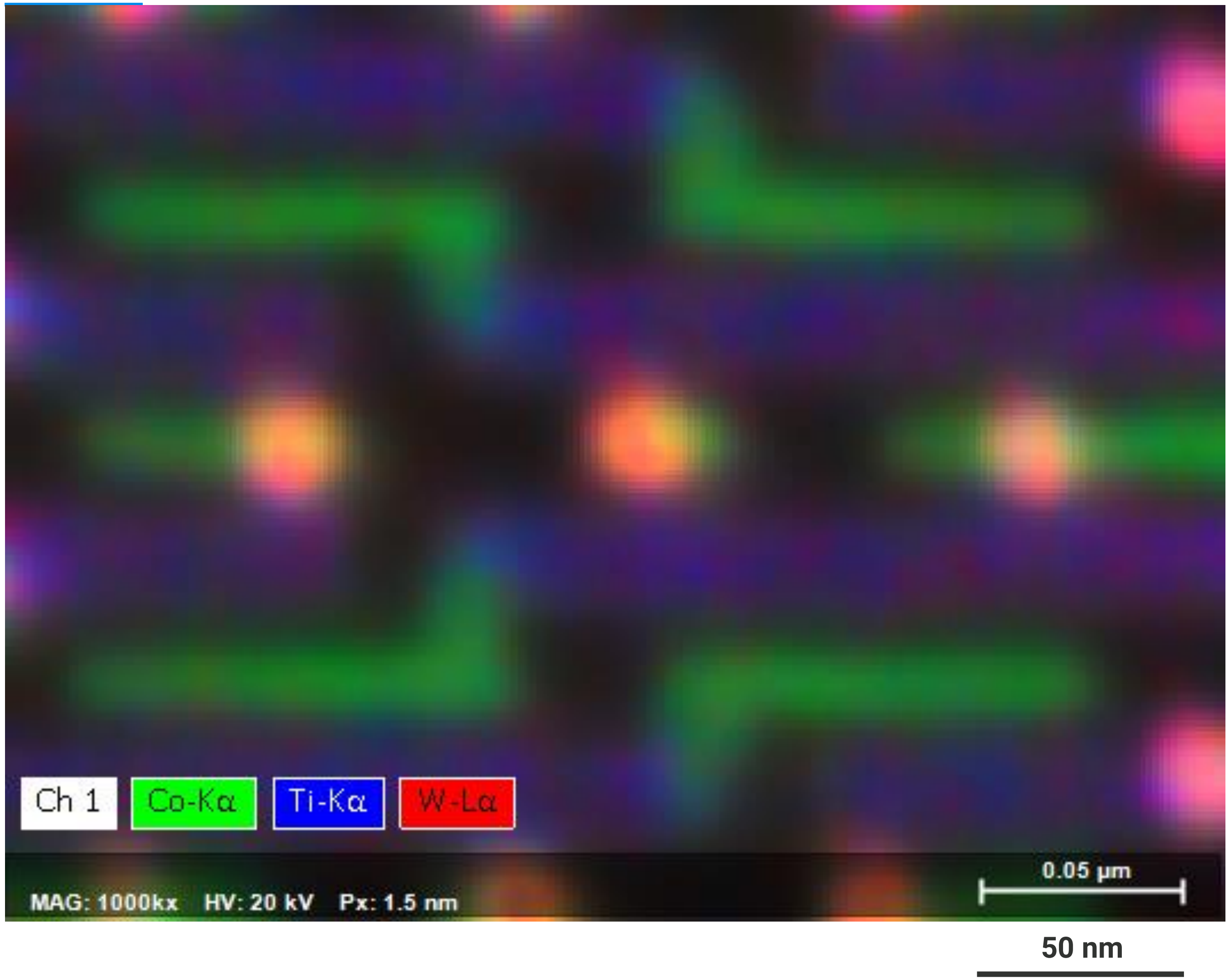


EDS MEASUREMENT PARAMETERS

Measurement time	21 min
Count rate	50500 cps
Probe current	220 pA
Dead time	27%
Total counts	3.7E+7 (37M)
H-FOV	1000 nm
Map size	250 x 187 px

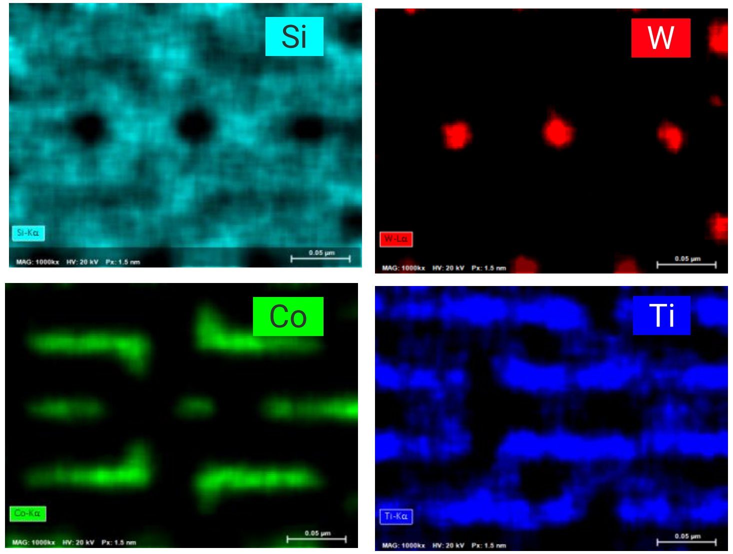


20 kV, 1Mx MAG, Above M0

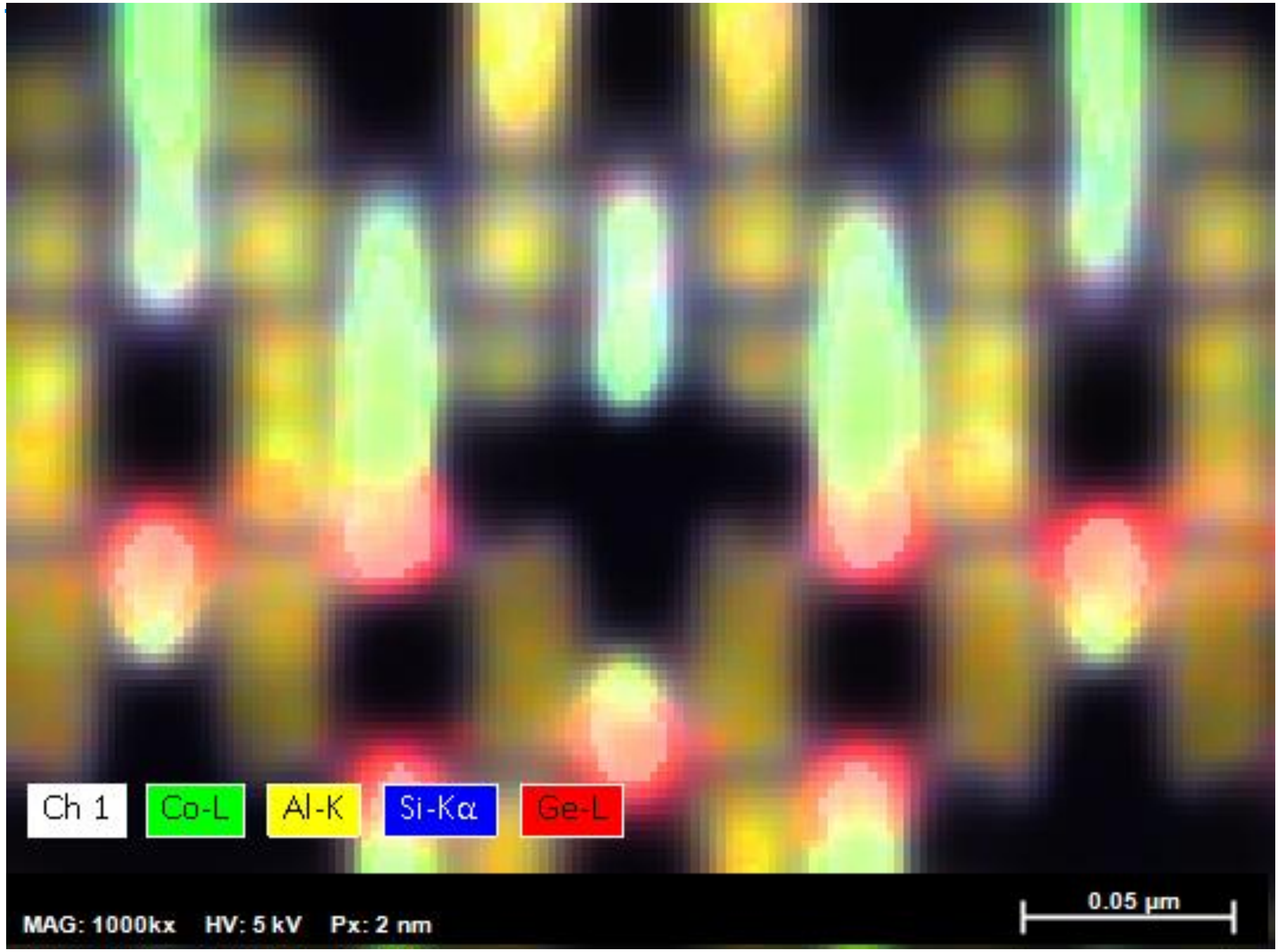


EDS MEASUREMENT PARAMETERS

Measurement time	577 s
Count rate	50900 cps
Probe current	210 pA
Dead time	27%
Total counts	2.1E+7 (27M)
H-FOV	300 nm
Map size	200 x 150 px



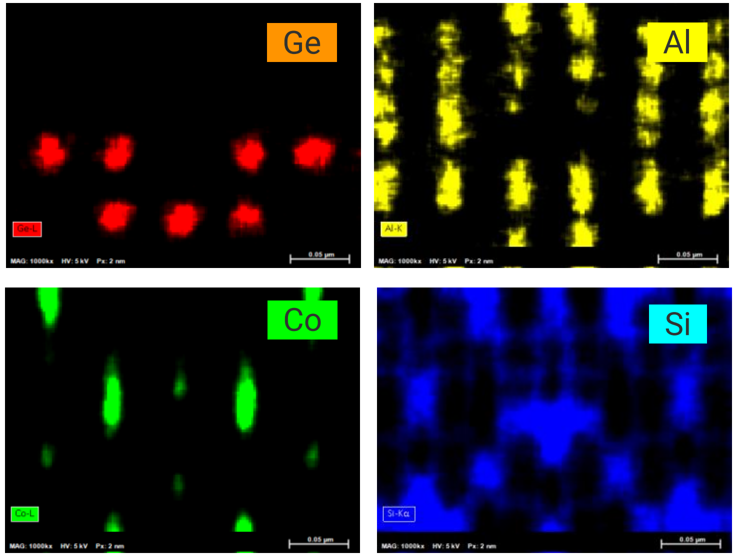
5 kV, 1Mx MAG, Below M0



50 nm

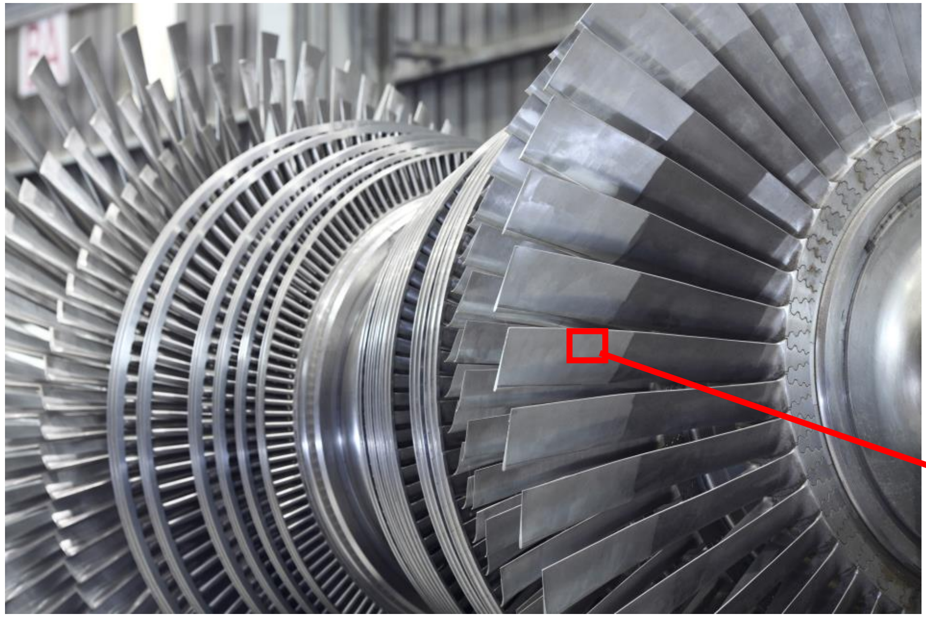
EDS MEASUREMENT PARAMETERS

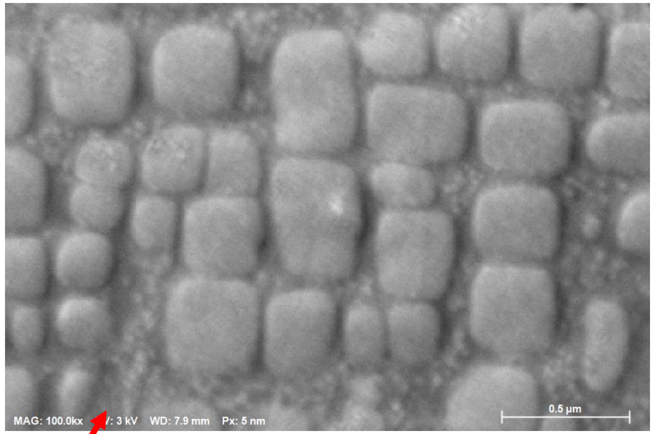
Measurement time	545 s
Count rate	15600 cps
Probe current	390 pA
Dead time	18%
Total counts	7E+6 (7M)
H-FOV	300 nm
Map size	200 x 150 px



Application examples

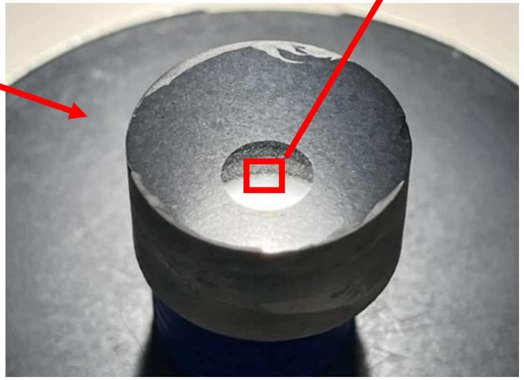
2. Ni based single crystal super alloy





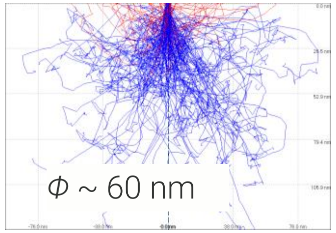
500 nm

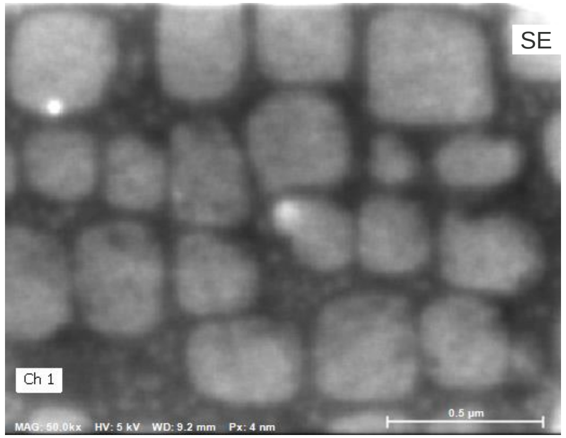
1,00,000x

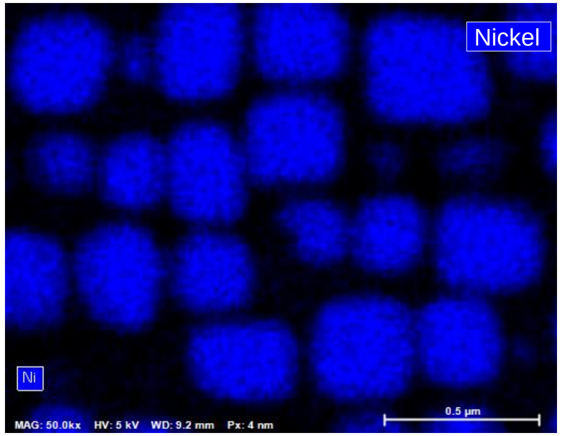


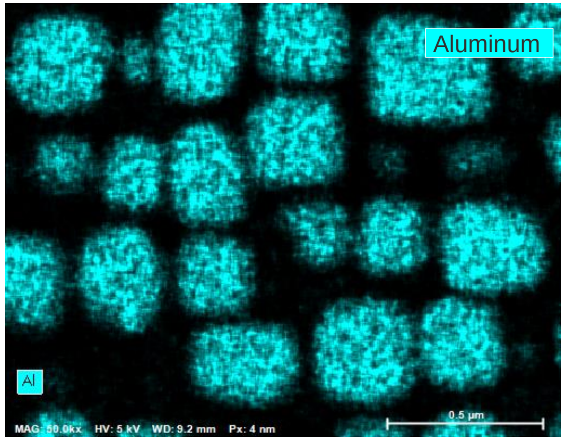
10 mm

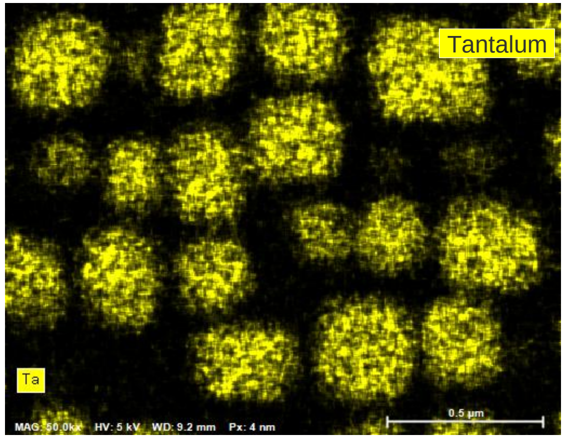
5 kV measurement at 50,000x magnification

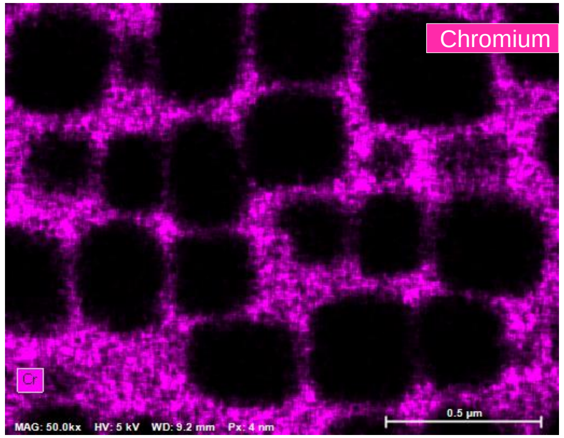


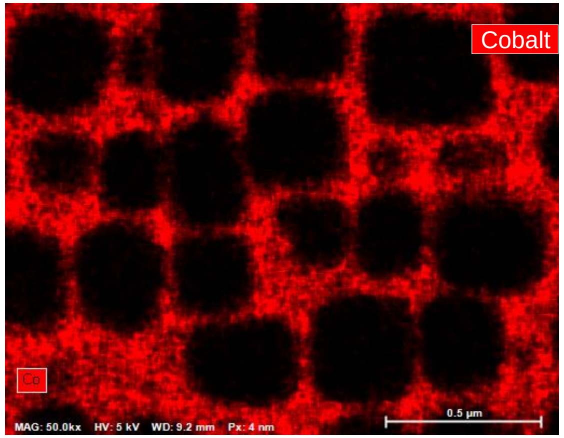


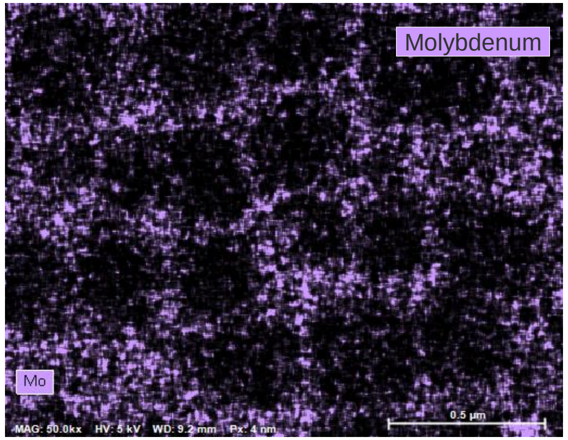


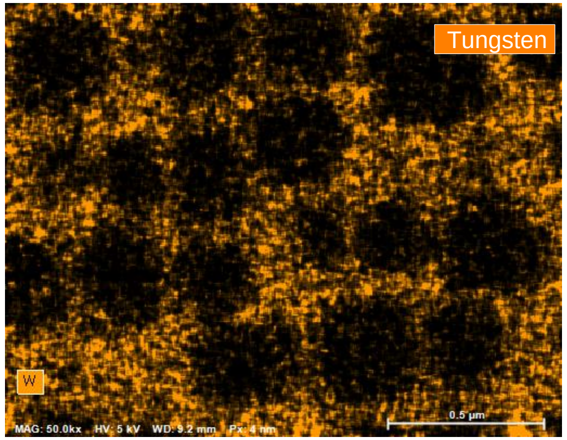








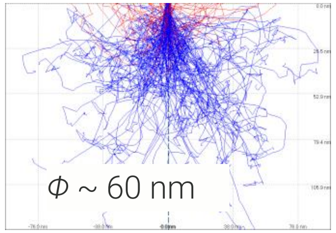


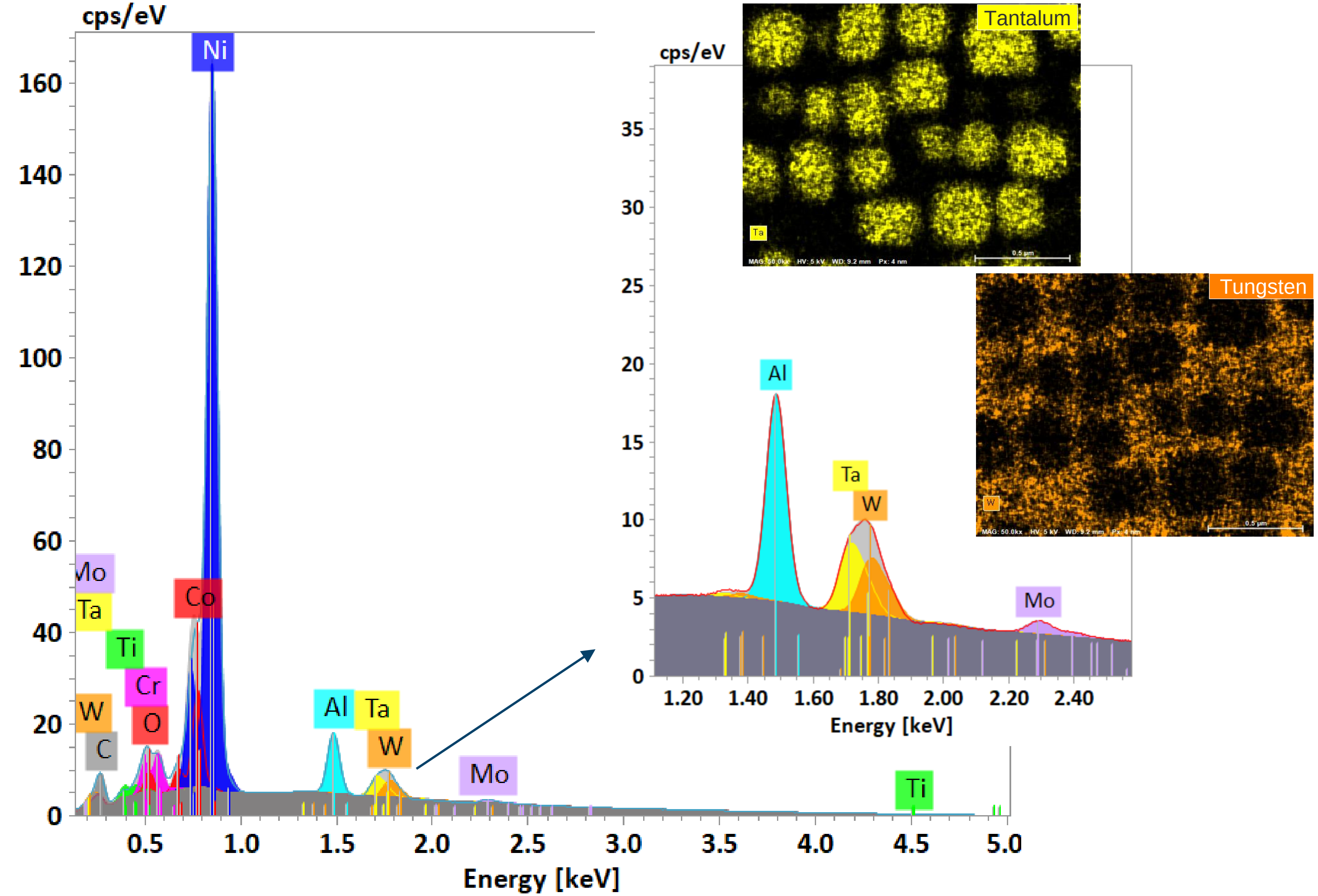


MAG: 50,000 x HV: 5 kV

500 nm

5 kV measurement at 50,000x magnification

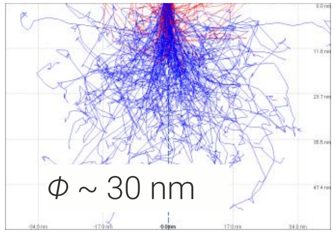


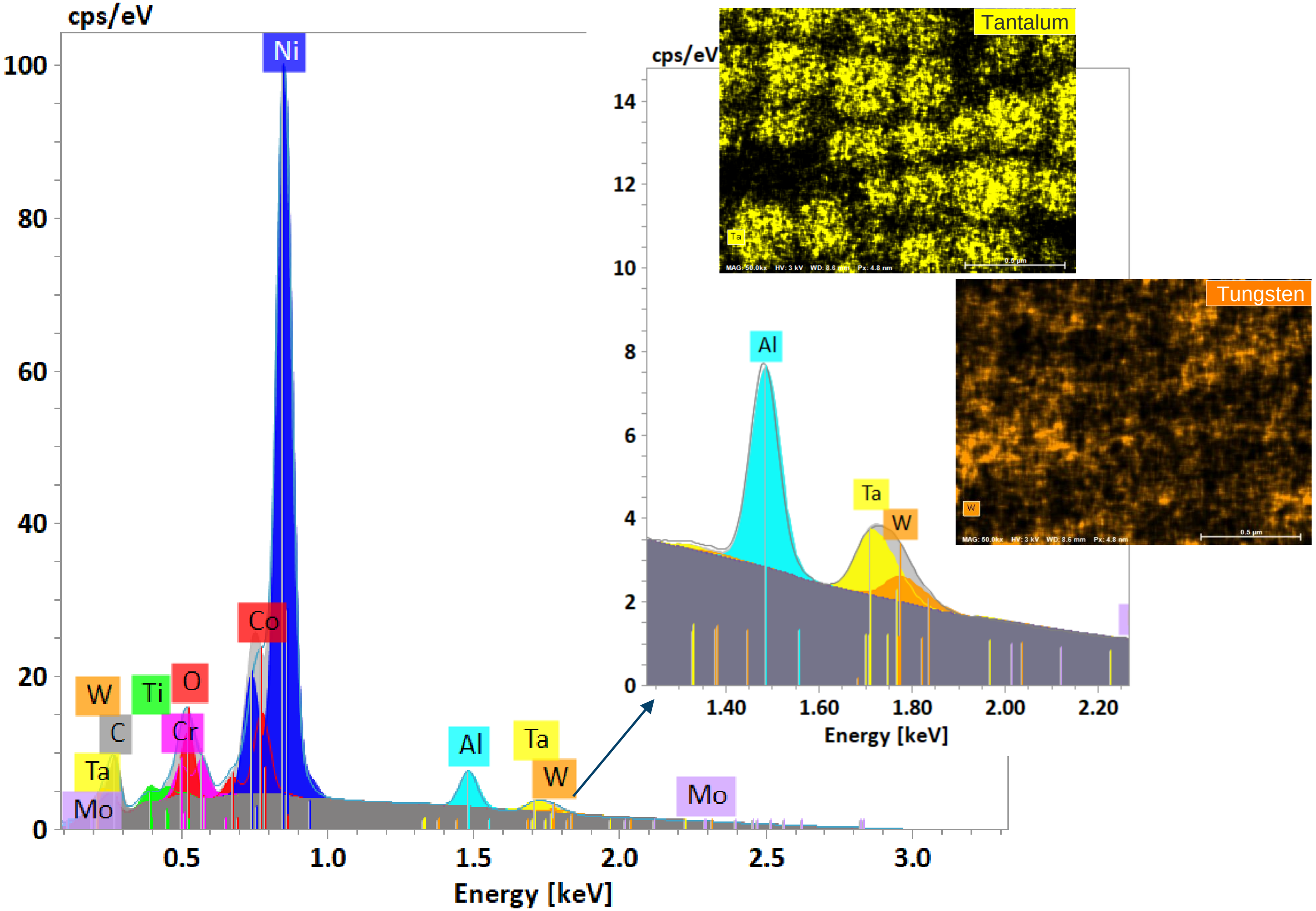


EDS MEASUREMENT PARAMETERS

Measurement time	15 min
Count rate	39000 cps
Dead time	23%
Total counts	3.6E+7 (36M)
Magnification	50,000 x (FOV 2.4 µm)
Map size	600 x 450 px

3 kV measurement at 50,000x magnification



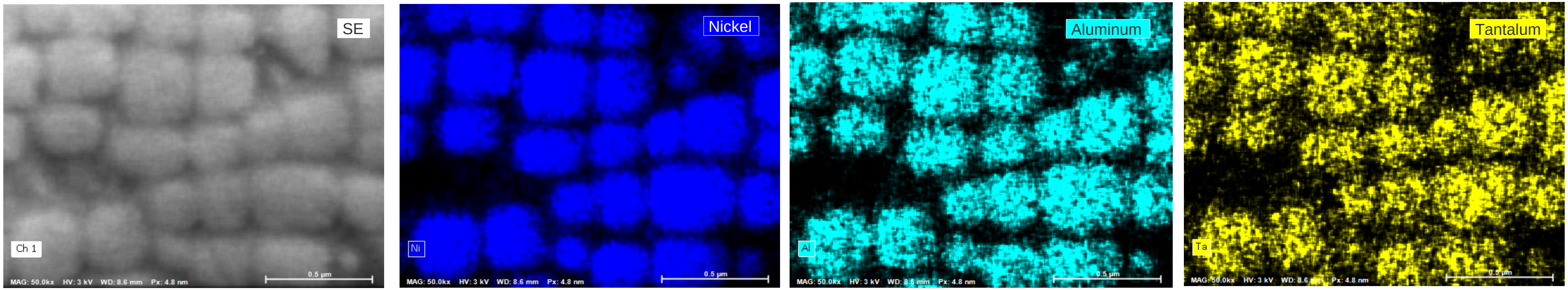


EDS MEASUREMENT PARAMETERS

Measurement time	35 min
Count rate	20,000 cps
Dead time	12%
Total counts	3.4E+7 (34M)
Magnification	50,000 x (FOV 2.4 µm)
Map size	500 x 375 px

3 kV maps: FEG-SEM 1 vs. FEG-SEM 2

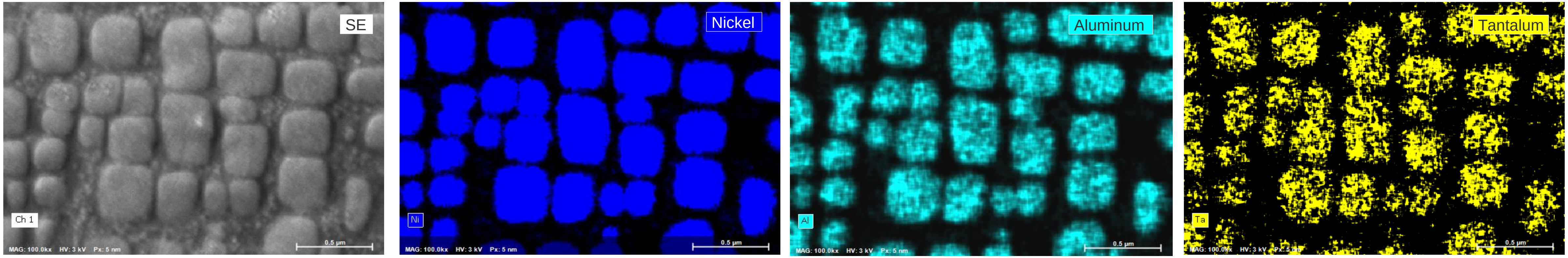
FEG-SEM 1



MAG: 50,000 x HV: 3 kV

500 nm

FEG-SEM 2

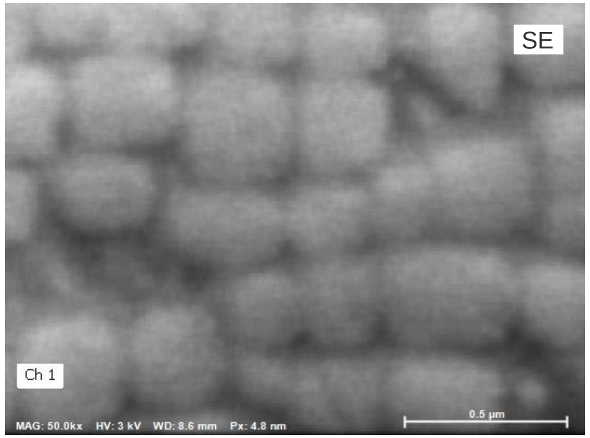


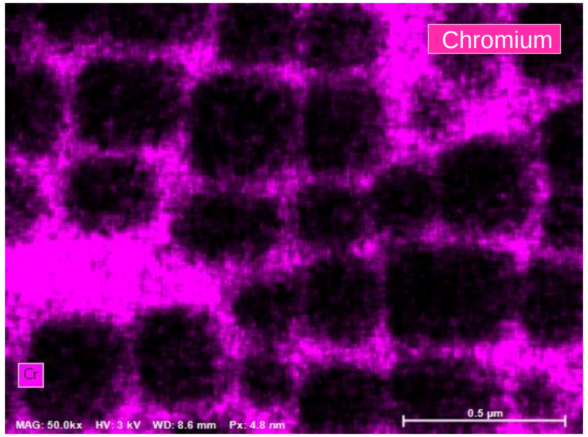
MAG: 100,000 x HV: 3 kV

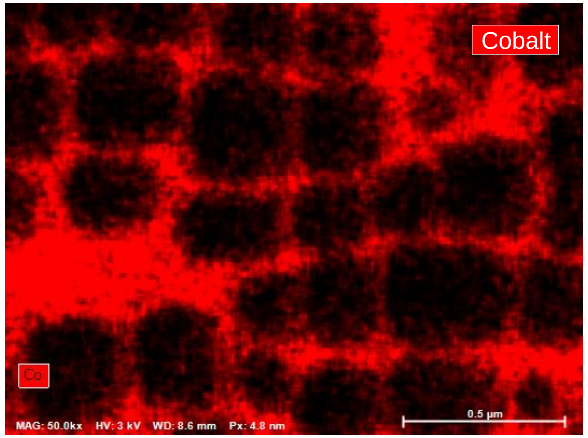
500 nm

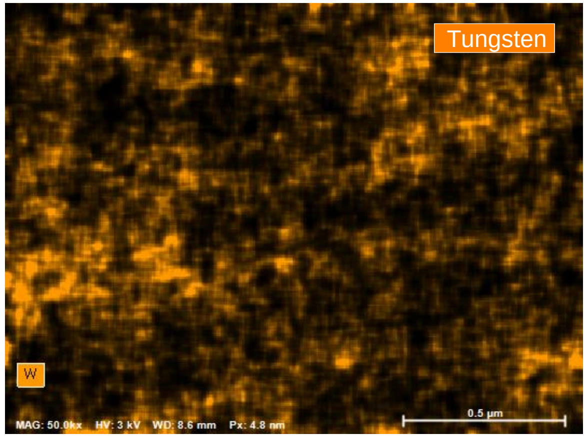
3 kV measurement at 50,000x magnification

FEG-SEM 1





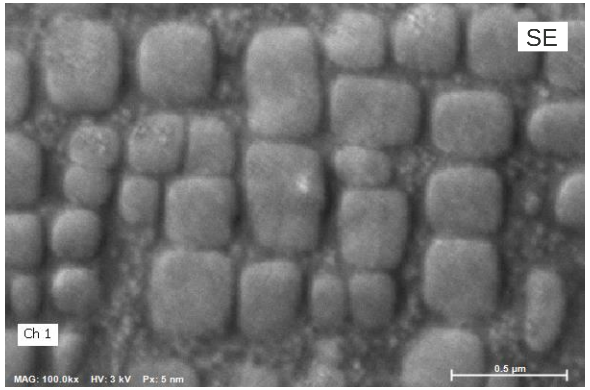


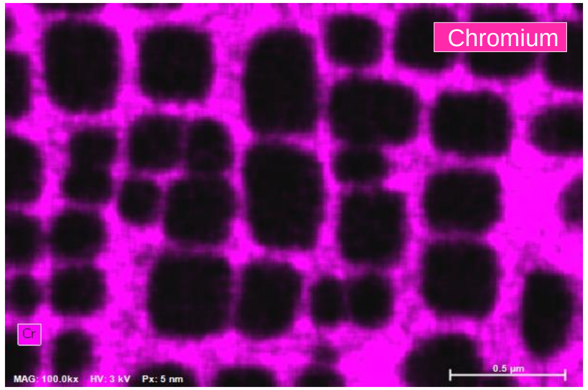


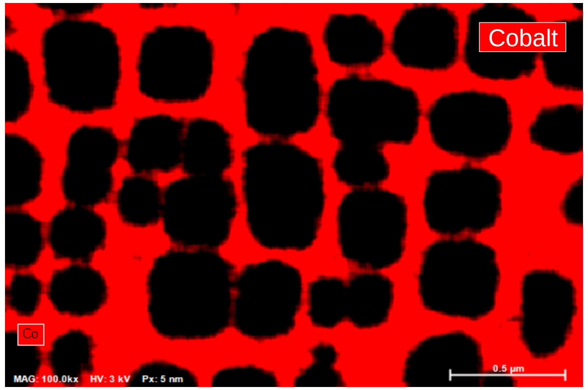
MAG: 50,000 x HV: 3 kV

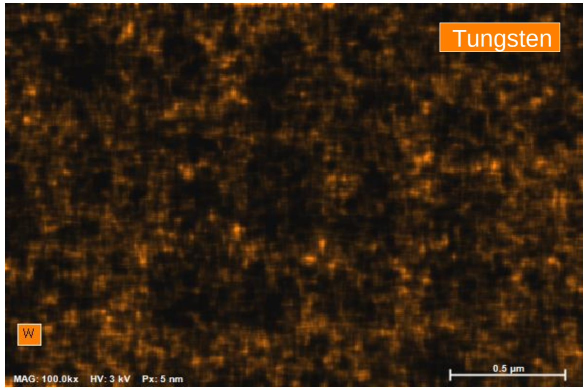
500 nm

FEG-SEM 2





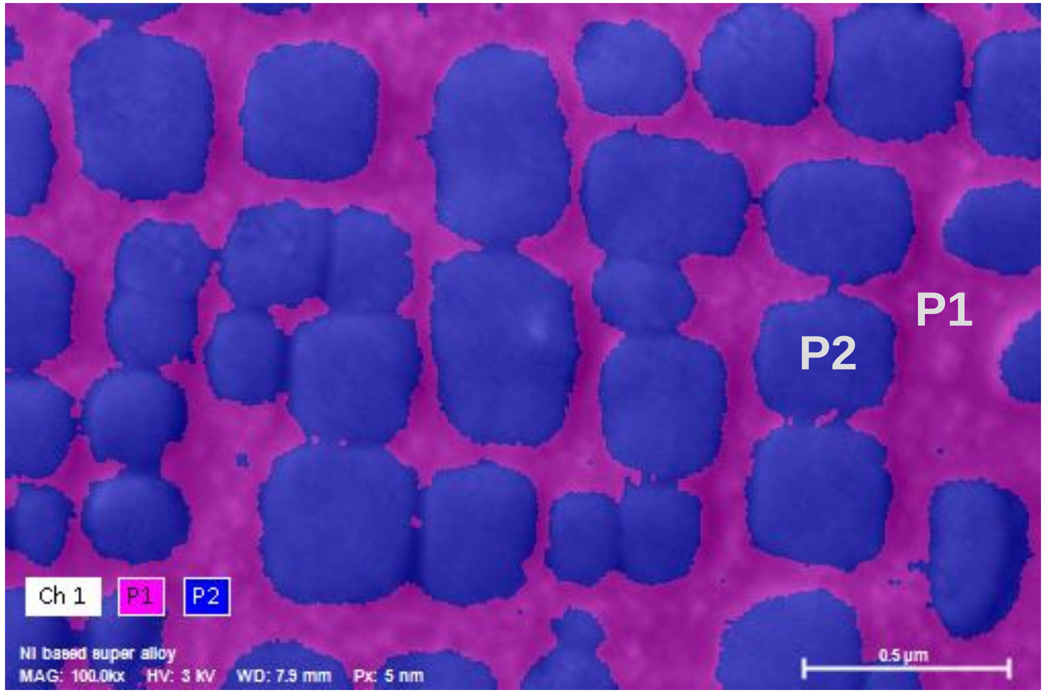


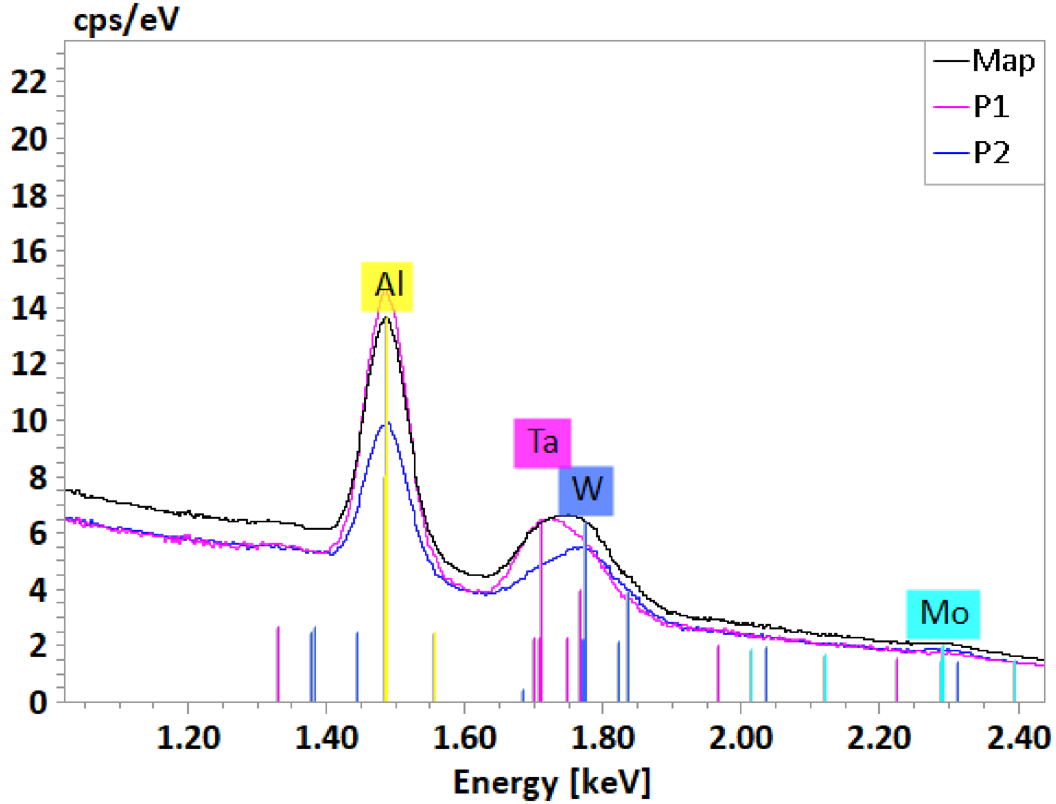


MAG: 100,000 x HV: 3 kV

500 nm

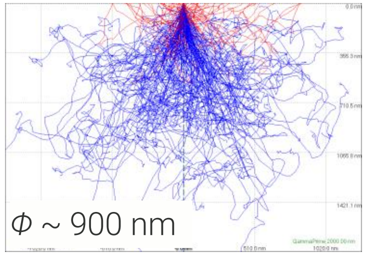
3 kV measurement at 100,000x magnification (FEG-SEM 2)

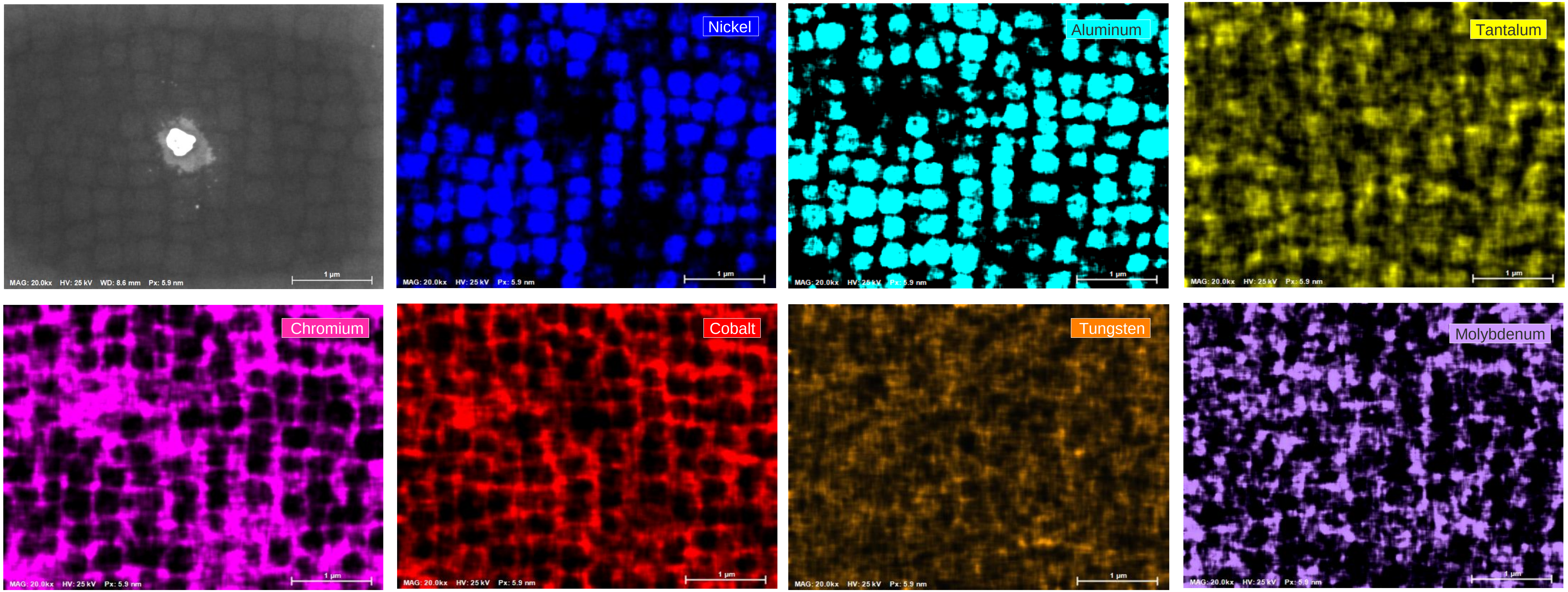




Gamma - P1
Gamma prime - P2

25 kV measurement at 20,000x magnification

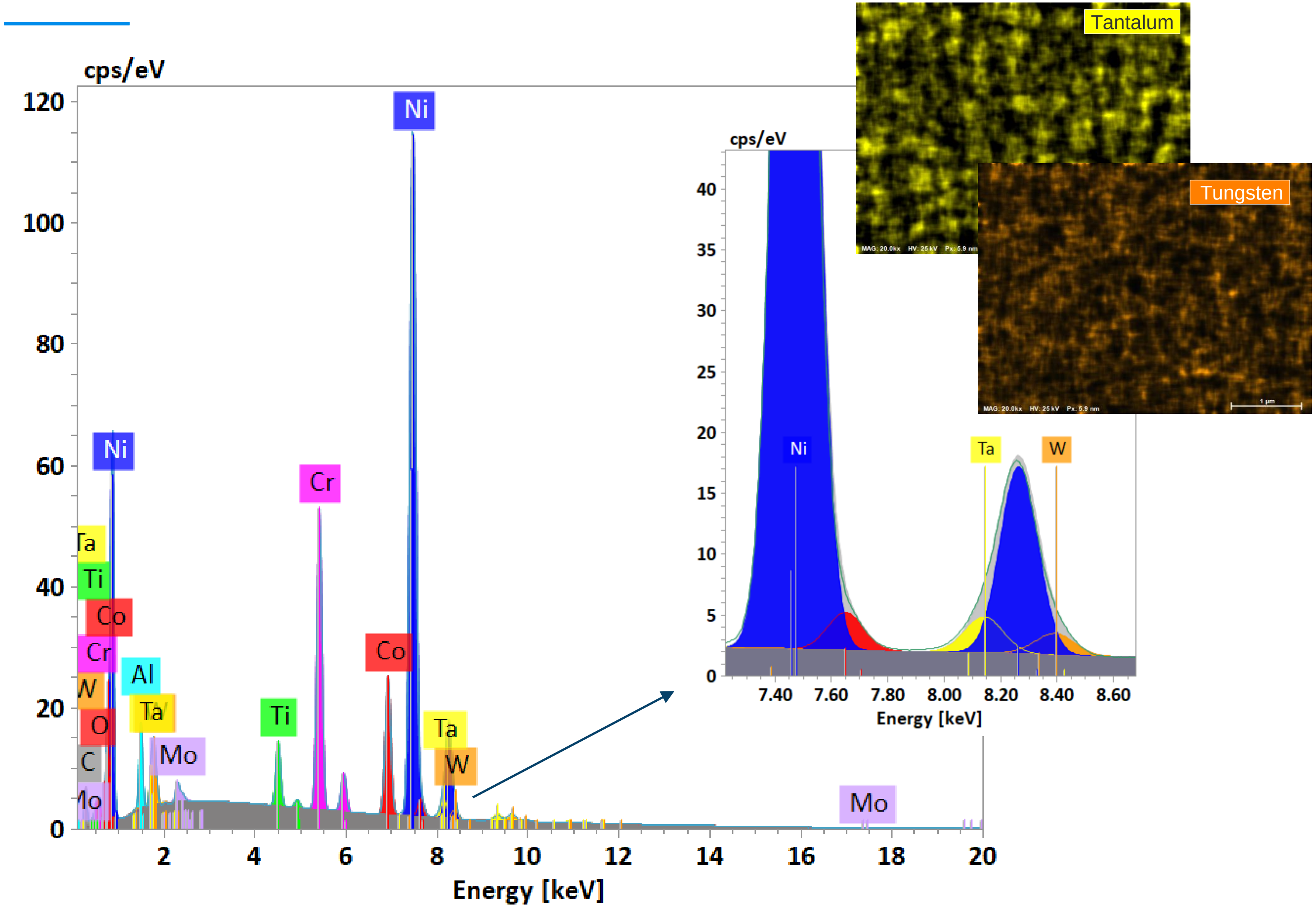




MAG: 20,000 x HV: 25 kV

1 µm

25 kV measurement at 20,000x magnification



EDS MEASUREMENT PARAMETERS

Measurement time	30 min
Count rate	119,000 cps
Dead time	32%
Total counts	1.46E+8 (146M)
Magnification	20,000 x
Map size	1000 x 750 px

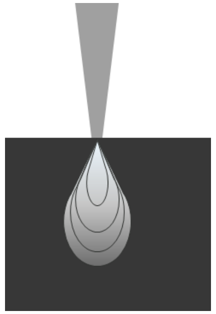
Detector used?

EDS/SEM SYSTEM CONFIGURATION

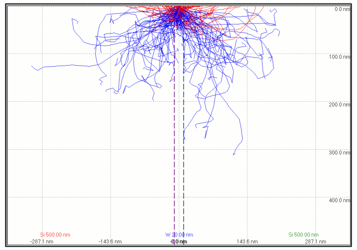
Detector type	Bruker 7th Gen XFlash
Resolution	126 eV @Mn Kα
Window	SLEW AP3.3

Results from windowless 100 mm^2 RaceTrack detector?

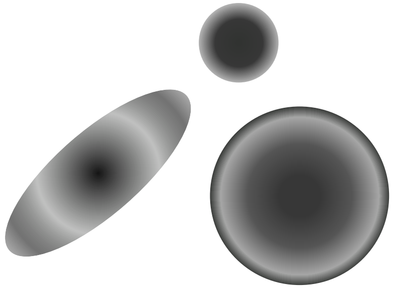
Summary - I



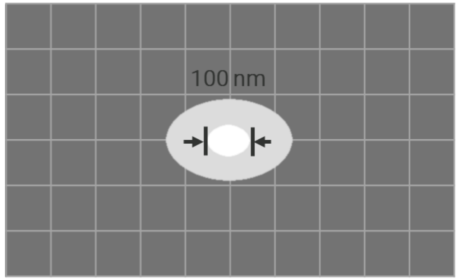
Interaction volume



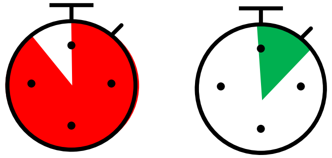
Material density



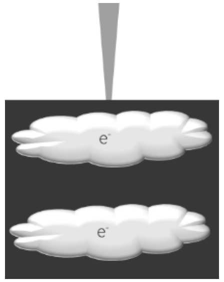
Beam footprint



Pixel/map size

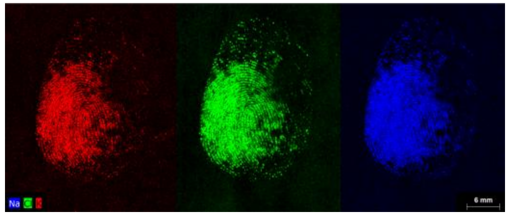


Charging due to higher dwell time



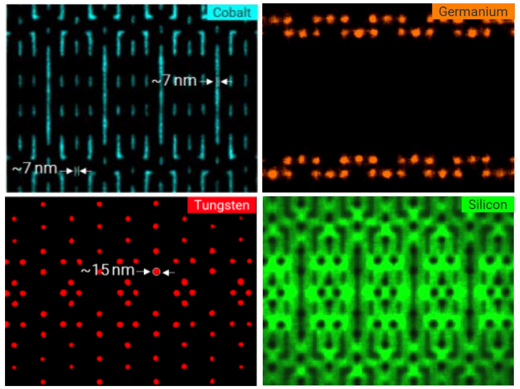
Charging due to beam conditions

Active drift correction

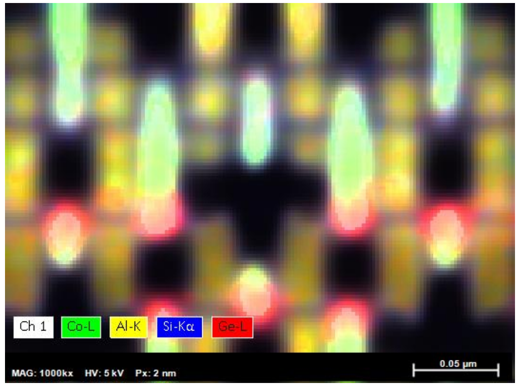


Avoid contamination

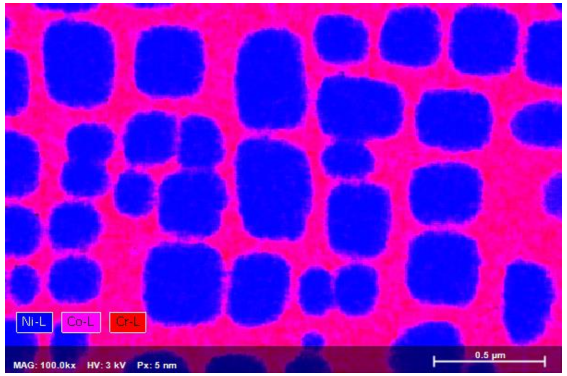
Summary - II



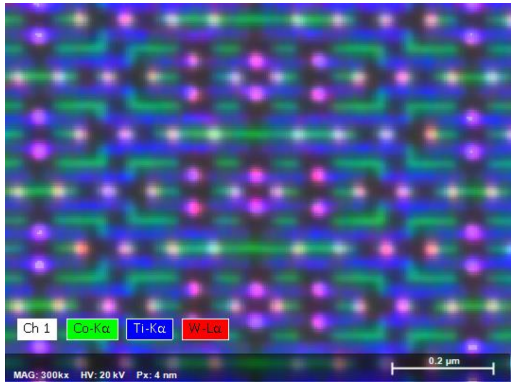
5 kV – 300,000x



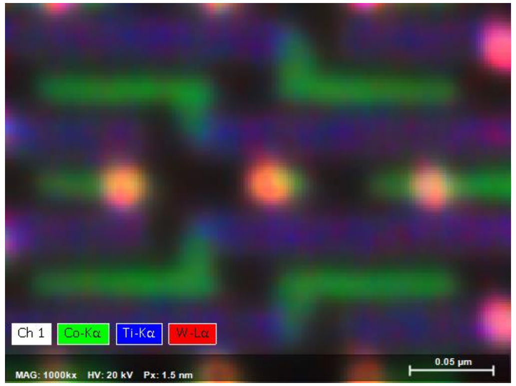
5 kV – 1,000,000x



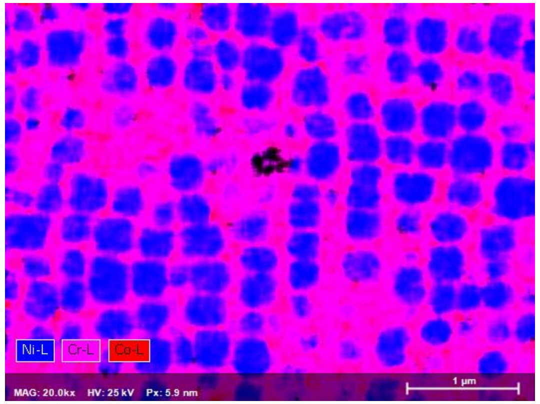
5 kV – 100,000x



20 kV – 300,000x



20 kV – 1,000,000x



25 kV – 20,000x

Thank you!

Q&A

Questions?

Please type in the questions

in the **Q&A box** and press ***Send*.**