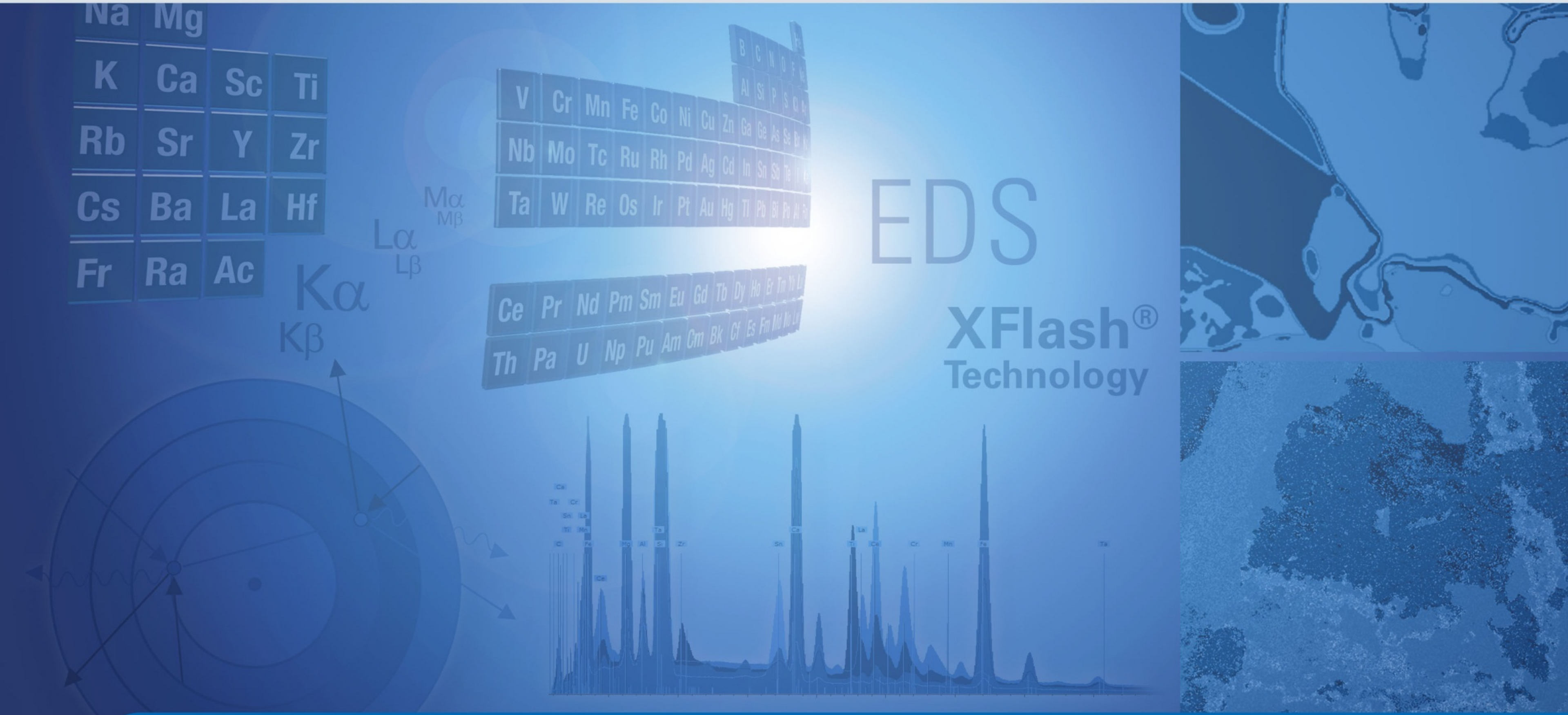
EDS on the Nanoscale in TEM/STEM and SEM

Bruker Nano Analytics, Berlin, Germany
Webinar, June 14, 2017



Presenters

Dr. Meiken Falke

Global Product Manager TEM
Bruker Nano Analytics, Berlin, Germany

Mats Eriksson

Electron microscopy department manager
Hitachi High-Tech Europe, Sweden

Dr. Igor Németh

Application Scientist, EDS
Bruker Nano Analytics, Berlin, Germany

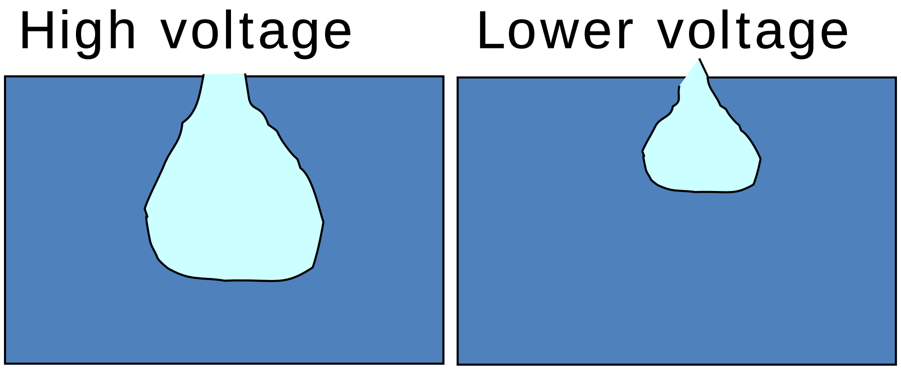
Outline

- Technology and options provided
- Examples of nanoanalysis approaches in TEM/STEM
- Approaches for nanoanalysis in (T)SEM (Flatquad detector)

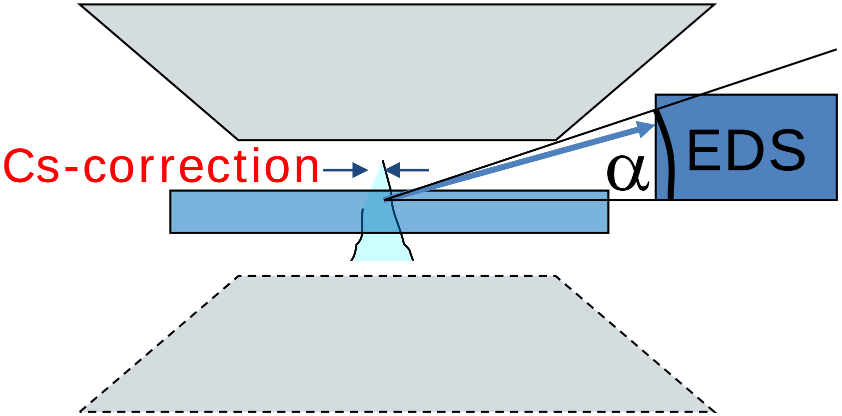
- High sensitivity EDS combined with Cold Field Emission in SEM

Spatial Resolution: Cs- Correction and Brightness

SEM: bulk



S/TEM: thin specimen, small probe



S/B Signal to background ratio

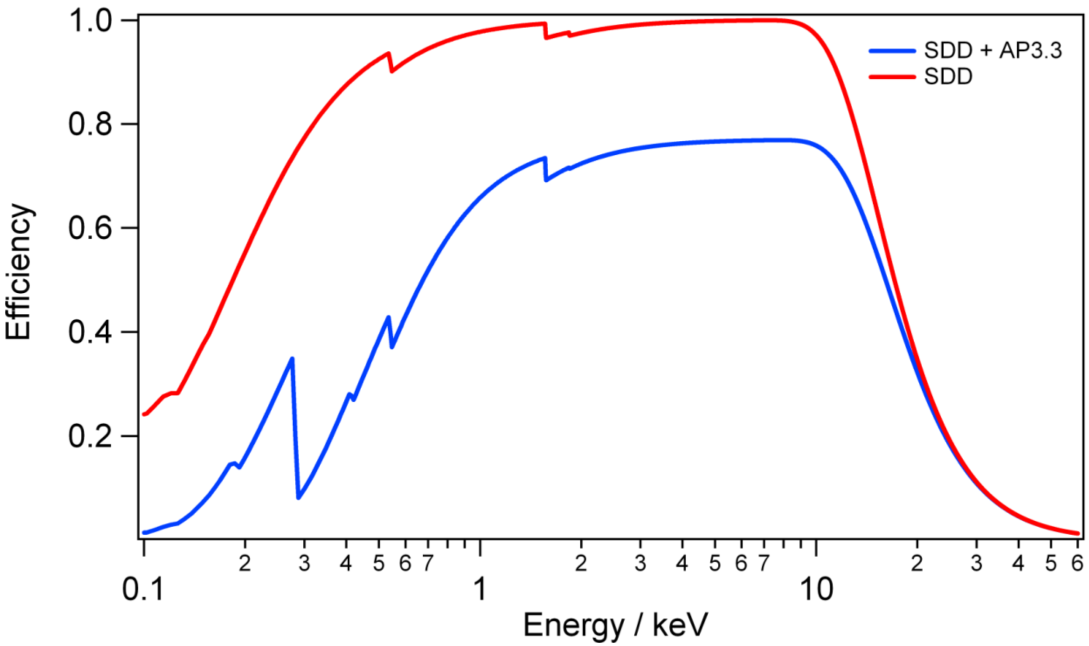
σ_a	*atoms cross section*
d_p	*probe diameter*
d_d	*delocalisation from inelastic scattering*
I_p	*probe current (typ. 500 pA)*
ε	*detection efficiency*
t	*acquisition time*
ρ	*number of atoms per unit area*

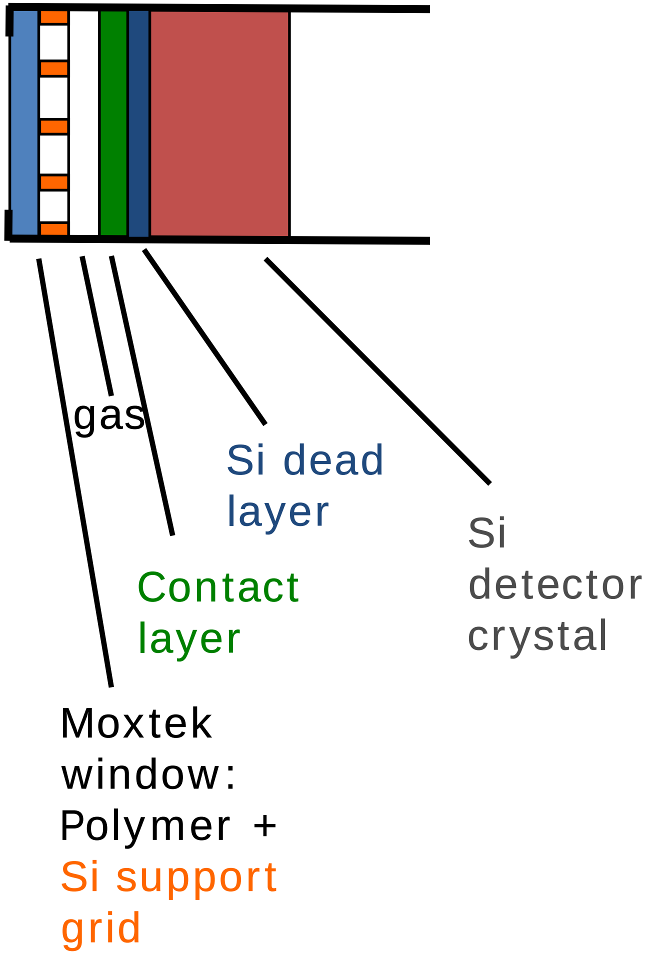
$$S/B = Sa/\sqrt{Sb}$$

$$= \sigma_a/(d_p^2 + d_d^2) * \sqrt{I_p \varepsilon t/(\sigma_b \rho_b e)}$$

O. Krivanek, Chapter in P. Hawkes „Advances in Imaging and Electron Physics“

Detector quantum efficiency





gas

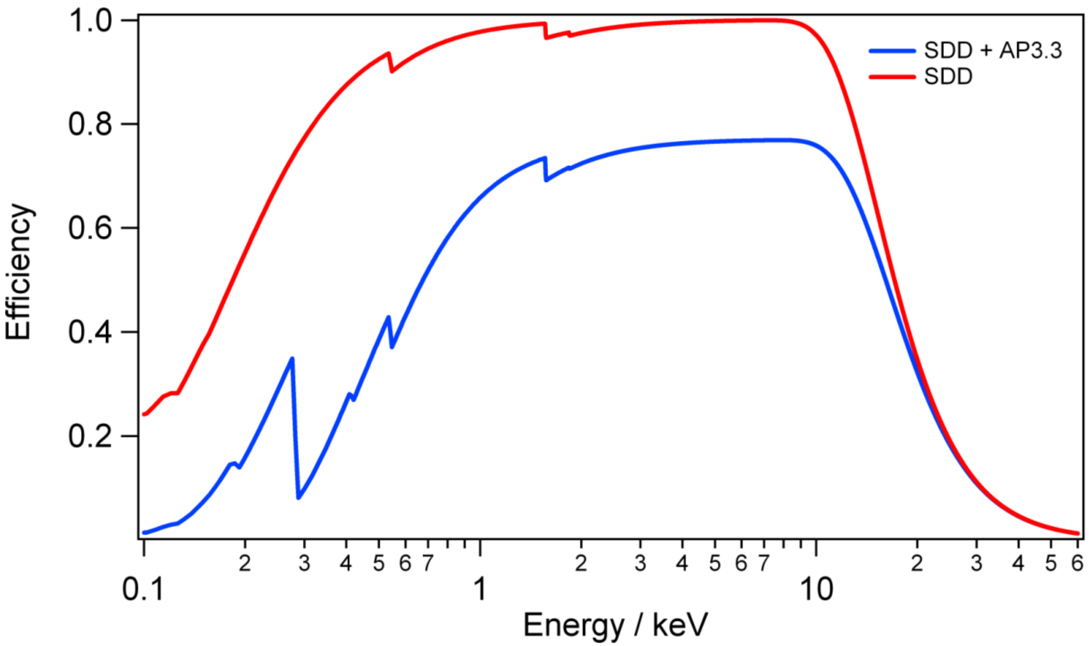
Si dead layer

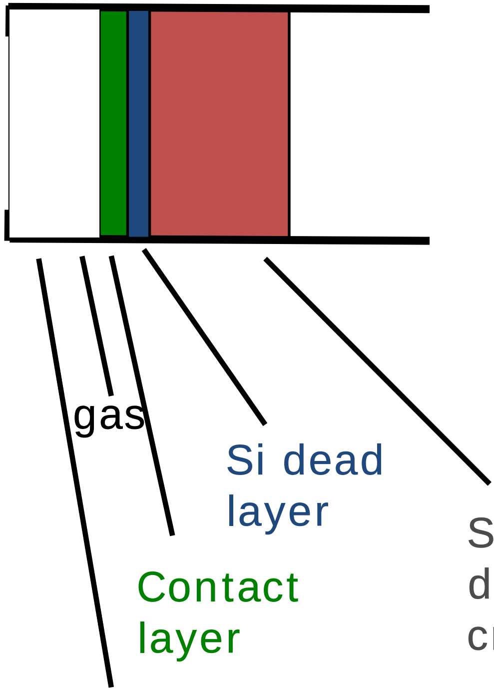
Contact layer

Si detector crystal

Moxtek window: Polymer + Si support grid

Detector quantum efficiency





gas

Si dead layer

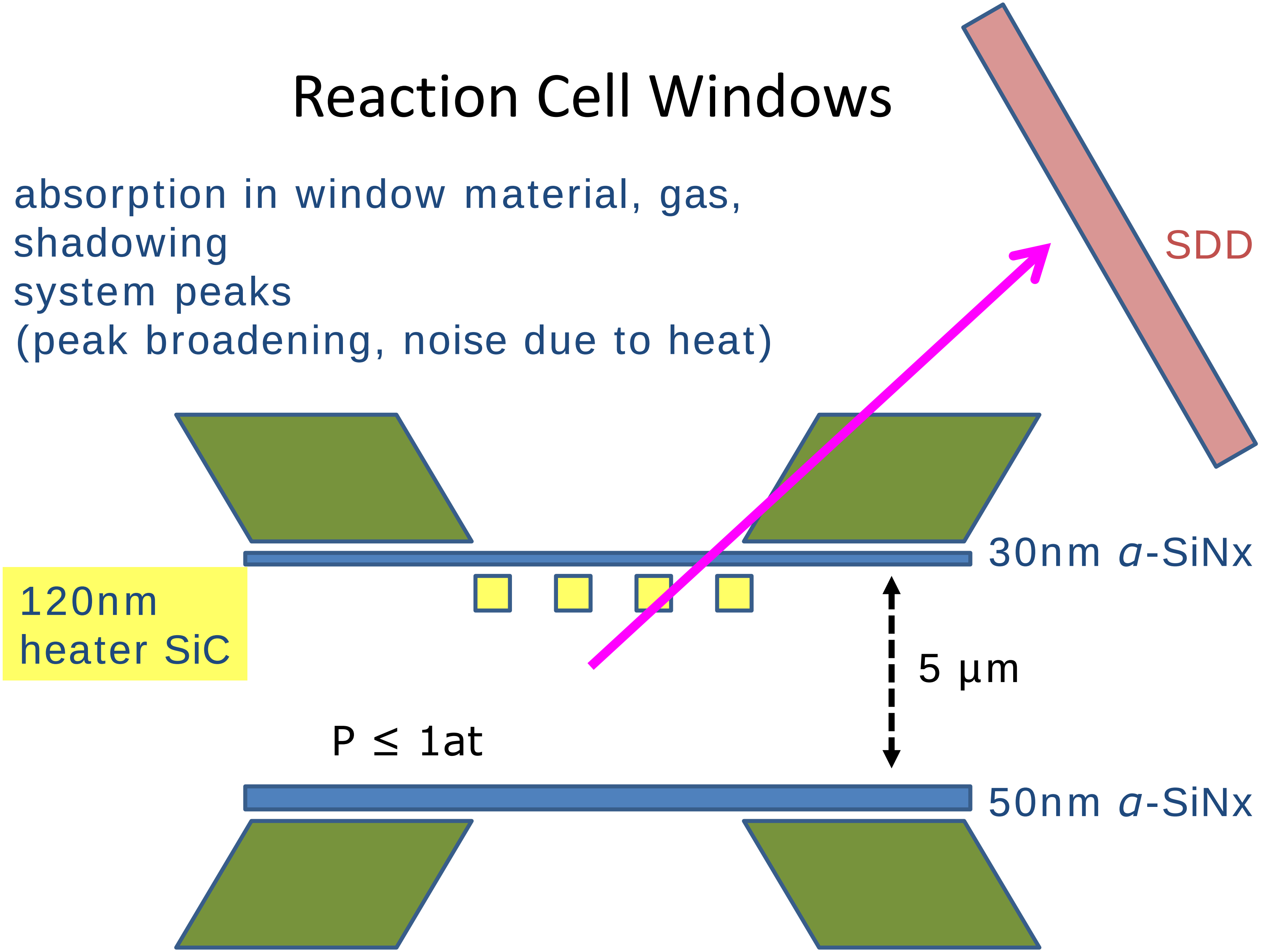
Contact layer

Si detector crystal

Moxtek window:
Polymer +
Si support grid

Reaction Cell Windows

- absorption in window material, gas,
- shadowing
- system peaks
- (peak broadening, noise due to heat)



SDD

30nm *a*-SiNx

120nm heater SiC

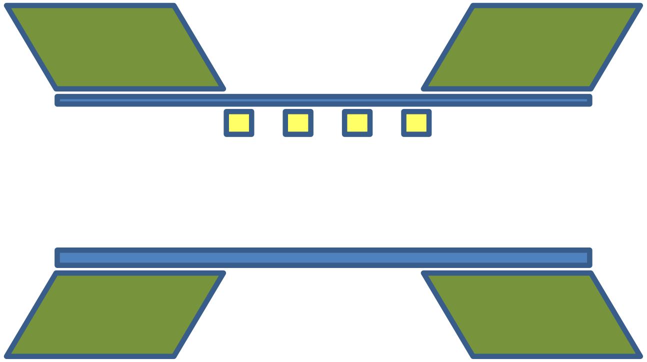
5 µm

P ≤ 1at

50nm *a*-SiNx

O-rings, Au-spacers, ..., reaction species sticking to walls
Webinar, L. Allard

Reaction Cell Windows

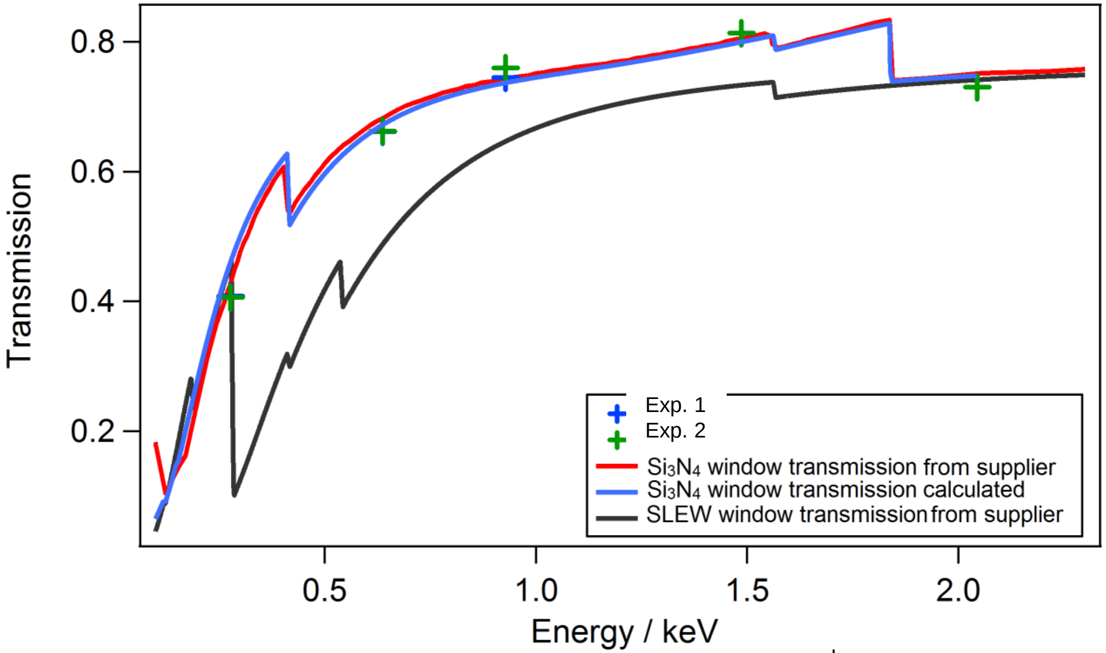


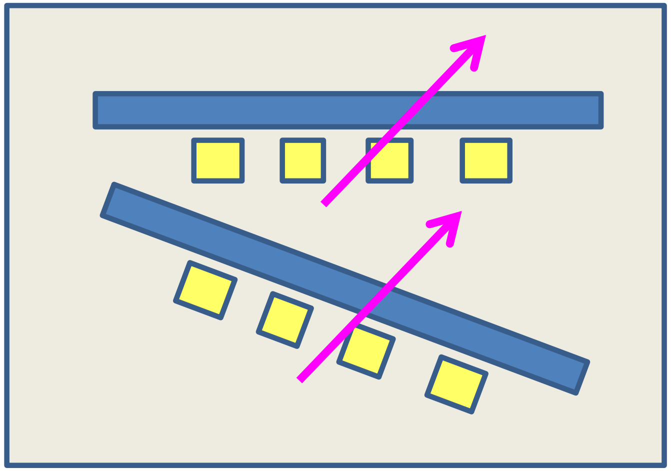
Gas, liquid, + heat … cells:
Window materials:
- graphene,
- Si3N4 / alpha SiNx
    - thickness,
    - support (grid): Si, polymer film, SiC (heating)
    - Al film (light tight))
- Reaction species sticking to cell walls

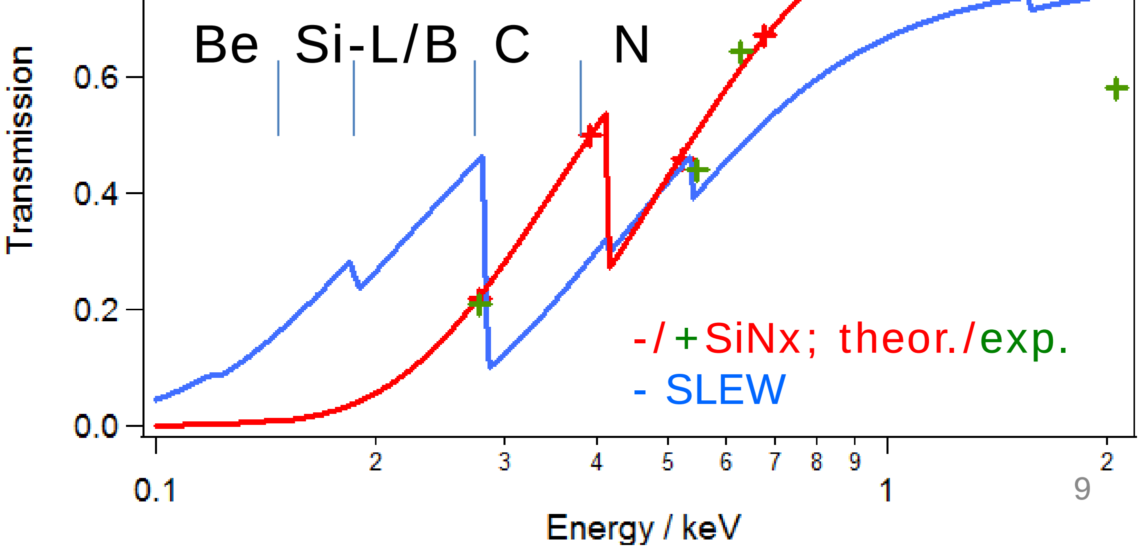
> All affect transmission (efficiency) curve

calculate transmission depending on thickness here:
http://henke.lbl.gov/optical_constants/filter2.html
suggests materials too, but
e.g. 30nm Al cover and window support not included

In situ: Reaction Cell and Detector Windows

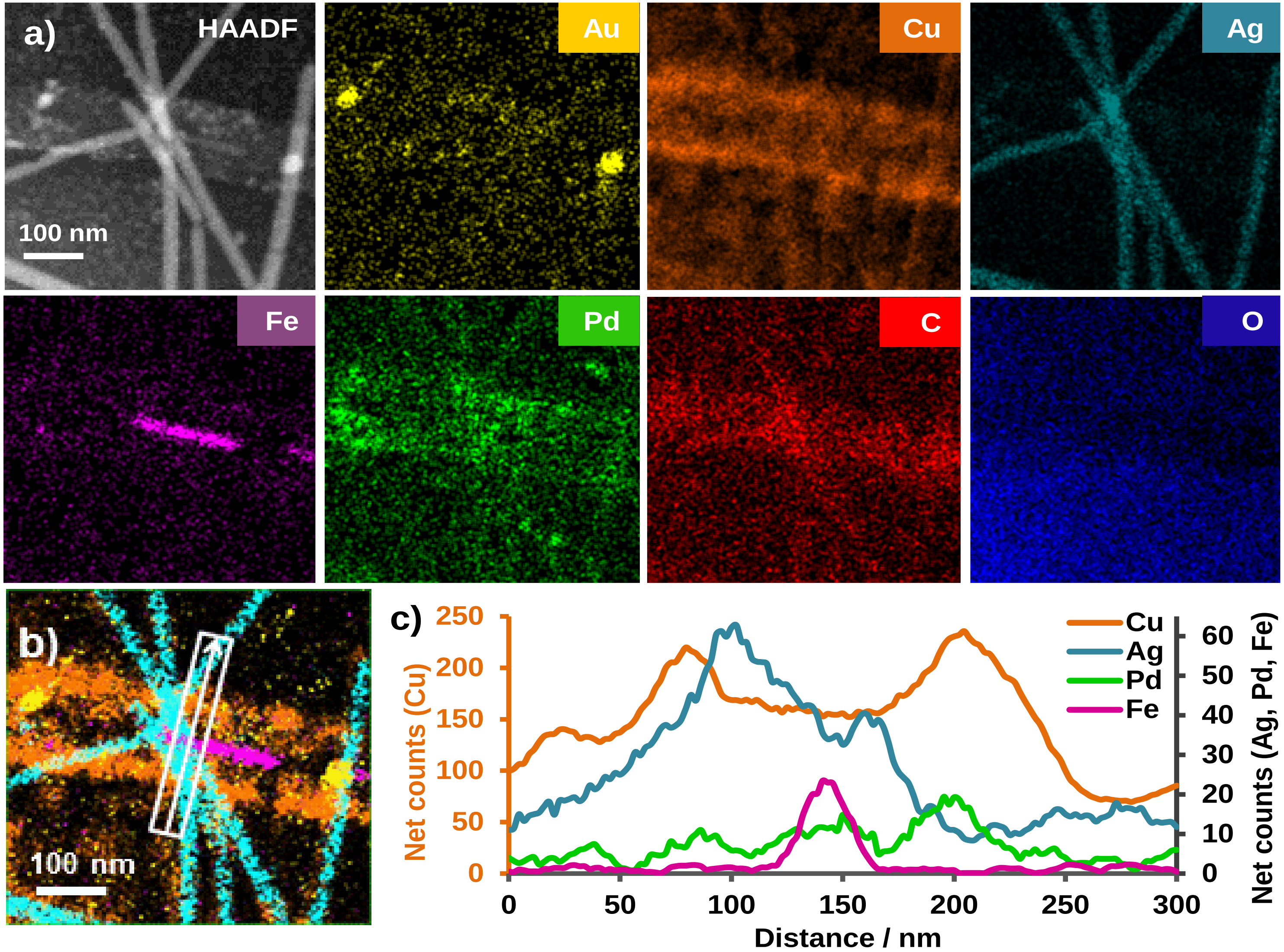






Bruker acquired Hysitron: Nanoindenters for SEM and TEM/STEM delivering Force - distance Measurements and video

EDXS Elemental mapping in liquids

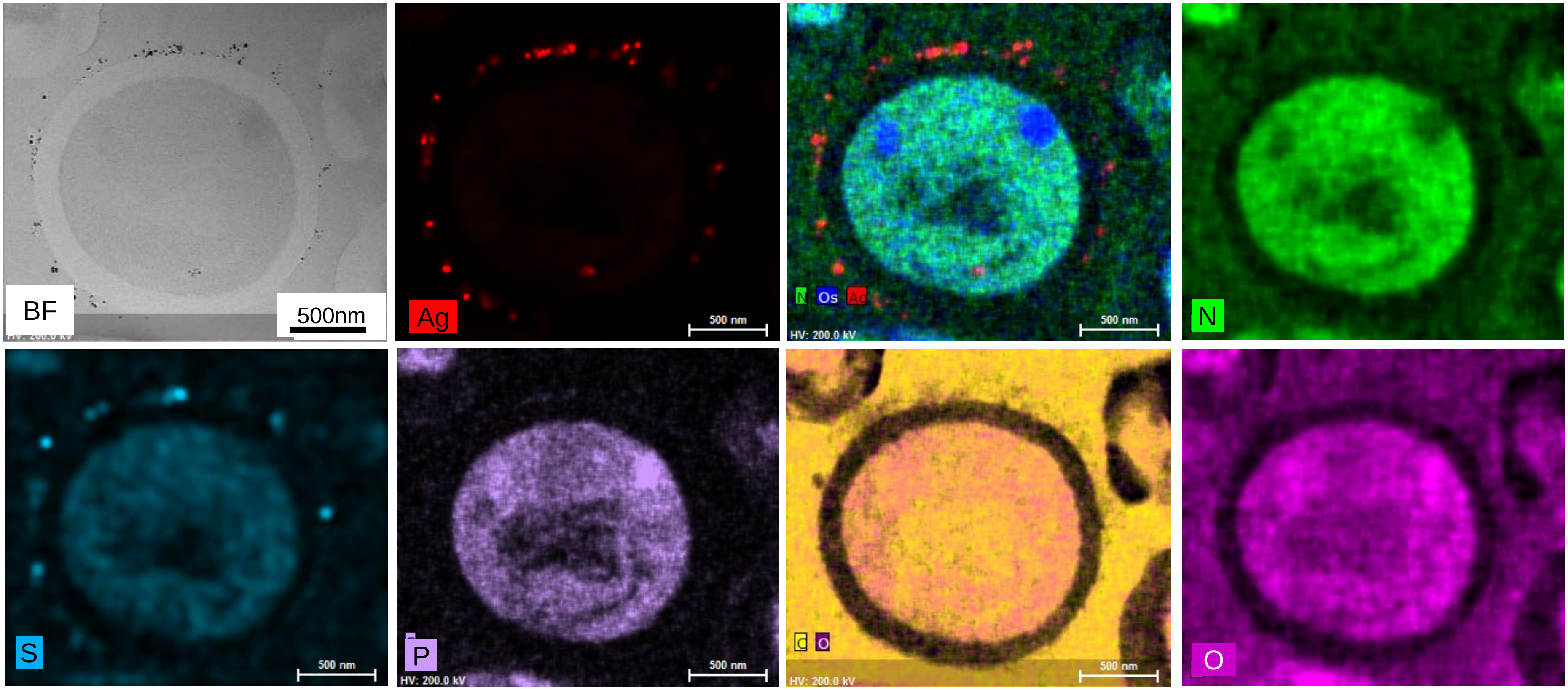


Sarah Haigh group: Lewis et al Chem Comm (2014) 50, 70, 10019-22

EDS for Life Science at 0.1sr

Yeast Cell: Element Mapping of immunolabels and light and heavy elements

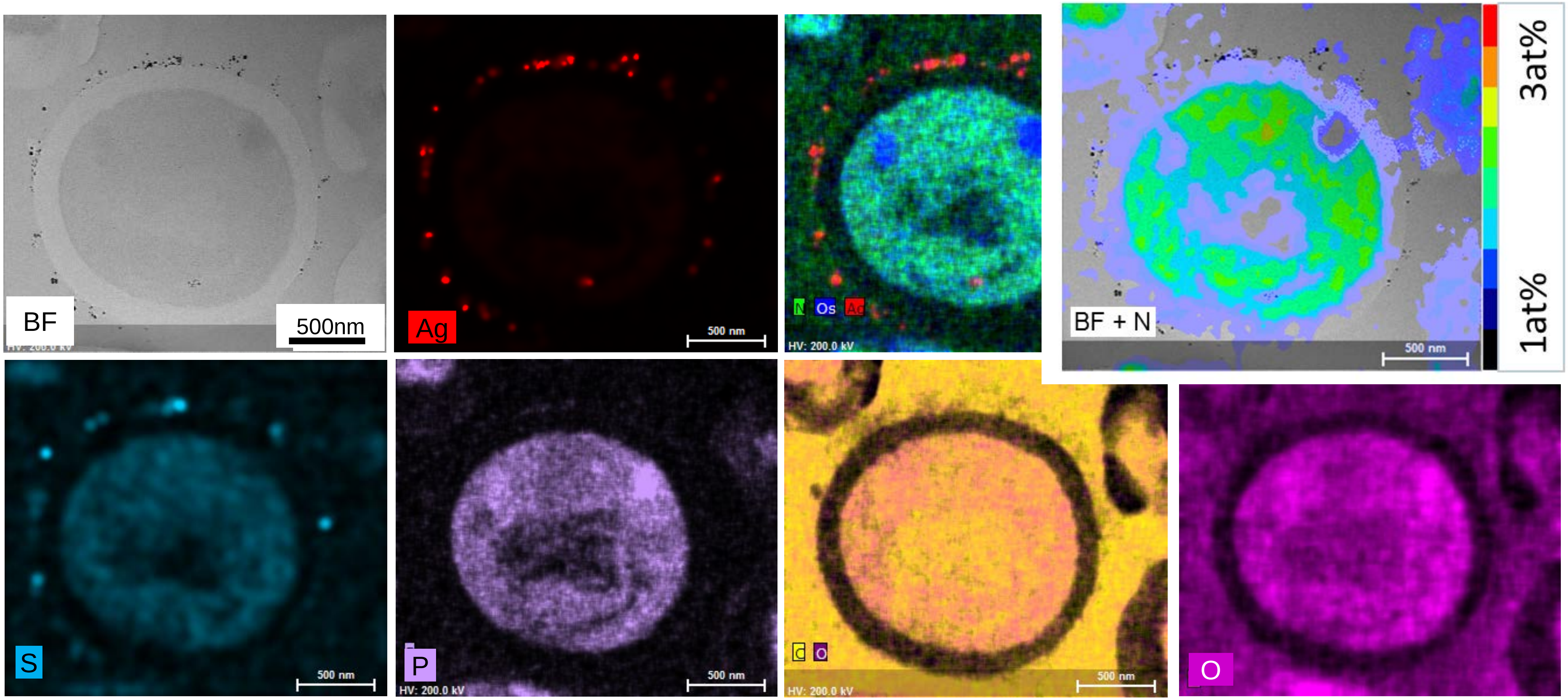
30 mm², 0.12 sr (Standard EDS); Conventional STEM

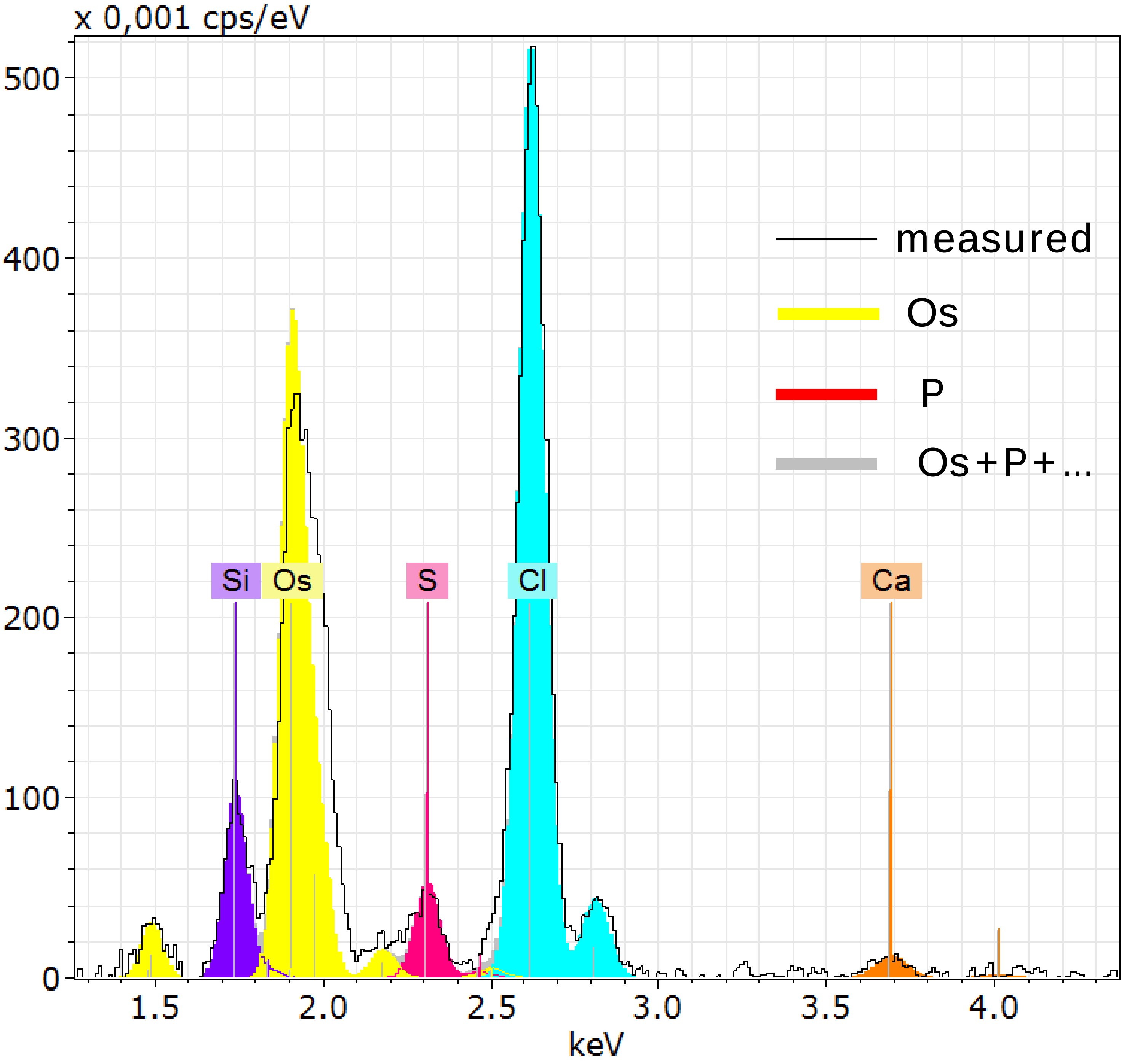


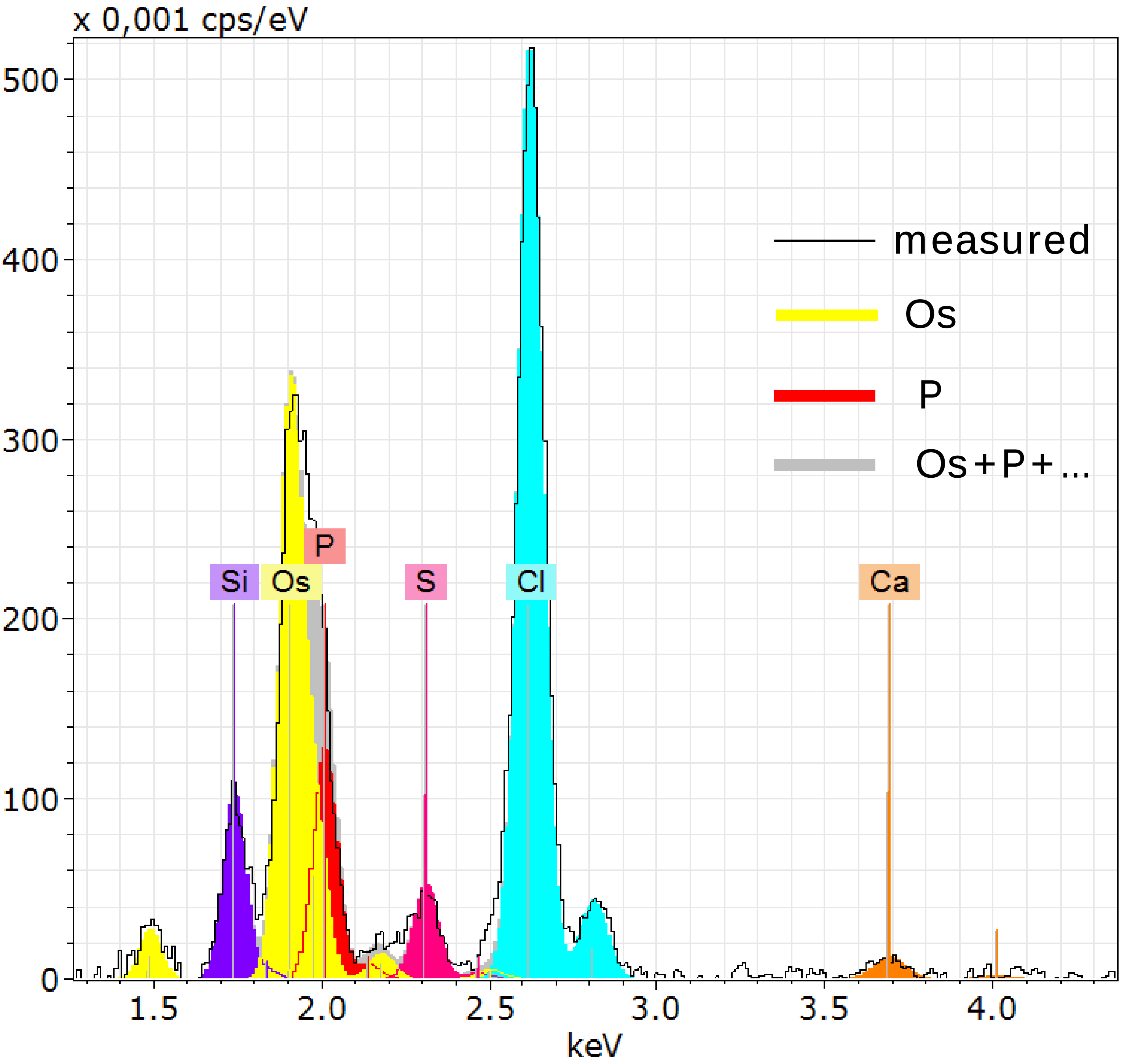
EDS for Life Science at 0.1sr

Yeast Cell: Element Mapping of immunolabels and light and heavy elements

30 mm^2, 0.12 sr (Standard EDS); Conventional STEM




x 0,001 cps/eV
500
400
300
200
100
0
1.5
2.0
2.5
3.0
3.5
4.0
keV
Si
Os
S
Cl
Ca
measured
Os
P
Os+P+...


x 0,001 cps/eV
500
400
300
200
100
0
1.5
2.0
2.5
3.0
3.5
4.0
keV
Si
Os
P
S
Cl
Ca
measured
Os
P
Os+P+...

TEM EDS Quantification; R. Egerton

1994, line intensity for a particular element line / transition

$$I_x = N_A\,\sigma_A\,\omega_A\,(\Omega/4\pi)\,\varepsilon\,N_e = n_A\,t\,\sigma_A\,\omega_A\,(\Omega/4\pi)\,\varepsilon\,N_e$$

Cliff and Lorimer: $\dfrac{I_A}{I_B} = \dfrac{C_A}{k_{AB}\,C_B}$ k_{AB} can be determined experimentally **or theoretically**

I_x	number of X-ray photons in a characteristic peak of species A
N	number of atoms per unit volume
$n\,t$	number of atoms per unit area times thickness
σ	ionization cross section (Casnati et al., 1982, Bote et al., 2009)
ω	fluorescence yield (Hubbell et al., 1994, Krause, 1979)
$\Omega/4\pi$	solid angle / geometrical collection efficiency
ε	detection quantum efficiency
N_e	number of incident electrons

+ absorption

TEM EDS Quantification; R. Egerton

1994, line intensity for a particular element line / transition

Zeta-Factor

$$I_x = N_A \sigma_A \omega_A (\Omega/4\pi) \varepsilon N_e = n_A t \sigma_A \omega_A (\Omega/4\pi) \varepsilon N_e$$

Cliff and Lorimer:

$$\frac{I_A}{I_B} = \frac{C_A}{k_{AB} C_B}$$

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ε	detection quantum efficiency
N_e	number of incident electrons

+ absorption

TEM EDS Quantification
Zeta-factor Method vs Cliff Lorimer

The CL-method is a ratio method by Graham Cliff and Gordon Lorimer:

$$\frac{C_A}{C_B} = k_{AB} \frac{I_A}{I_B}$$

M. Watanabe J. of Micr. 2005:

For a **standard with known thickness *t***
ζ can be determined:

$$\rho_A \, t = \zeta_A \frac{I_A}{C_A D_e} \quad \ldots$$

***D*$_e$ (total electron dose) must be known for all measurements.**

Then, for a sample C_A, C_B ... ρ and t are unknown.
N equations with N unknown variables.

$$C_A + C_B = 1$$

$$C_1 + C_2 + \ldots = 1$$

$$\rho \, t = \frac{\zeta_A I_A + \zeta_B I_B}{D_e}$$

A_A

A_B

$$C_A = \frac{\zeta_A I_A}{\zeta_A I_A + \zeta_B I_B}$$

$$C_B = \ldots$$

absorption corr.
> ρt > iteration

TEM EDS Quantification

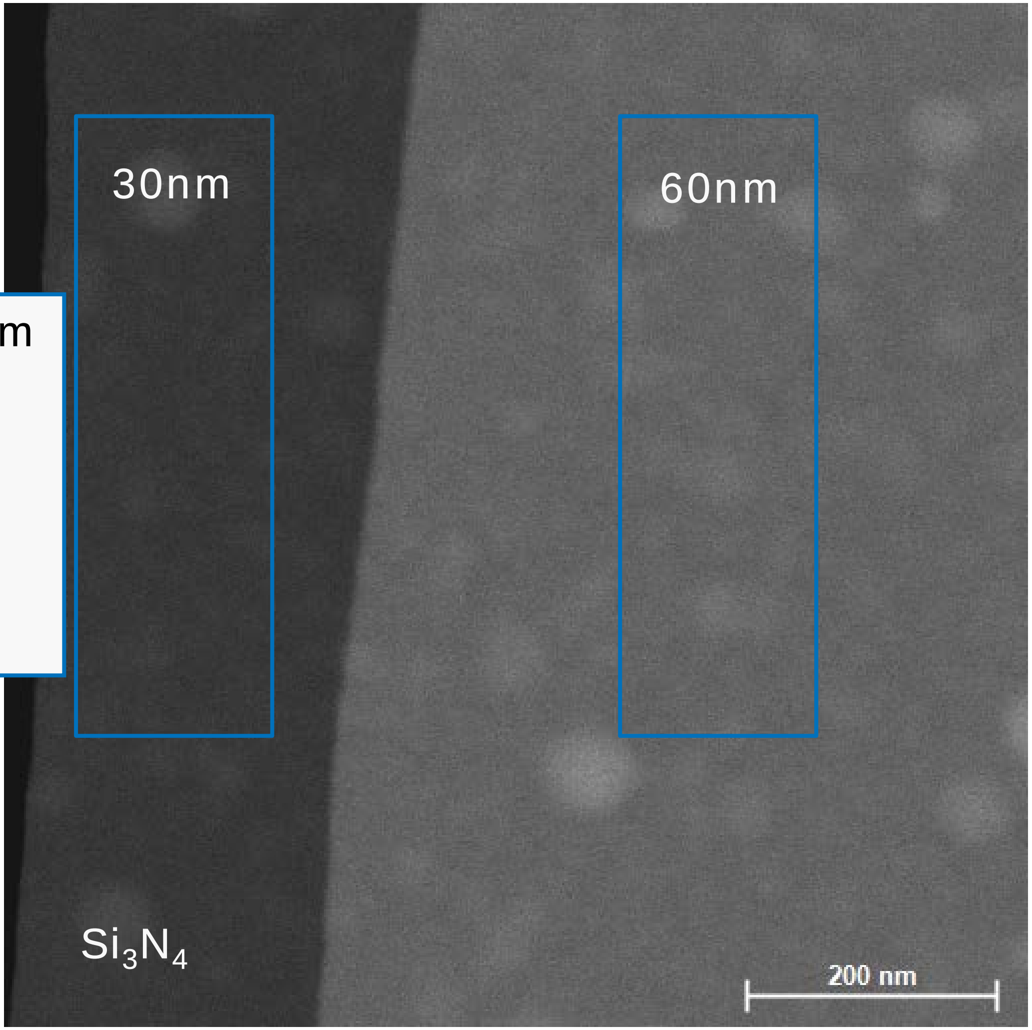
Zeta vs CL

- For testing we used Si_3N_4

a single layer (30nm) as the sample
a double layer (60nm) as the standard

- STEM probe current: 344pA

Standard:	Si at%	N at%	d nm
Si3N4_expected	42,86	57,14	
Si3N4_60nm_st.	42,86	57,14	
CL:			
Si3N4_30nm	43,84	56,16	
Zeta:			
Si3N4_30nmZeta	41,96	58,04	30



- Further tests with Al_2O_3, TiO_2, GaP

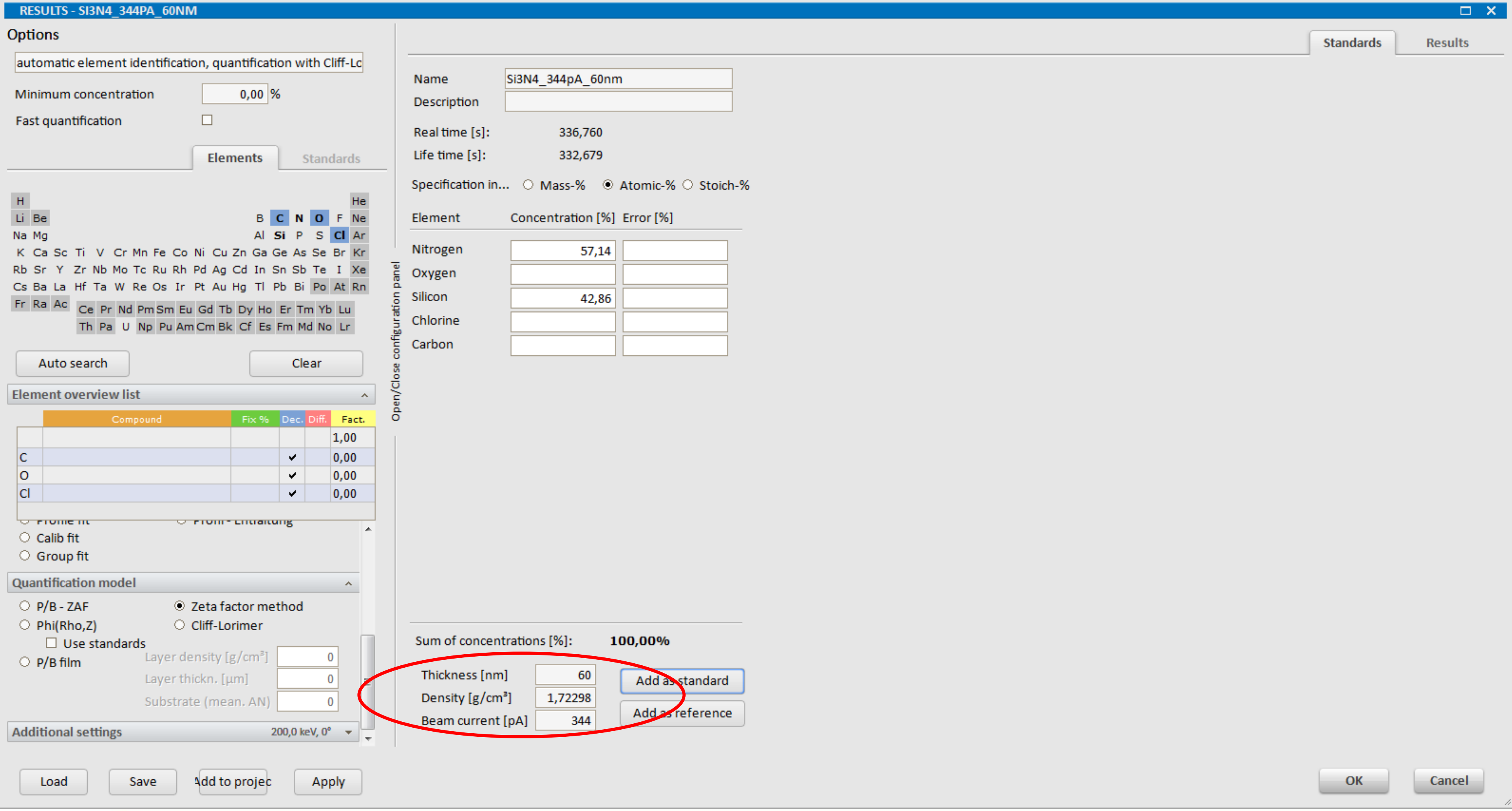
(G. Kothleitner, W. Grogger, K. Volz)

- Very sensitive to
  - probe current and
  - thickness variations

G. Kothleitner, et al., Microsc. Microanal. 20, 678–686, 2014

TEM EDS Quantification in Esprit 2.1

Zeta Method: Set up using Si_3N_4 60nm



RESULTS - SI3N4_344PA_60NM

Options

automatic element identification, quantification with Cliff-Lc

Minimum concentration: 0,00 %

Fast quantification ☐

Element overview list

	Compound	Fix %	Dec.	Diff.	Fact.
					1,00
C			✓		0,00
O			✓		0,00
Cl			✓		0,00

○ Profile fit ○ Profil - Entfaltung

○ Calib fit

○ Group fit

Quantification model

○ P/B - ZAF ● Zeta factor method

○ Phi(Rho,Z) ○ Cliff-Lorimer

☐ Use standards

○ P/B film

Layer density [g/cm³]: 0

Layer thickn. [µm]: 0

Substrate (mean. AN): 0

Additional settings: 200,0 keV, 0°

Name: Si3N4_344pA_60nm

Description:

Real time [s]: 336,760

Life time [s]: 332,679

Specification in... ○ Mass-% ● Atomic-% ○ Stoich-%

Element	Concentration [%]	Error [%]
Nitrogen	57,14	
Oxygen		
Silicon	42,86	
Chlorine		
Carbon		

Sum of concentrations [%]: **100,00%**

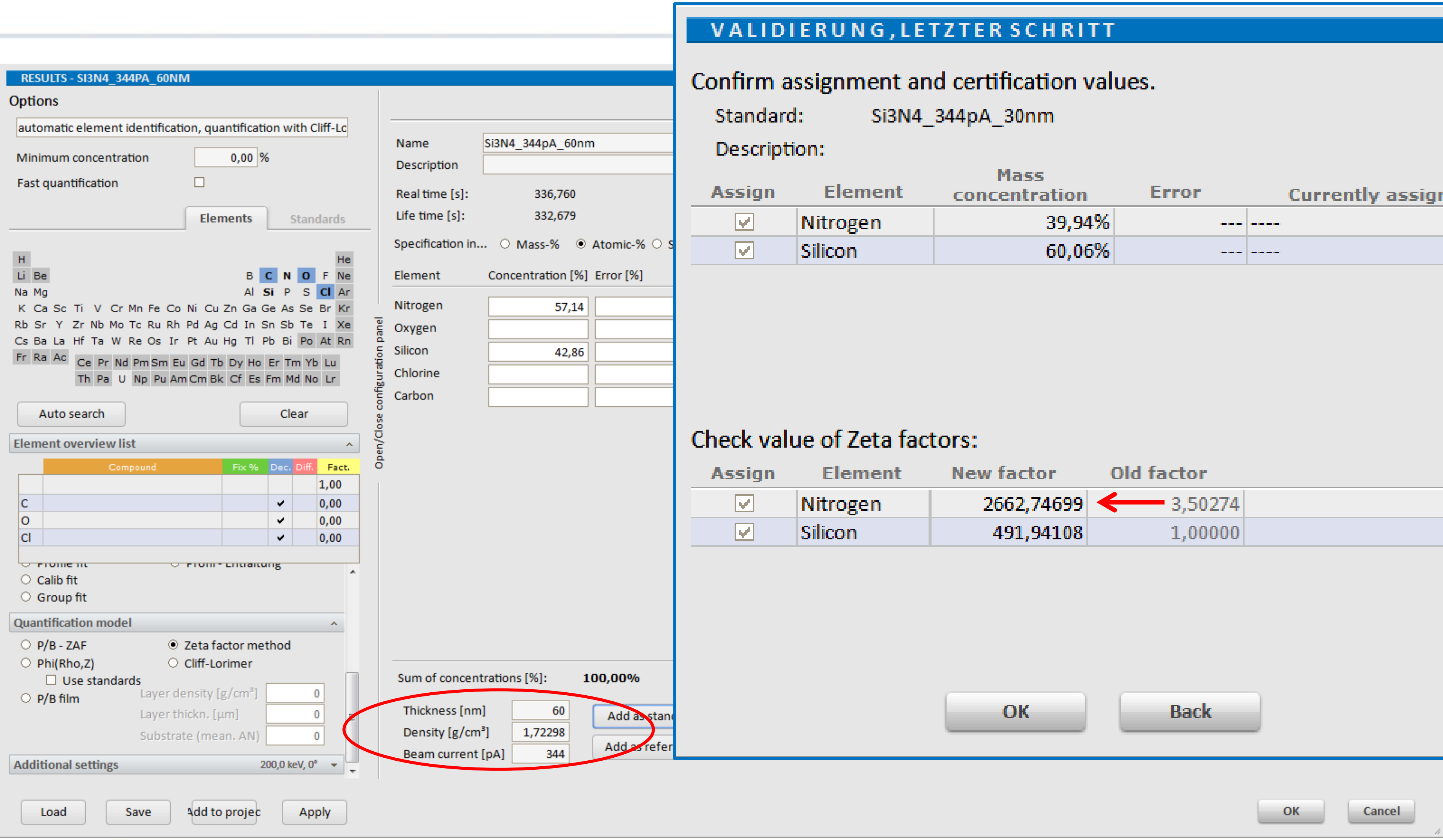
Thickness [nm]: 60

Density [g/cm³]: 1,72298

Beam current [pA]: 344

TEM EDS Quantification in Esprit 2.1

Zeta Method: Set up using Si_3N_4 60nm



automatic element identification, quantification with Cliff-Lo

Minimum concentration 0,00 %

Fast quantification ☐

Compound	Fix %	Dec.	Diff.	Fact.
				1,00
C		✓		0,00
O		✓		0,00
Cl		✓		0,00

○ Profile fit ○ Profil - Entfaltung
○ Calib fit
○ Group fit

Quantification model

○ P/B - ZAF ● Zeta factor method
○ Phi(Rho,Z) ○ Cliff-Lorimer
☐ Use standards
○ P/B film

Layer density [g/cm³] 0
Layer thickn. [µm] 0
Substrate (mean. AN) 0

200,0 keV, 0°

Name Si3N4_344pA_60nm
Description

Real time [s]: 336,760
Life time [s]: 332,679

Specification in... ○ Mass-% ● Atomic-% ○ S

Element	Concentration [%]	Error [%]
Nitrogen	57,14	
Oxygen		
Silicon	42,86	
Chlorine		
Carbon		

Sum of concentrations [%]: 100,00%

Thickness [nm] 60
Density [g/cm³] 1,72298
Beam current [pA] 344

Confirm assignment and certification values.

Standard: Si3N4_344pA_30nm

Description:

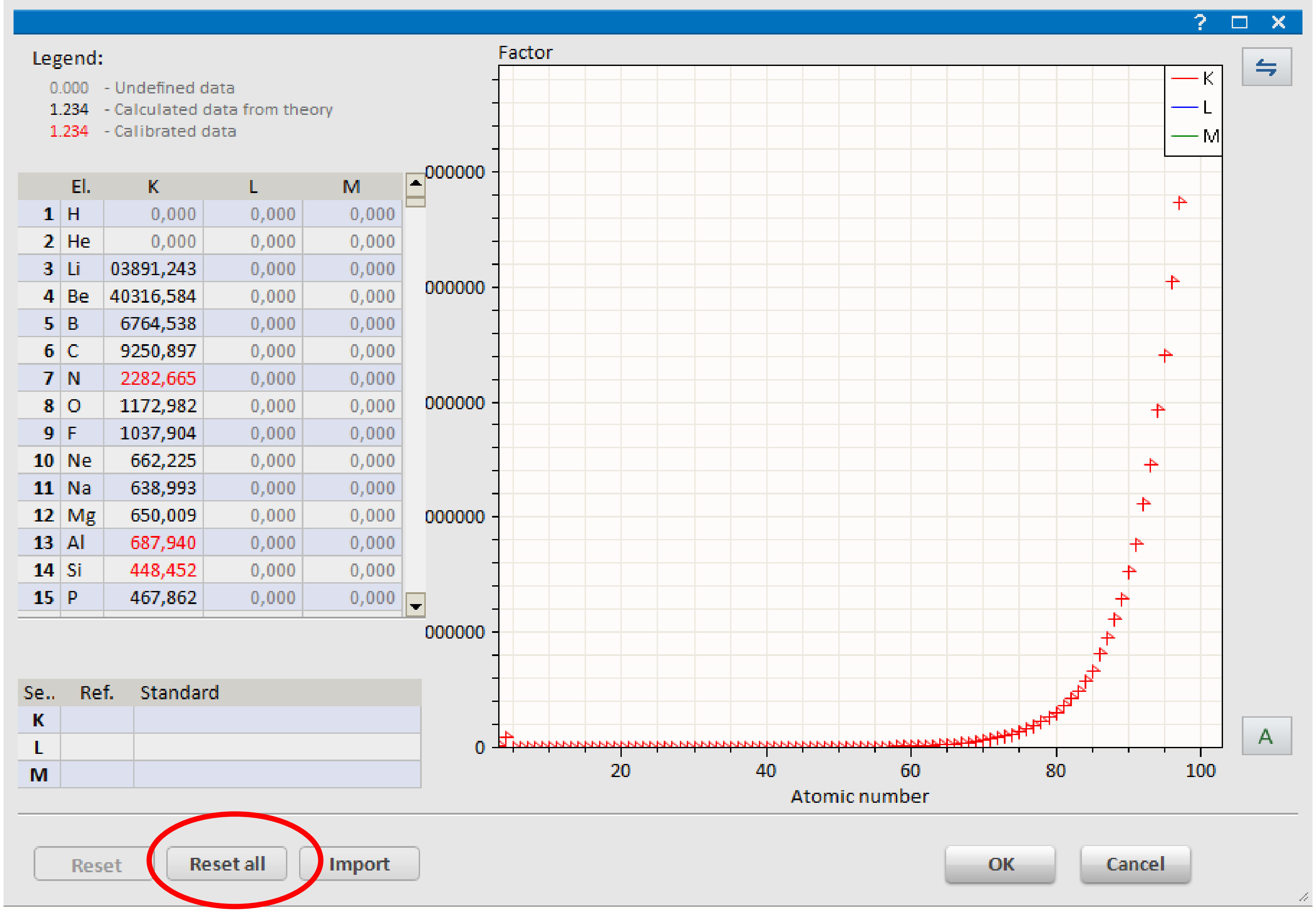
Assign	Element	Mass concentration	Error	Currently assig
☑	Nitrogen	39,94%	---	----
☑	Silicon	60,06%	---	----

Check value of Zeta factors:

Assign	Element	New factor	Old factor
☑	Nitrogen	2662,74699 ←	3,50274
☑	Silicon	491,94108	1,00000

TEM EDS Quantification in Esprit 2.1

with 1-2 standards all other Zeta – factors can be obtained from theoretical C-L-factors



Legend:

0.000 - Undefined data
1.234 - Calculated data from theory
1.234 - Calibrated data

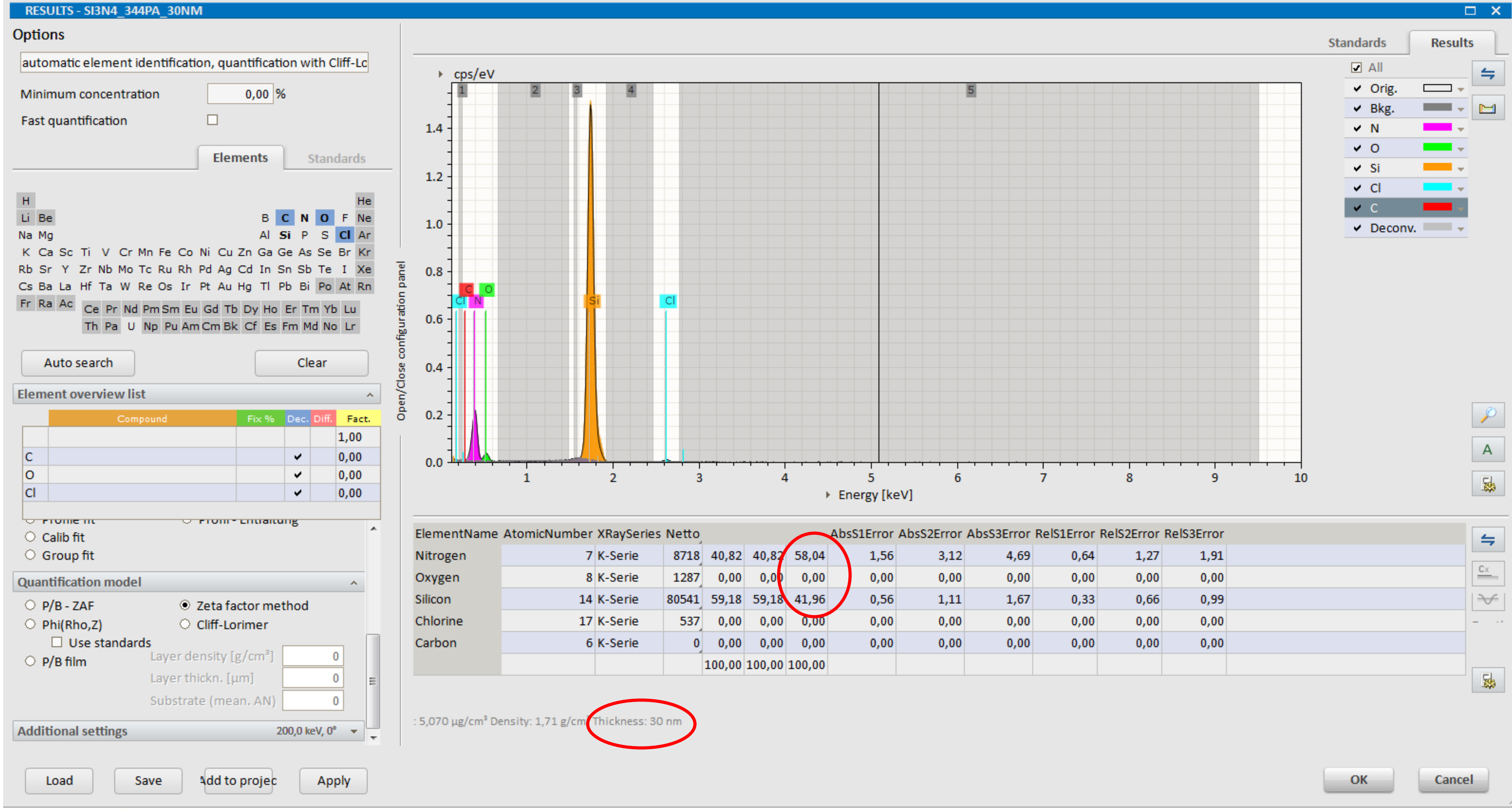
	El.	K	L	M
1	H	0,000	0,000	0,000
2	He	0,000	0,000	0,000
3	Li	03891,243	0,000	0,000
4	Be	40316,584	0,000	0,000
5	B	6764,538	0,000	0,000
6	C	9250,897	0,000	0,000
7	N	2282,665	0,000	0,000
8	O	1172,982	0,000	0,000
9	F	1037,904	0,000	0,000
10	Ne	662,225	0,000	0,000
11	Na	638,993	0,000	0,000
12	Mg	650,009	0,000	0,000
13	Al	687,940	0,000	0,000
14	Si	448,452	0,000	0,000
15	P	467,862	0,000	0,000

Se..	Ref.	Standard
K		
L		
M		

TEM EDS Quantification in Esprit 2.1

Zeta Method: Set up using Si_3N_4 60nm

Zeta: 344pA, single layer Si_3N_4 d=?



RESULTS - SI3N4_344PA_30NM

Options

automatic element identification, quantification with Cliff-Lc

Minimum concentration 0,00 %

Fast quantification ☐

Element overview list

	Compound	Fix %	Dec.	Diff.	Fact.
					1,00
C			✓		0,00
O			✓		0,00
Cl			✓		0,00

○ Calib fit
○ Group fit

Quantification model

○ P/B - ZAF ● Zeta factor method
○ Phi(Rho,Z) ○ Cliff-Lorimer
☐ Use standards
○ P/B film

Layer density [g/cm³] 0
Layer thickn. [µm] 0
Substrate (mean. AN) 0

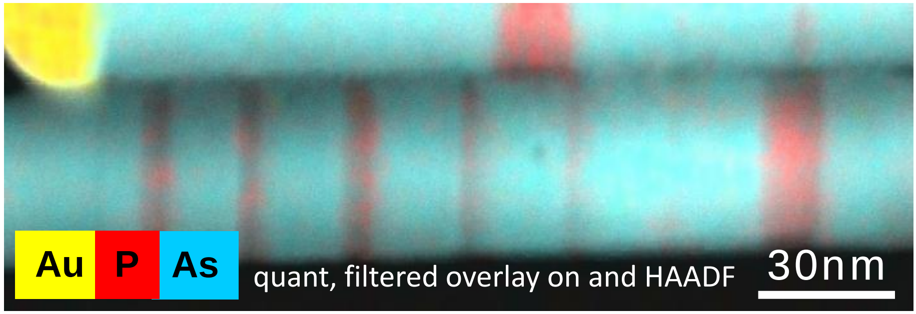
Additional settings 200,0 keV, 0°

ElementName	AtomicNumber	XRaySeries	Netto				AbsS1Error	AbsS2Error	AbsS3Error	RelS1Error	RelS2Error	RelS3Error
Nitrogen	7	K-Serie	8718	40,82	40,82	58,04	1,56	3,12	4,69	0,64	1,27	1,91
Oxygen	8	K-Serie	1287	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
Silicon	14	K-Serie	80541	59,18	59,18	41,96	0,56	1,11	1,67	0,33	0,66	0,99
Chlorine	17	K-Serie	537	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
Carbon	6	K-Serie	0	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
				100,00	100,00	100,00						

: 5,070 µg/cm³ Density: 1,71 g/cm³ Thickness: 30 nm

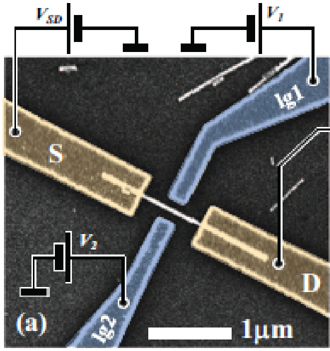
Quantified Linescan

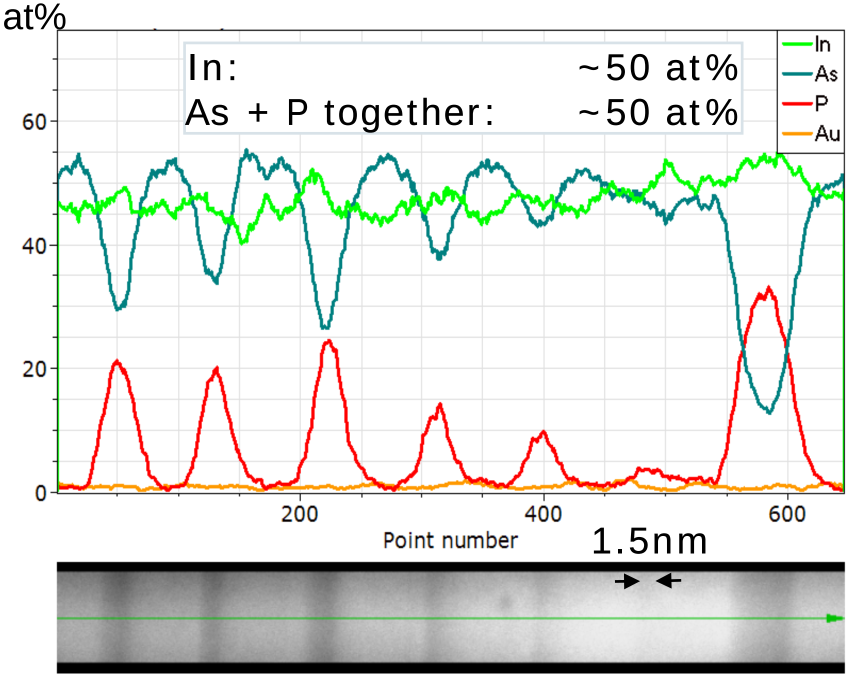
InAs Nanorods with P-rich layers: Deconvolution of P and Au, 0.12sr



quant, filtered overlay on and HAADF

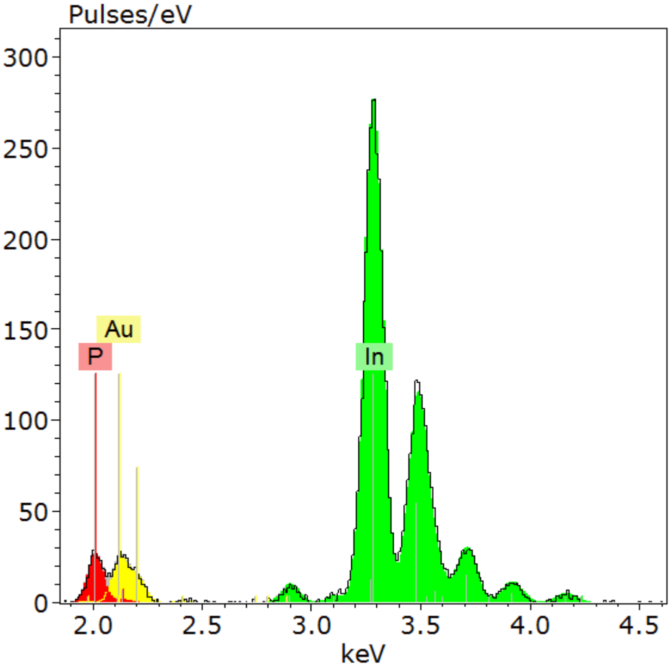
Single e^- transistor:



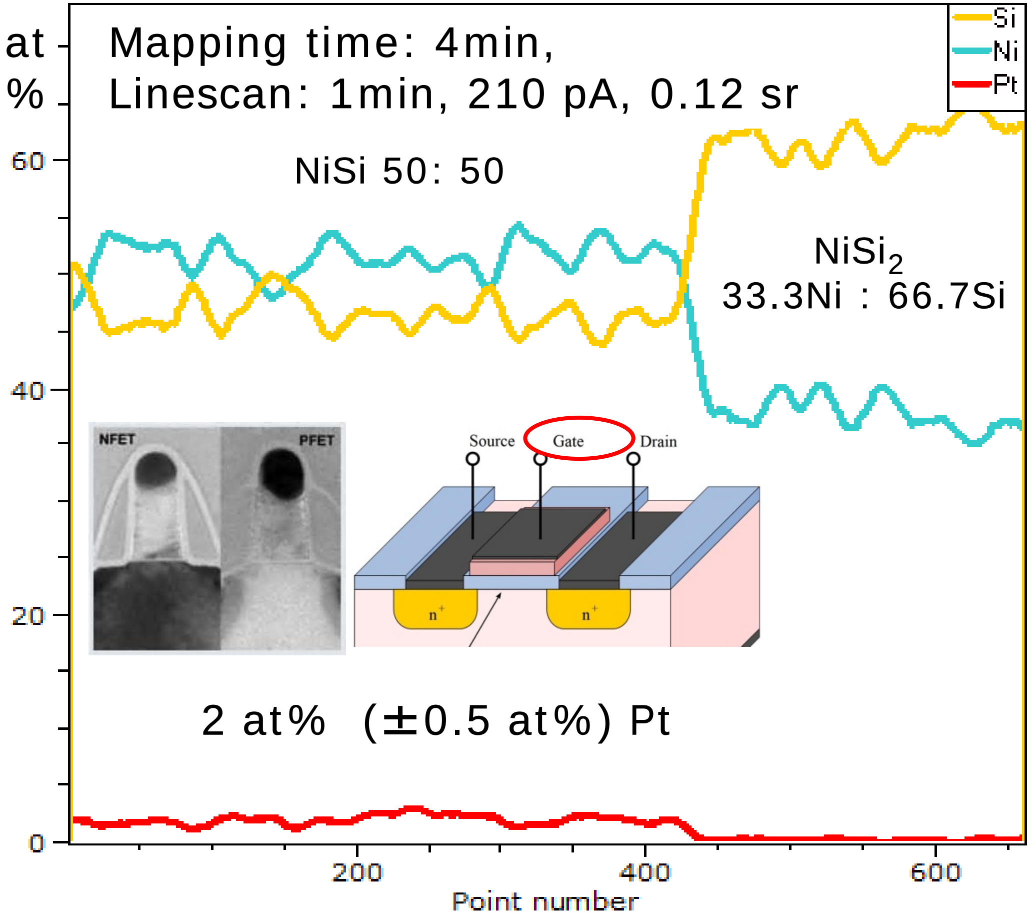


In: ~50 at%
As + P together: ~50 at%

Deconvolution of P and Au:



Quantified Linescan extracted from HyperMap: NiSi(Pt)-NiSi$_2$-Junction on Si

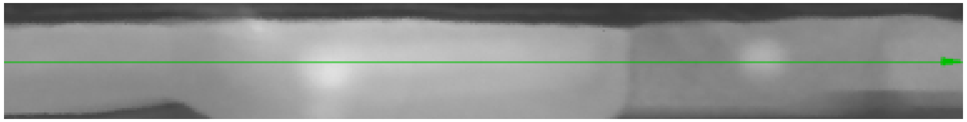


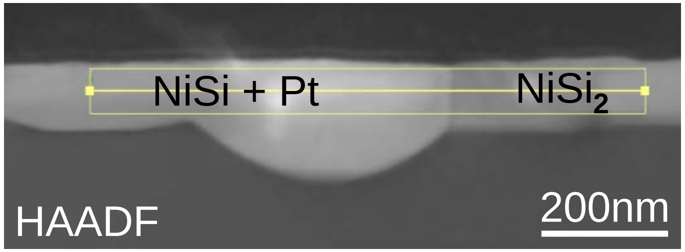
Mapping time: 4min,
Linescan: 1min, 210 pA, 0.12 sr

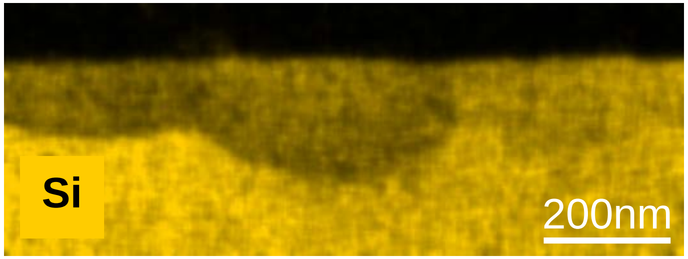
NiSi 50: 50

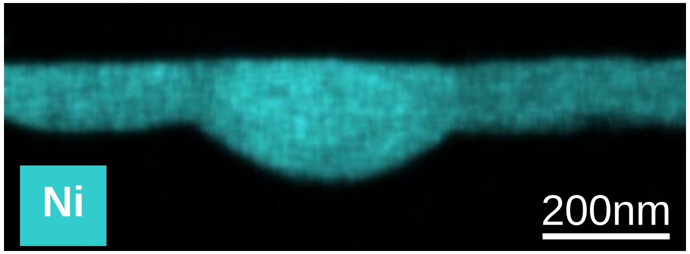
NiSi$_2$
33.3Ni : 66.7Si

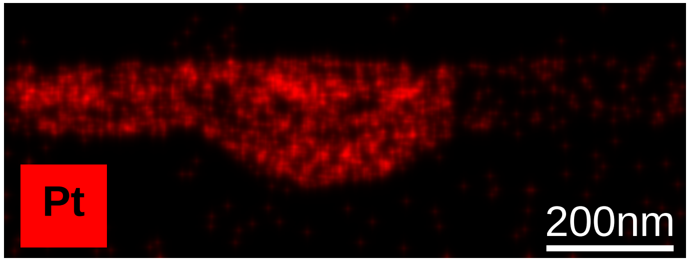
2 at% (±0.5 at%) Pt





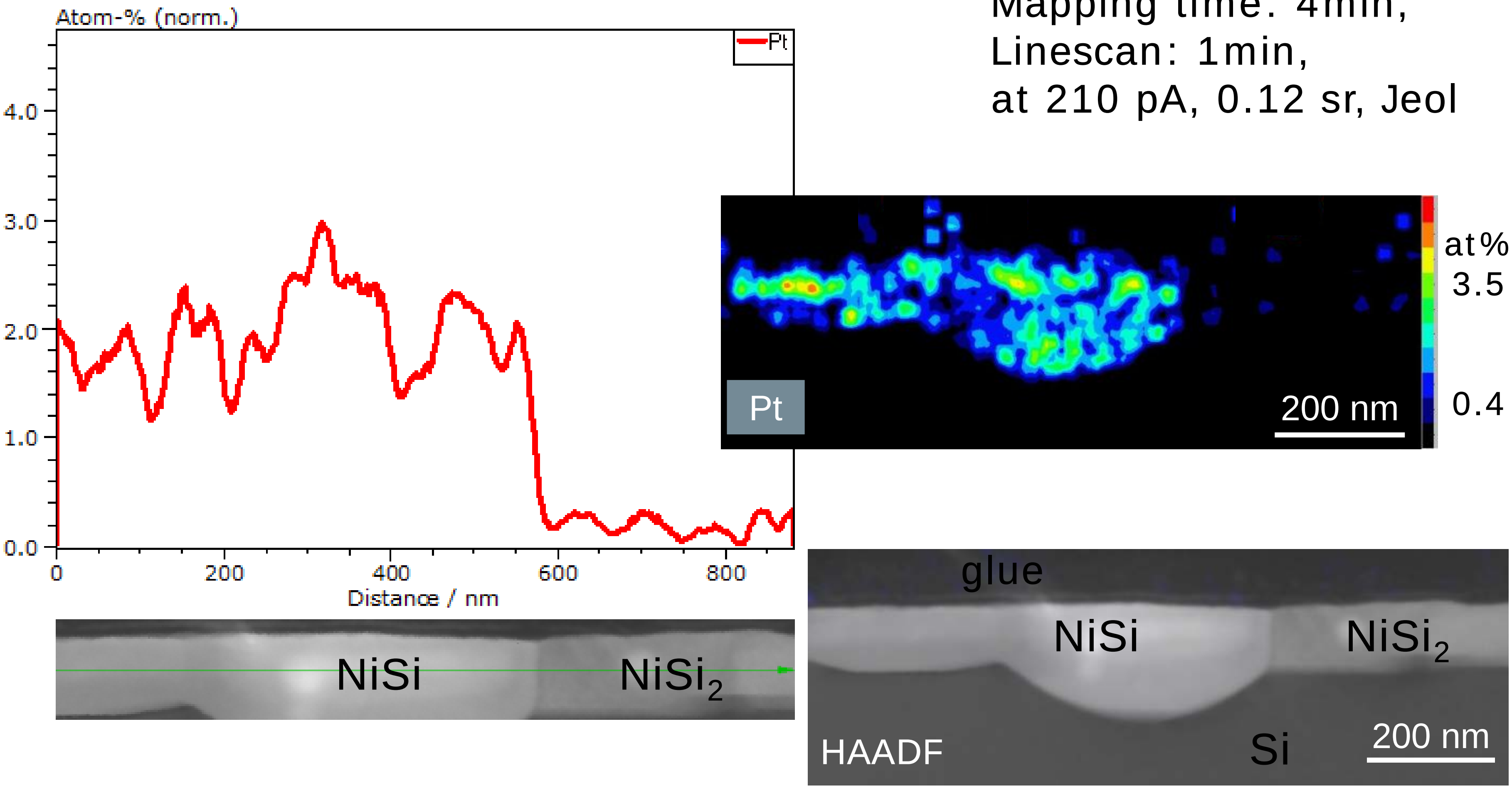




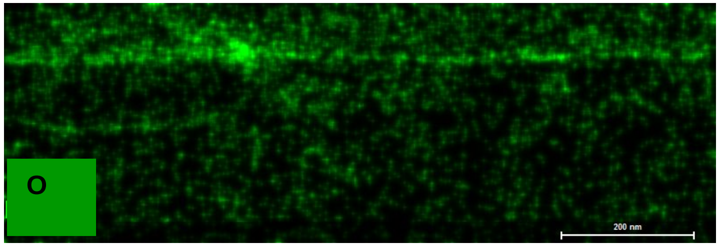


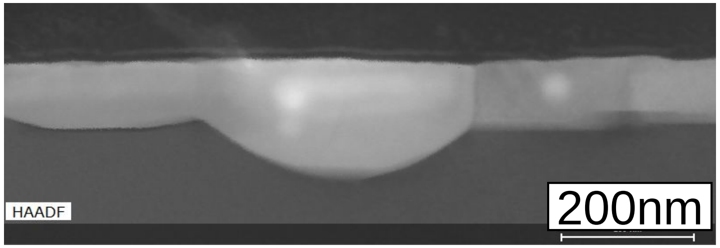
Quantified Pt-content in the HyperMap, and in Linescan extracted from HyperMap: NiSi(Pt)-$NiSi_2$-Junction on Si, 0.12sr

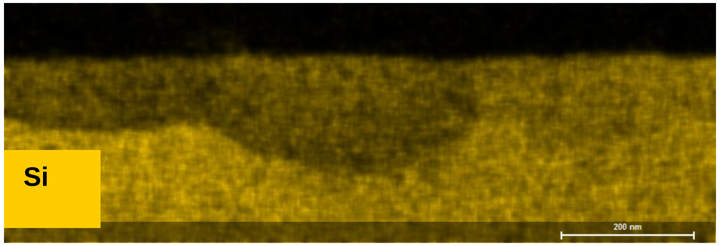
Mapping time: 4min,
Linescan: 1min,
at 210 pA, 0.12 sr, Jeol

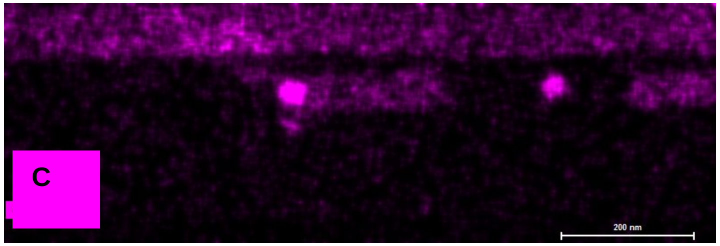


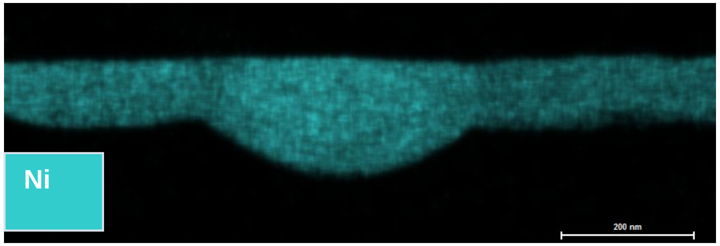
NiSi(Pt)-NiSi$_2$-junction on Si,
Map, explore other elements!

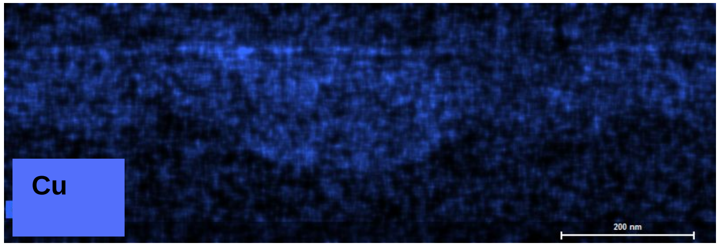


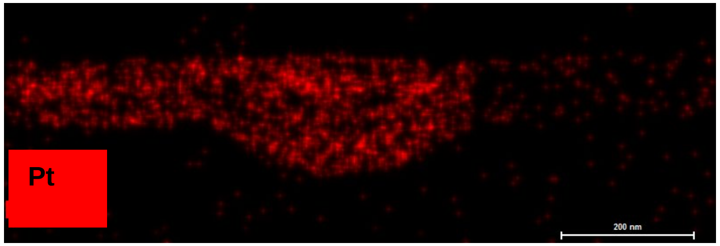








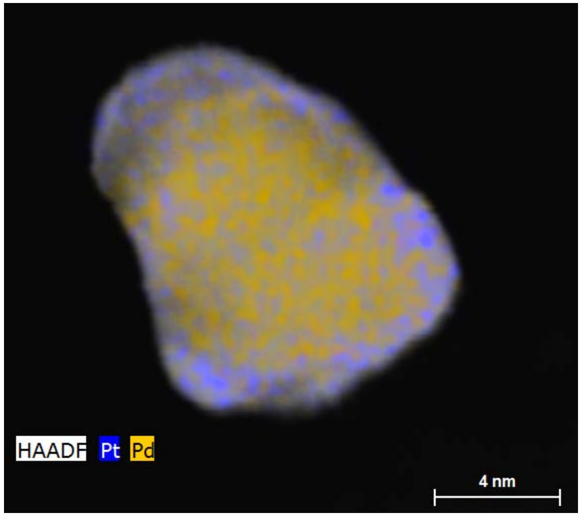


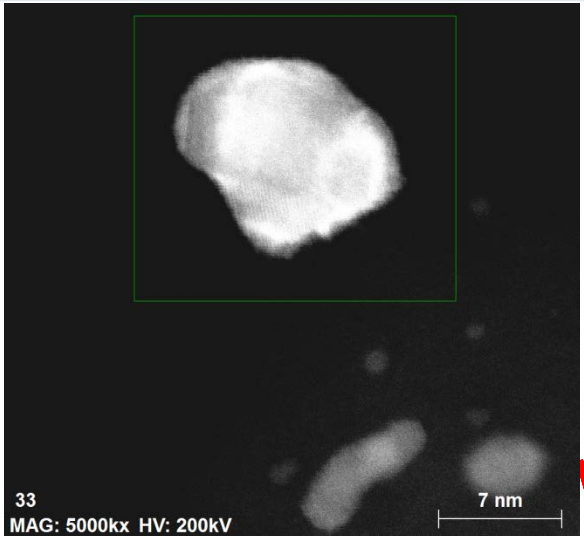


EDS for Catalysis, Quantification

Pt-Pd Core Shell Particles

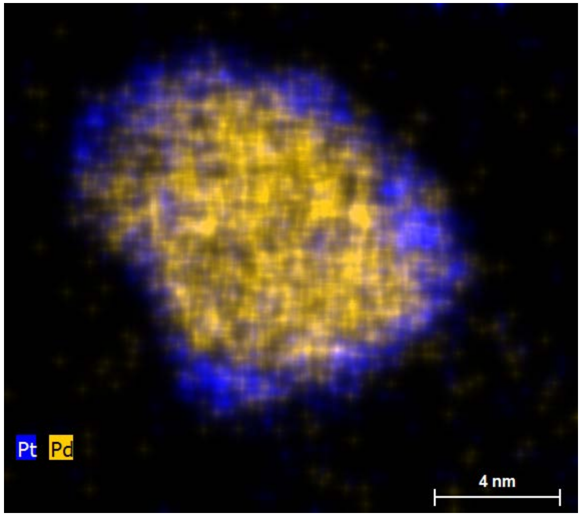
mass%, 30 mm², 0.12 sr (Standard EDS); Cs-corr. STEM

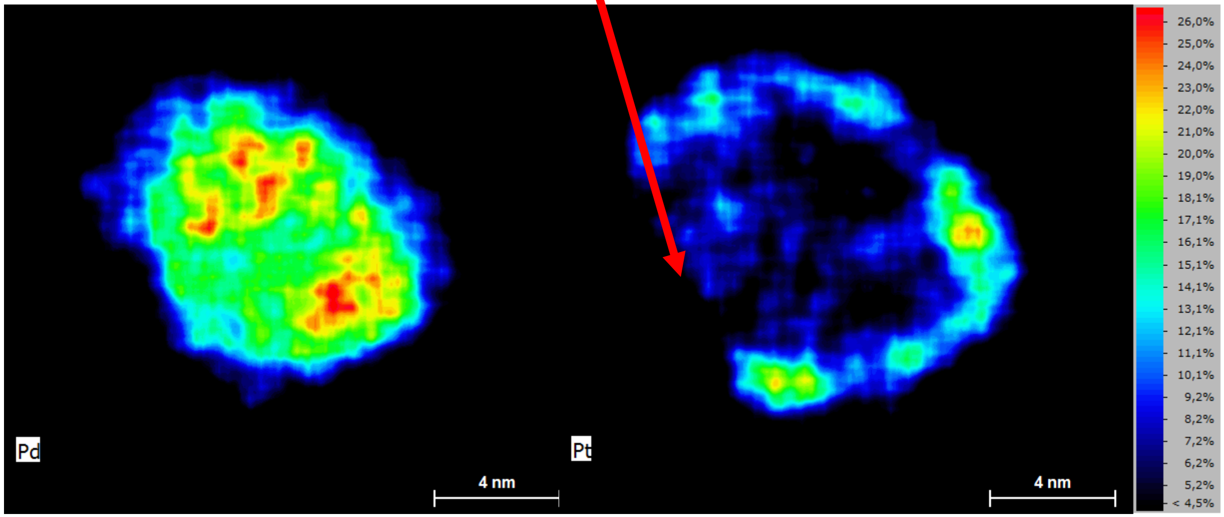




Data courtesy: Dogan Ozkaya, Johnson Matthey Technology Center

Pt shell not closed due to fabrication procedure





SDD for STEM (30mm^2, ~0.1sr)
Probe Cs-corrected

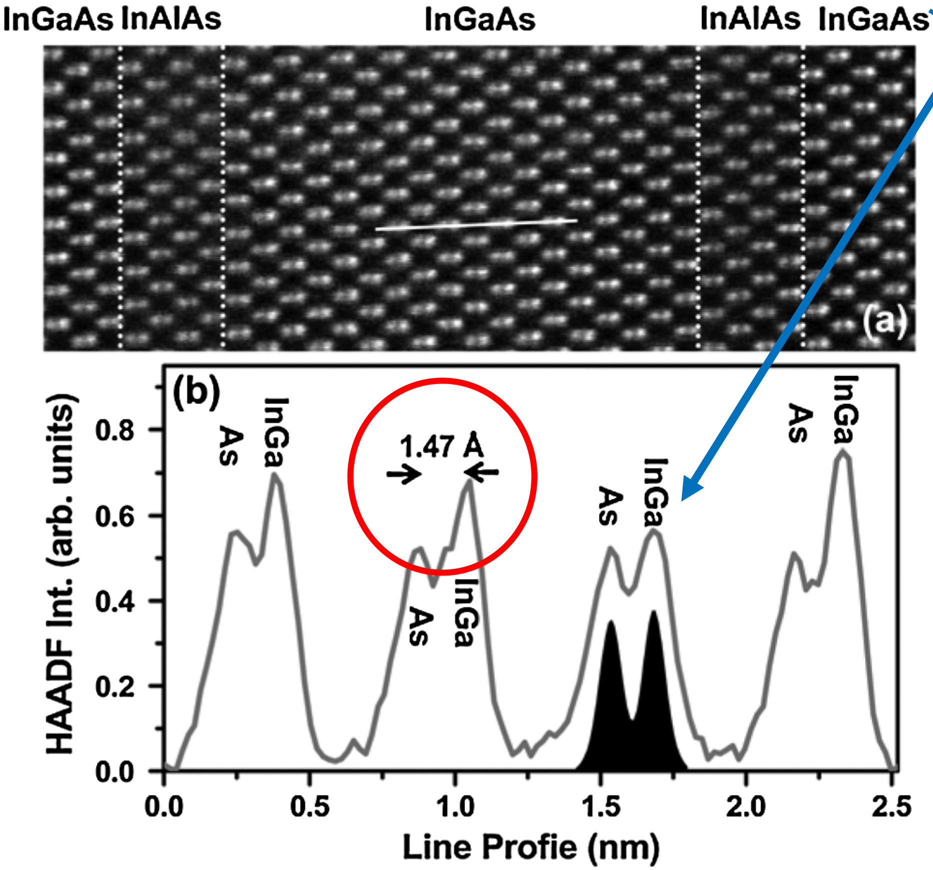
Indium missing in one atomic column

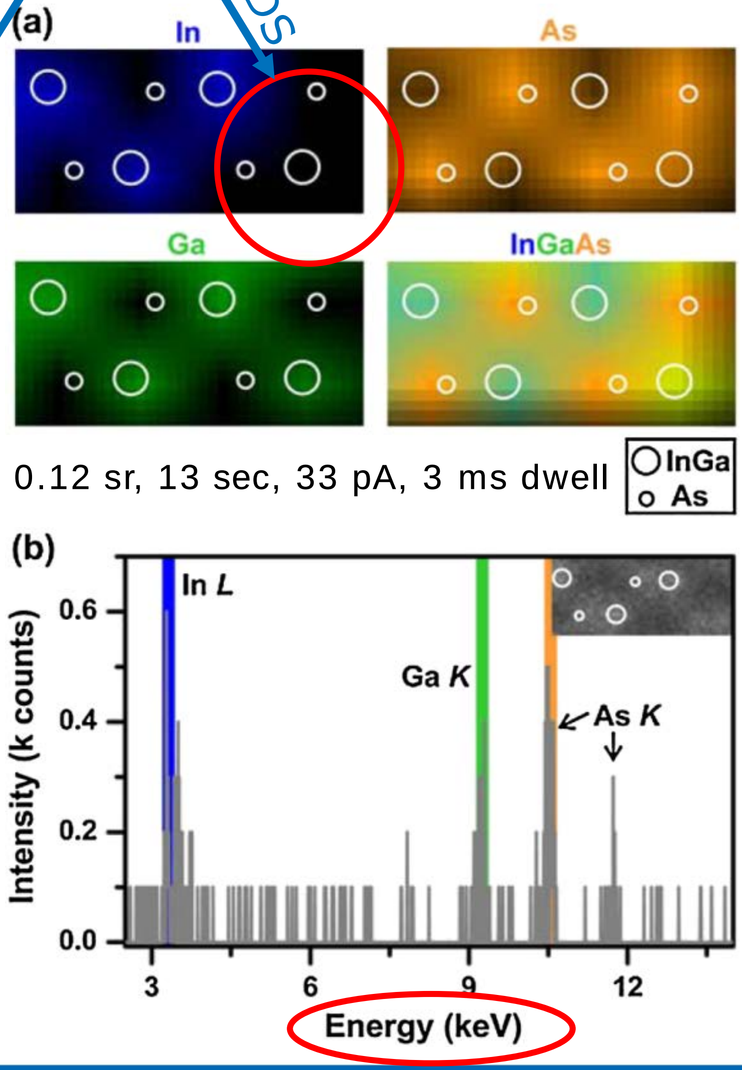
HAADF signal

EDS

M. W. Chu et al.

Phys. Rev. Lett. 104, 196101 (2010)

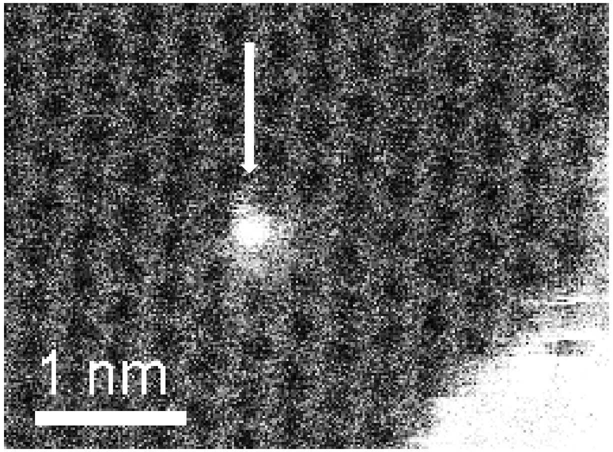


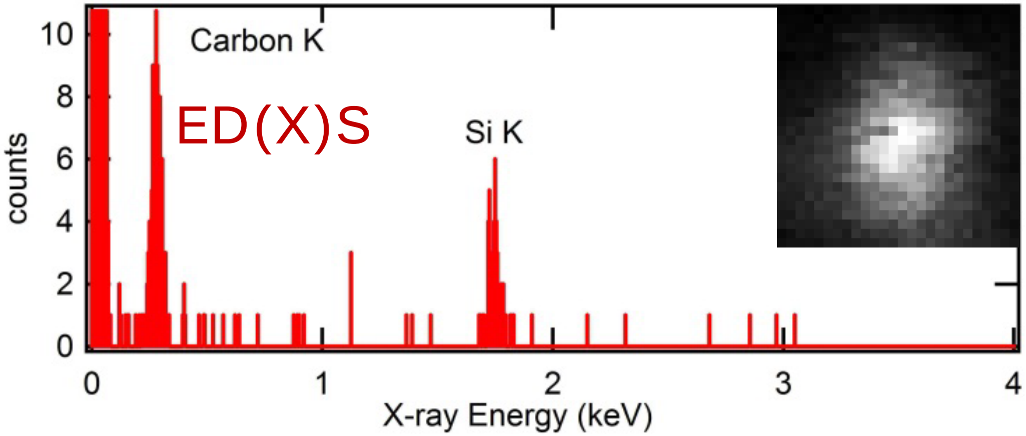


0.12 sr, 13 sec, 33 pA, 3 ms dwell

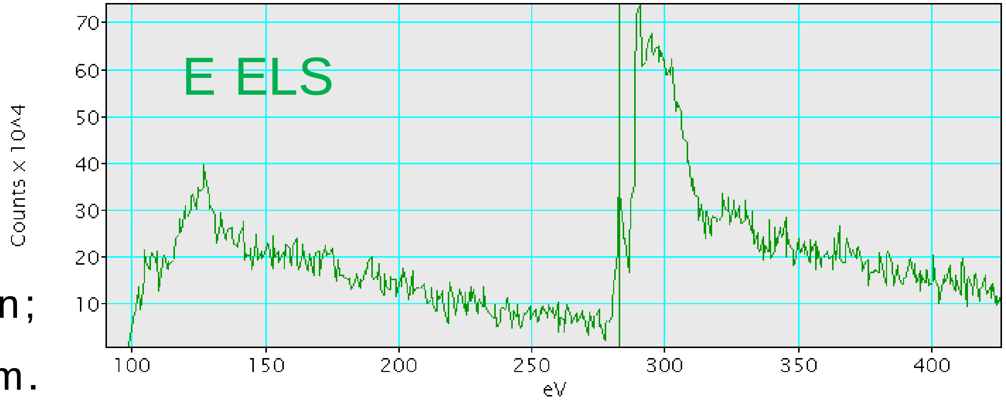
Simultaneous EDXS and EELS from a single Si atom, 30mm^2, SLEW, C-FEG STEM

Tracking movie of 1 Si atom on graphene as recorded during EDS spectrum acquisition





ADF image of a defect in monolayer graphene recorded ***after*** spectra were acquired. Arrow points to a tracked Si impurity atom.



EDXS and EELS data recorded simultaneously.

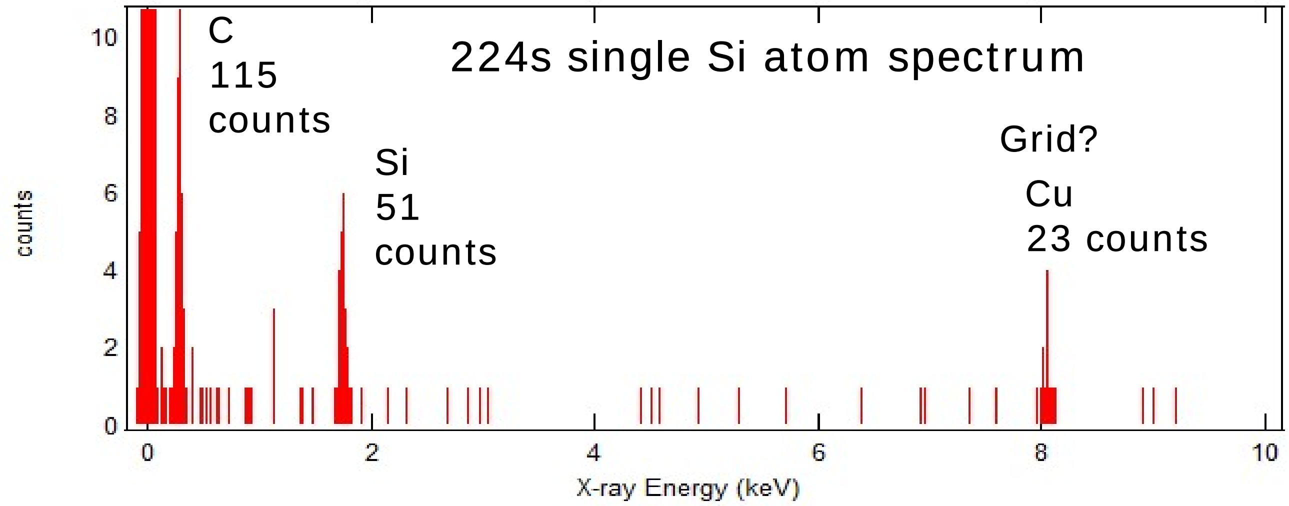
I_p = 190 pA, 0.09sr, 224 s acquisition;

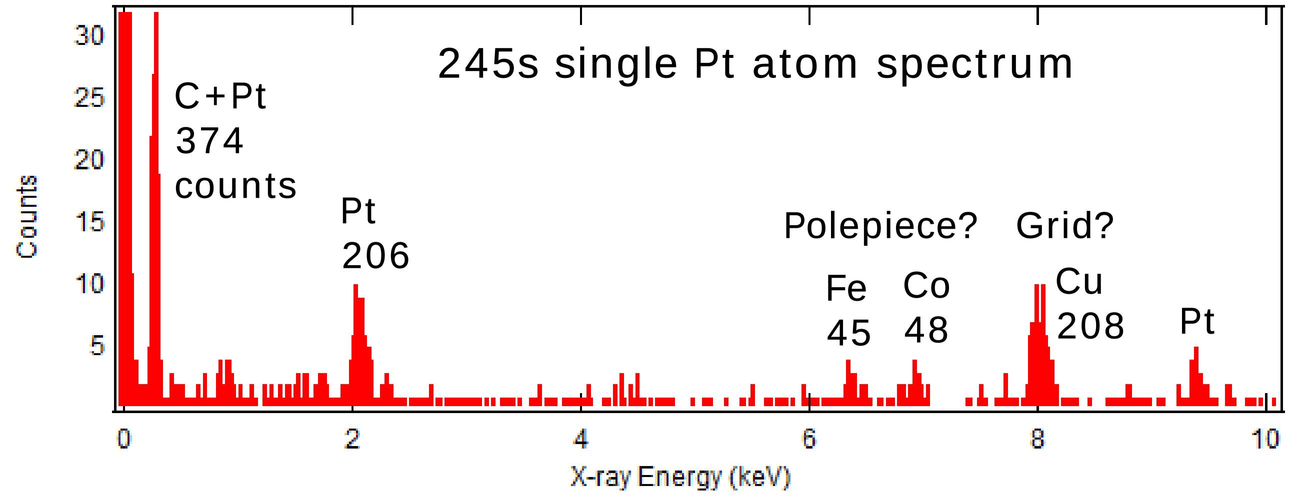
Thereof ~10s beam close to the atom.

Nion UltraSTEM100, 60 keV, Daresbury UK. Bruker SDD EDXS, Gatan Enfina EELS

T. C. Lovejoy et al., APL 100, 154101 (2012)

Single atom spectra





APL 2012

T. C. Lovejoy et al.

T. C. Lovejoy et al., APL 100, 154101 (2012)

Single atom spectra:
Theory vs. experiment

$$R=(n\cdot\sigma/A)(\omega\cdot\Omega/4\pi\cdot\varepsilon)$$

R: count rate, X-rays / s / atom
A: scanned area
N: beam current, electrons / s
σ: cross section for particular atom and shell
ω: fluorescence yield
$\Omega/4\pi$: geometrical efficiency (solid angle)
ε: quantum efficiency

	theo	~ 2x	exp
Si-K	7 cts/s		4 cts/s
C-K	2 cts/s		1 cts/s
Pt-M	28 cts/s		14 cts/s

T. C. Lovejoy et al., APL 100, 154101 (2012)

EDXS with 100 mm^2 windowless oval detector area;

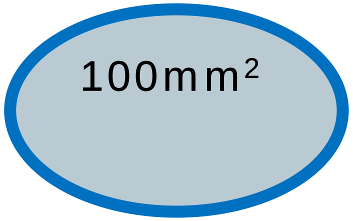
Nion UltraSTEM, Cs-corrected, high brightness source

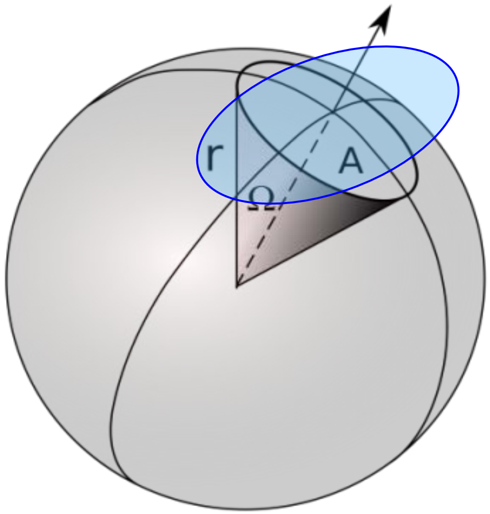
EDXS at ~0.7 sr. This is the real solid angle for a flat vertical SDD.

Wrong calculation:

$100\text{mm}^2 / (10.5\text{mm})^2 = 0.91\text{sr}$

TOA: 13.4°

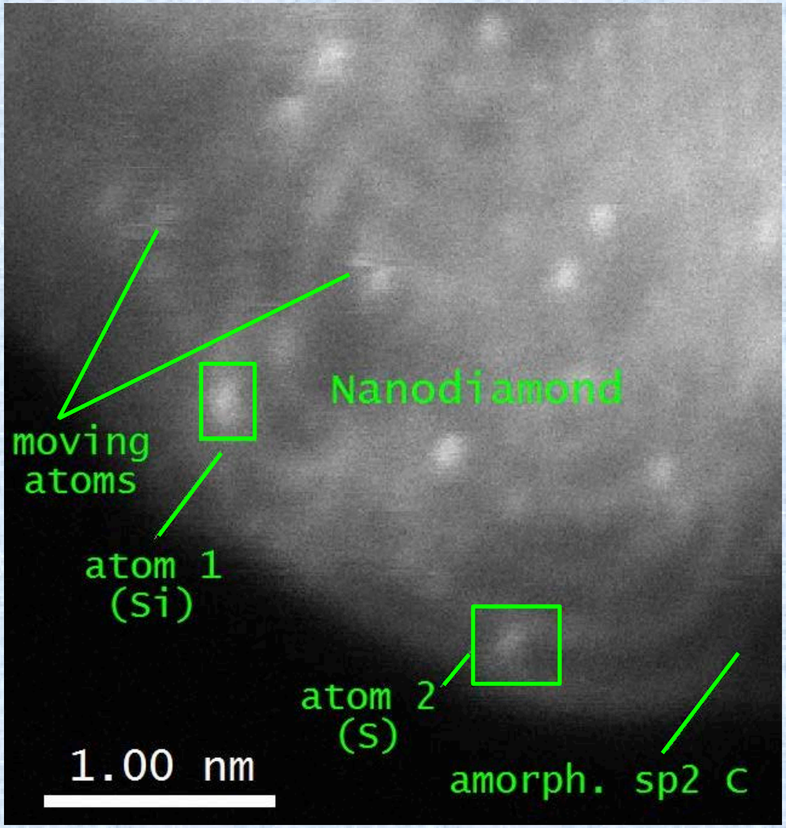




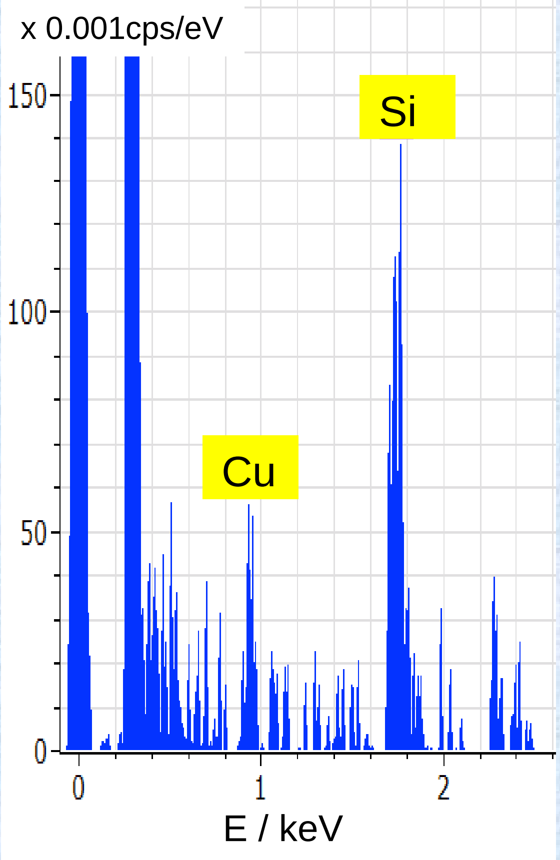
wikipedia

Identifying atoms by EDXS, one-by-one

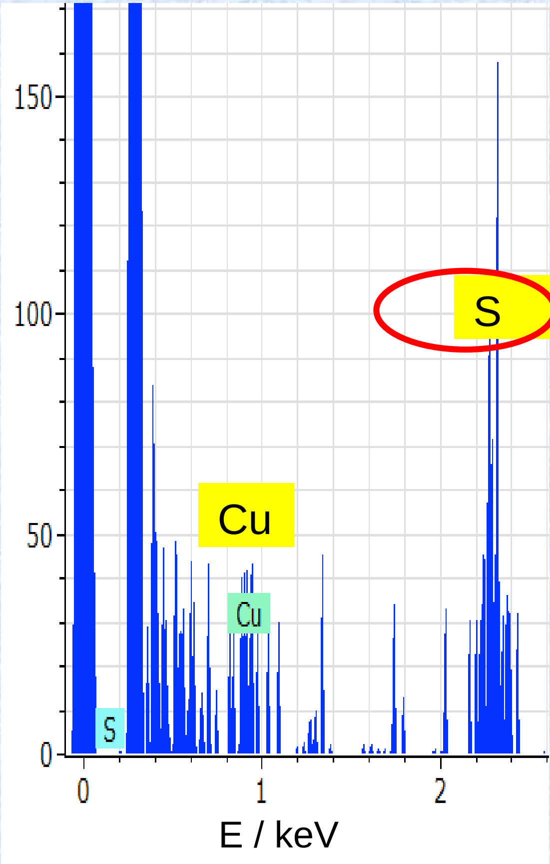
100 mm^2 windowless SDD
at 0.7 sr collection angle



HAADF image of **meteorite nanodiamond** with impurities > **not as ideal as graphene**!
Nion UltraSTEM200, 60 keV,
Bruker Quantax XFlash UHV windowless SDD.
courtesy Rhonda Stroud, NRL, M&M (2015)



EDXS of atom 1,
9.4 sec, **74 Si** counts



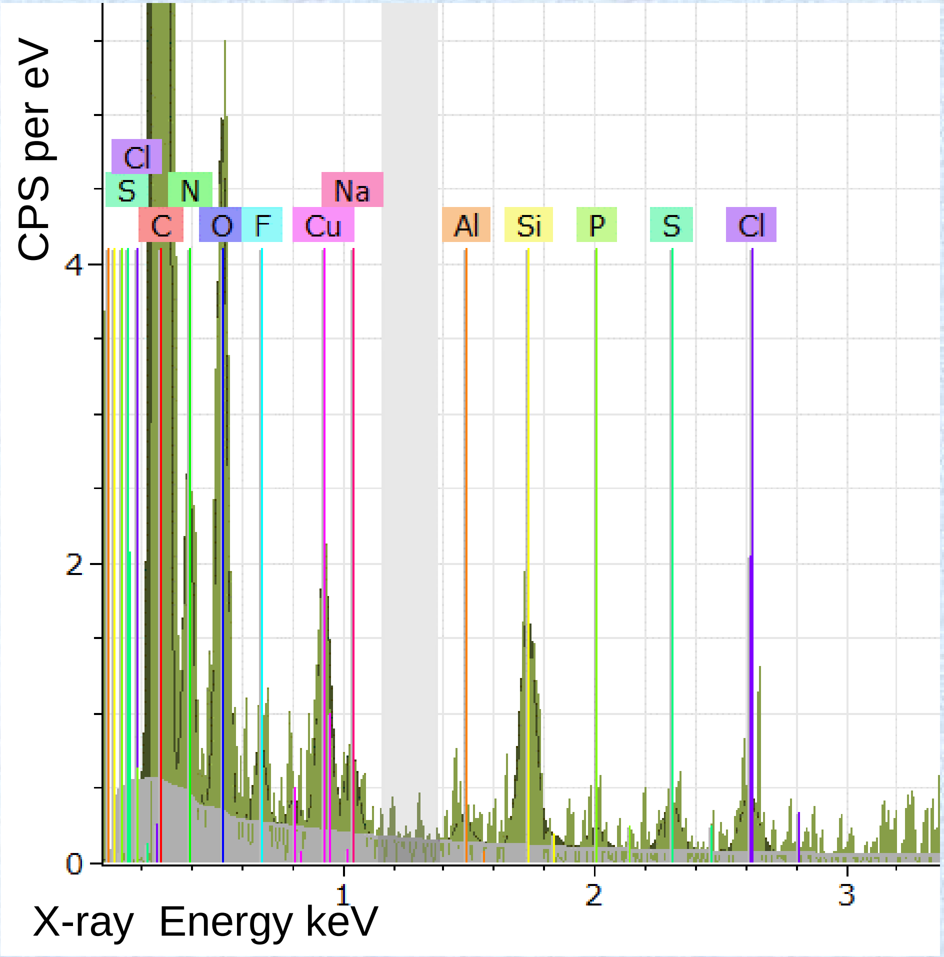
EDXS of atom 2,
8 sec, **33 S** counts*

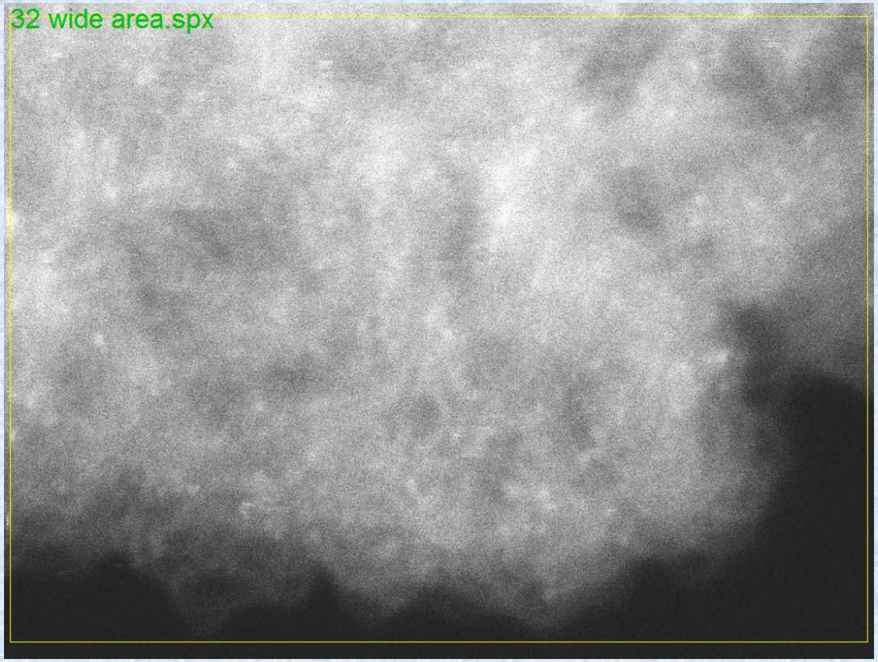
*tracking area was ~2x larger for S, hence the lower counts.
Cu is a system peak due to sample holder & polepiece caps.

*R. M. Stroud et al., APL **108**, 163101 (2016) open access*

EDXS detects single atoms *and* concentrations ~0.01%

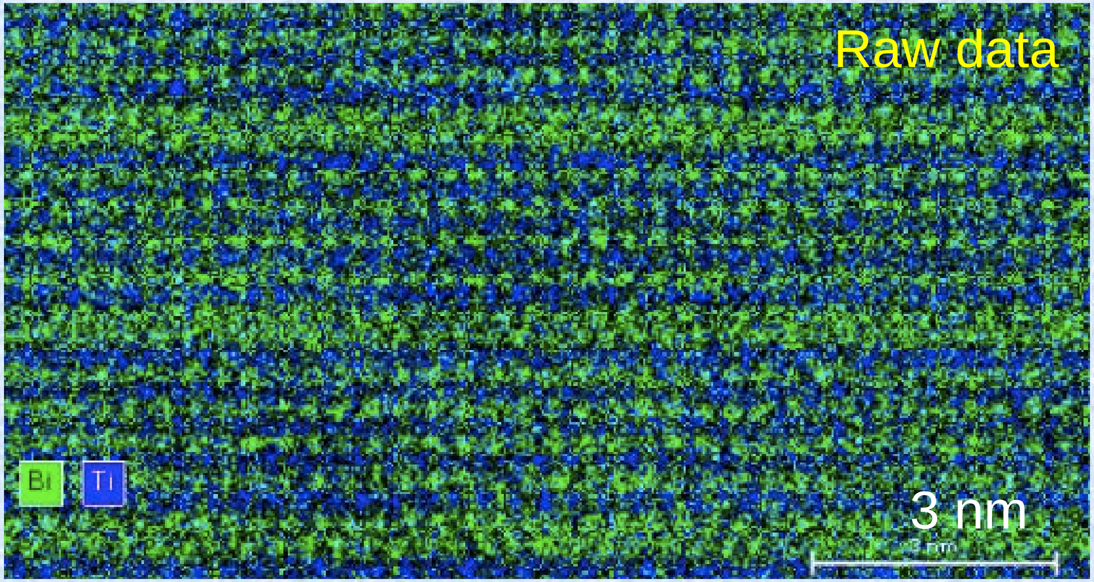
C (at.%)	N	O	F	Cu	Na	Al	Si	P	S	Cl
96.75	0.84	1.45	0.16	Sys.	0.11	0.05	0.4	0.04	0.08	0.11

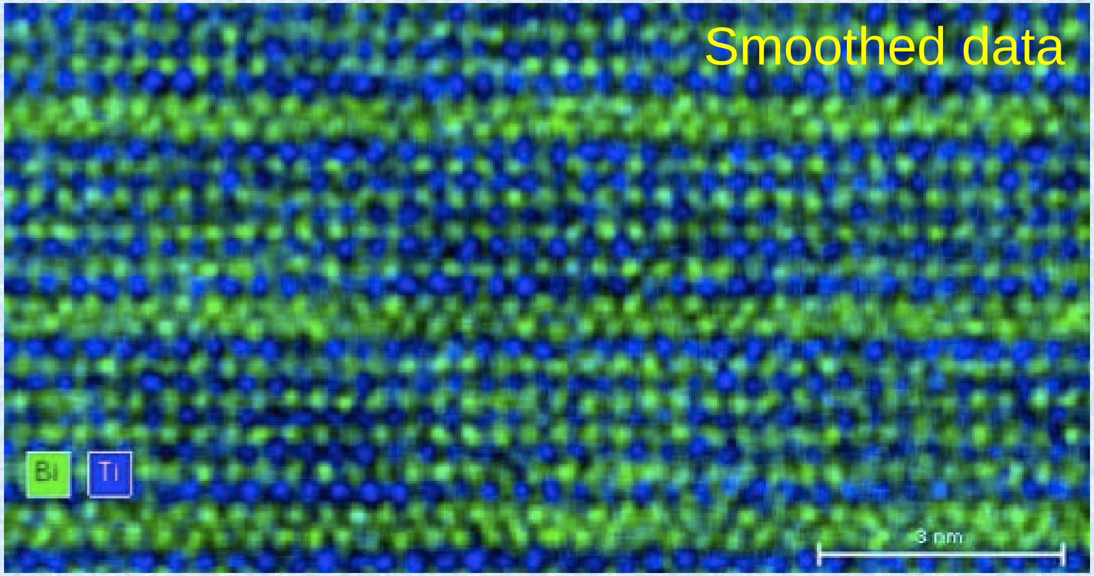




NRL UltraSTEM200 with Bruker X-flash detector, 60 kV. Concentrations as low as 0.01 atomic % can be explored. *Courtesy Rhonda Stroud, NRL.*

EDXS Mapping of $Bi_6Ti_xFe_yMn_zO_{18}$





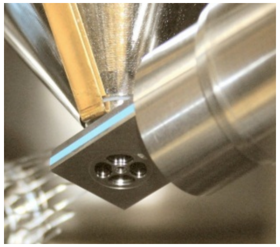
TCD (Trinity College Dublin) Nion UltraSTEM200XE with Bruker 100 mm^2 X-flash SD detector, 200 kV. 432x225 pixels, 4.1 msec/pix => 400 sec for map.

No drift correction.
Bi = green, Ti = blue.

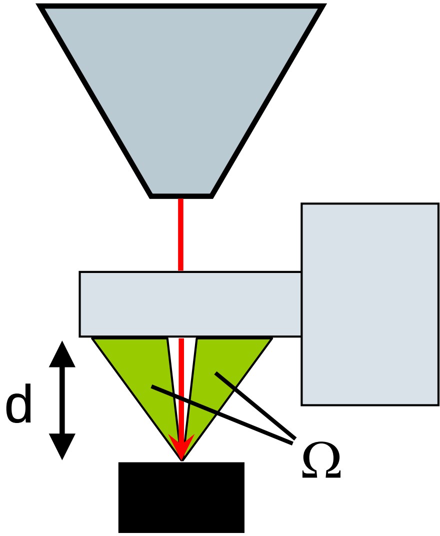
*courtesy Lynette Keeney, Clive Downing and Valeria Nicolosi. TCD, Ireland. See “Direct atomic scale determination of magnetic ion partition in a room temperature multiferroic material” Scientific Reports **7**, Article number: 1737 (2017)*

100 mm^2 windowless SDD
at 0.7 sr collection angle

SEM: Four channel annular SDD: XFlash® 5060FQ, >1 sr collection angle



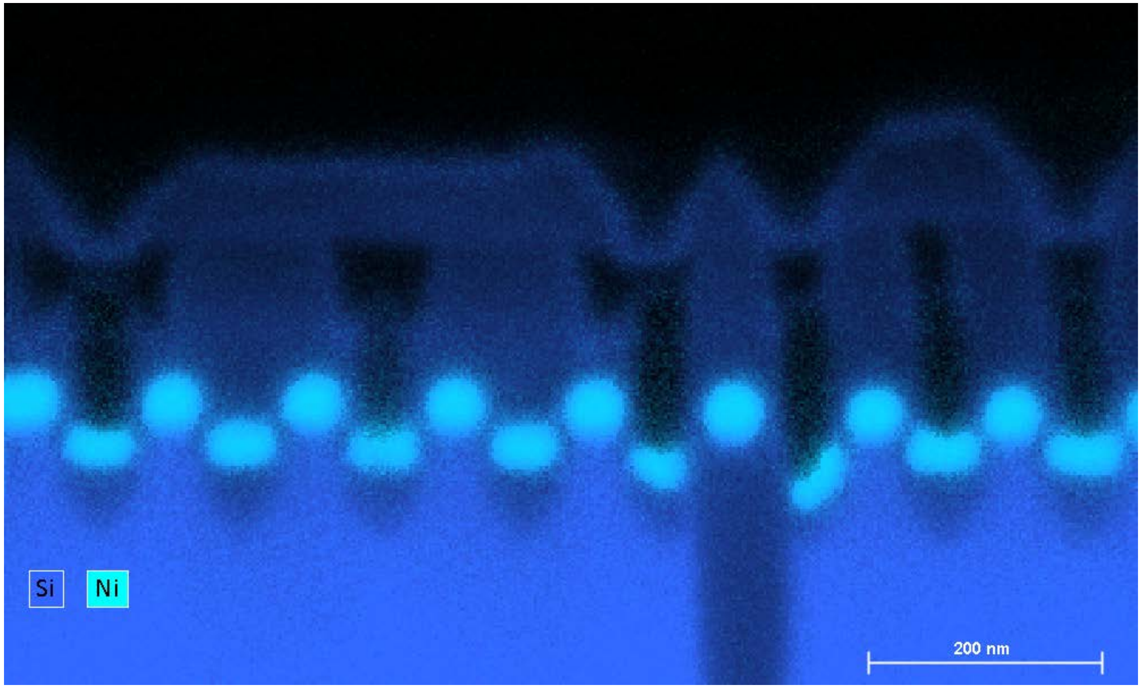
Flat QUAD detector in combination with a conventional XFlash detector at the Hitachi SU8000 series (Cold-Emission FE-SEM)



Example – Semiconductor Structure

FLATQUAD in SEM

Semiconductor chip structure prepared with FIB in cross section

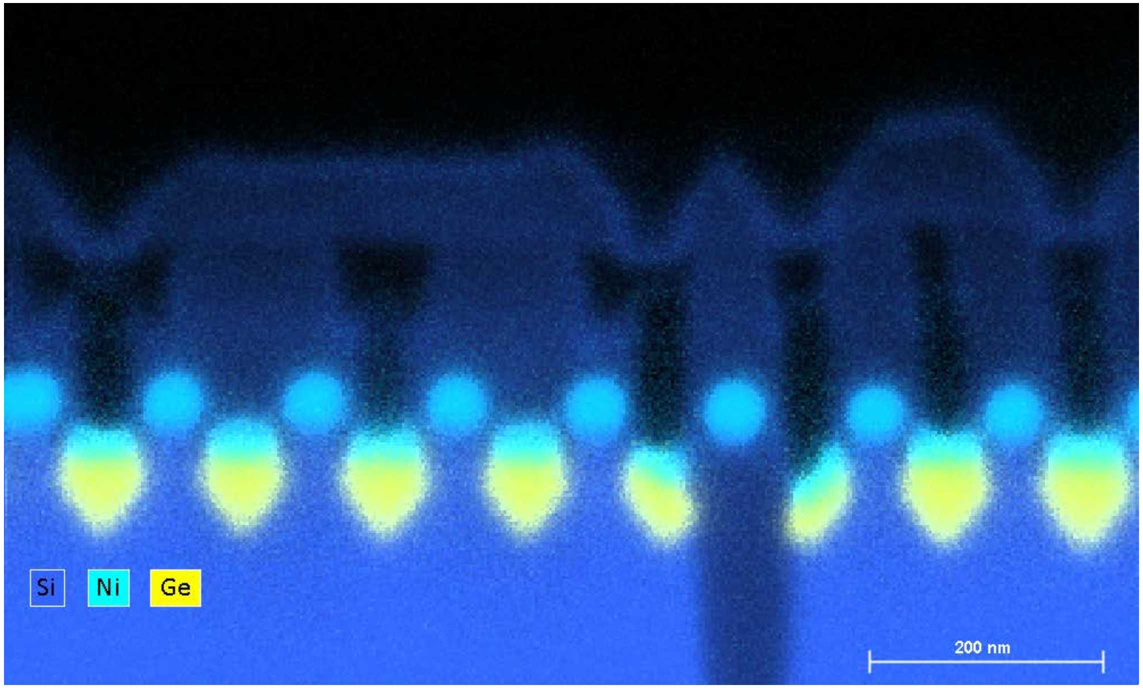


Mapping parameter: 400 x 240 pixels
Pixel size: 2 nm
Measurement time: 60 minutes
Input count rate: 380 kcps
HV: 20 kV Schottky field emission SEM
WD: 14 mm

Example – Semiconductor Structure

FLATQUAD in SEM

Semiconductor chip structure prepared with FIB in cross section



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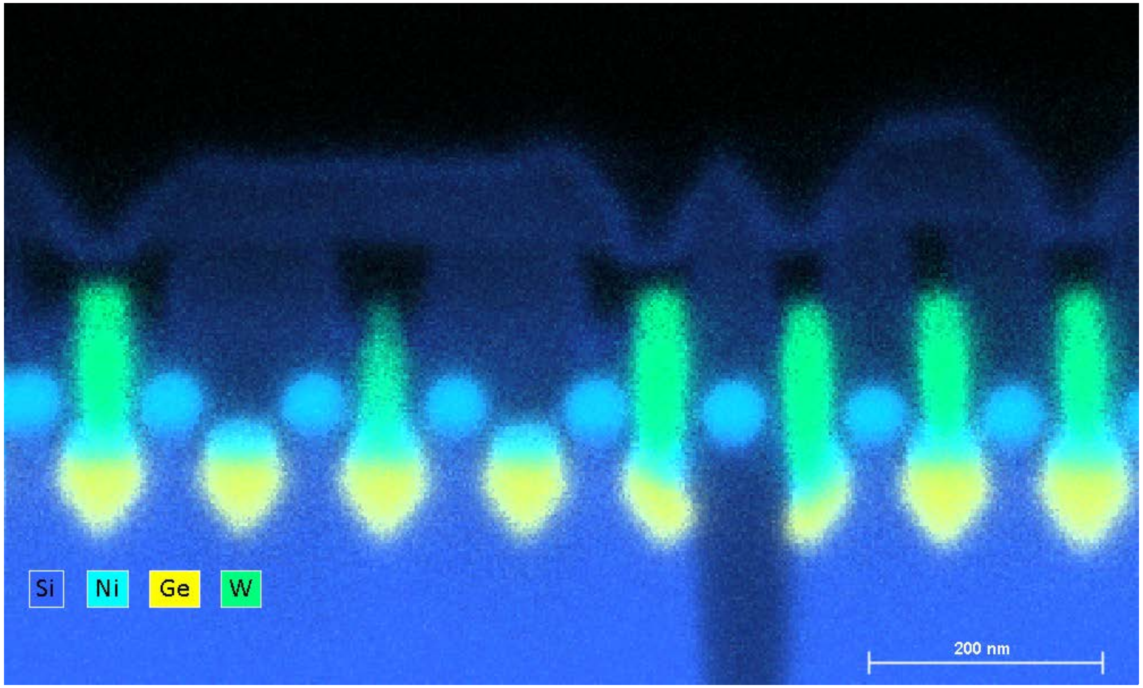

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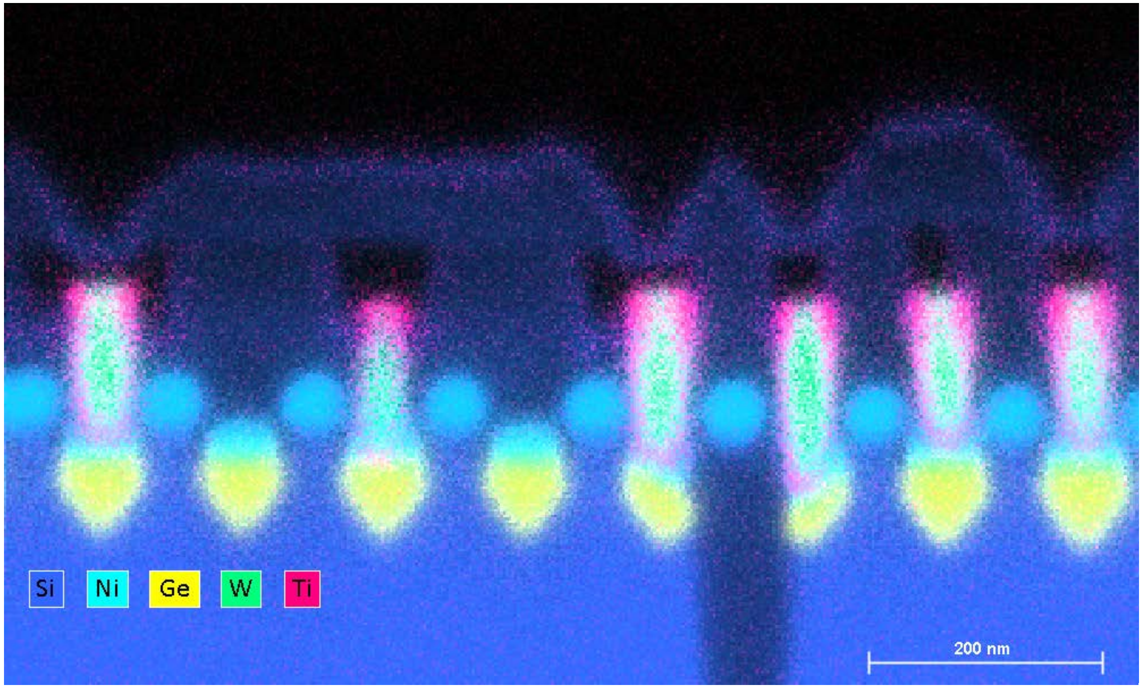

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Example – Semiconductor Structure

FLATQUAD in SEM

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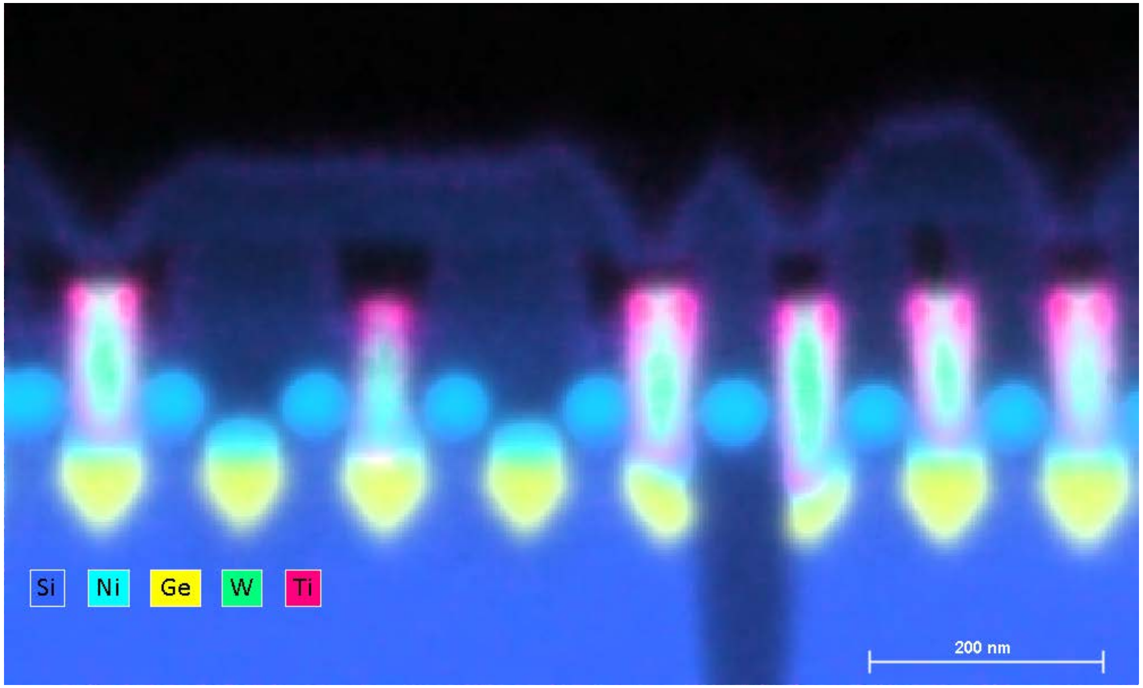
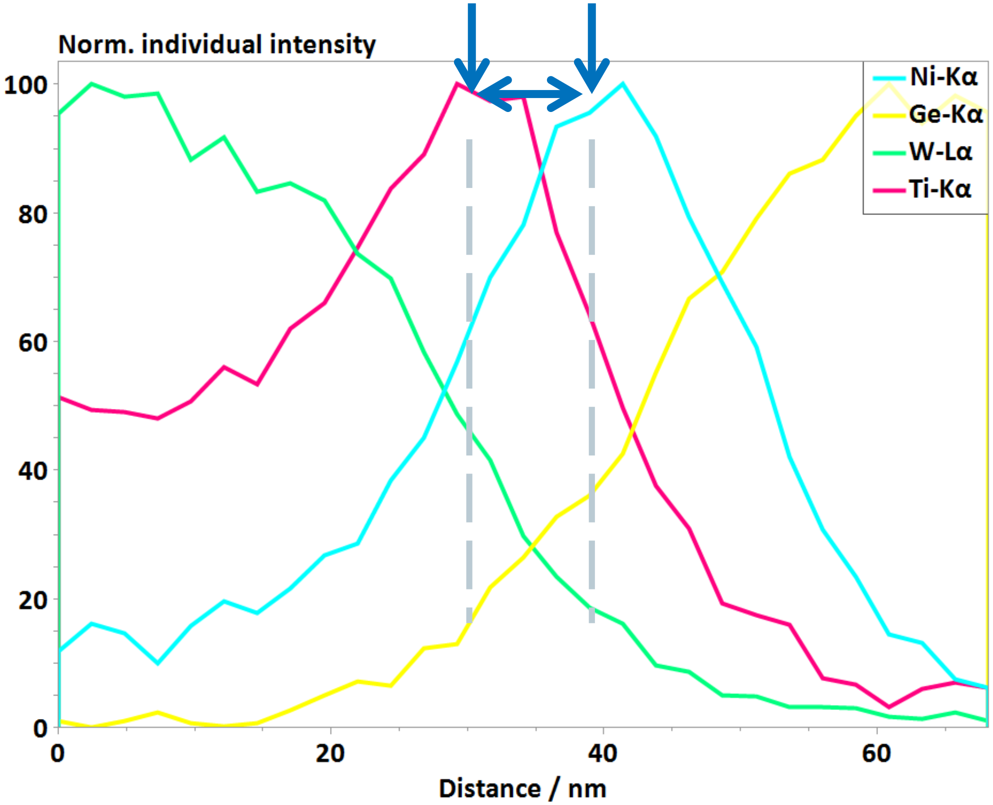
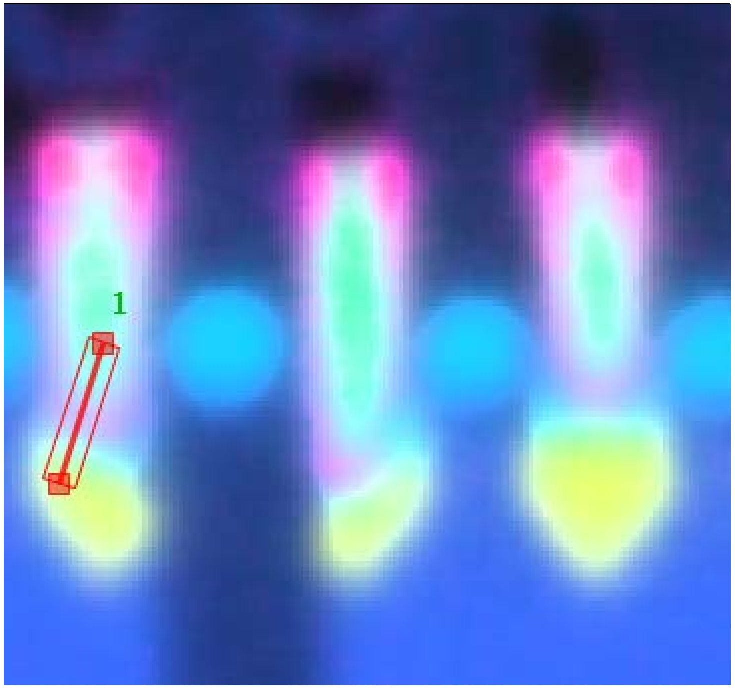


Mapping parameter: 400 x 240 pixels
Pixel size: 2 nm
Measurement time: 60 minutes
Input count rate: 380 kcps
HV: 20 kV Schottky field emission SEM
WD: 14 mm

Example – Semiconductor Structure

10 nm lateral resolution of Ni and Ti distribution maxima





Extracted linescan from the map data
Effective measurement time of lineprofiles: 8 s

More Information

For more information, please contact us:

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Igor.nemeth@bruker.com

info.bna@bruker.com

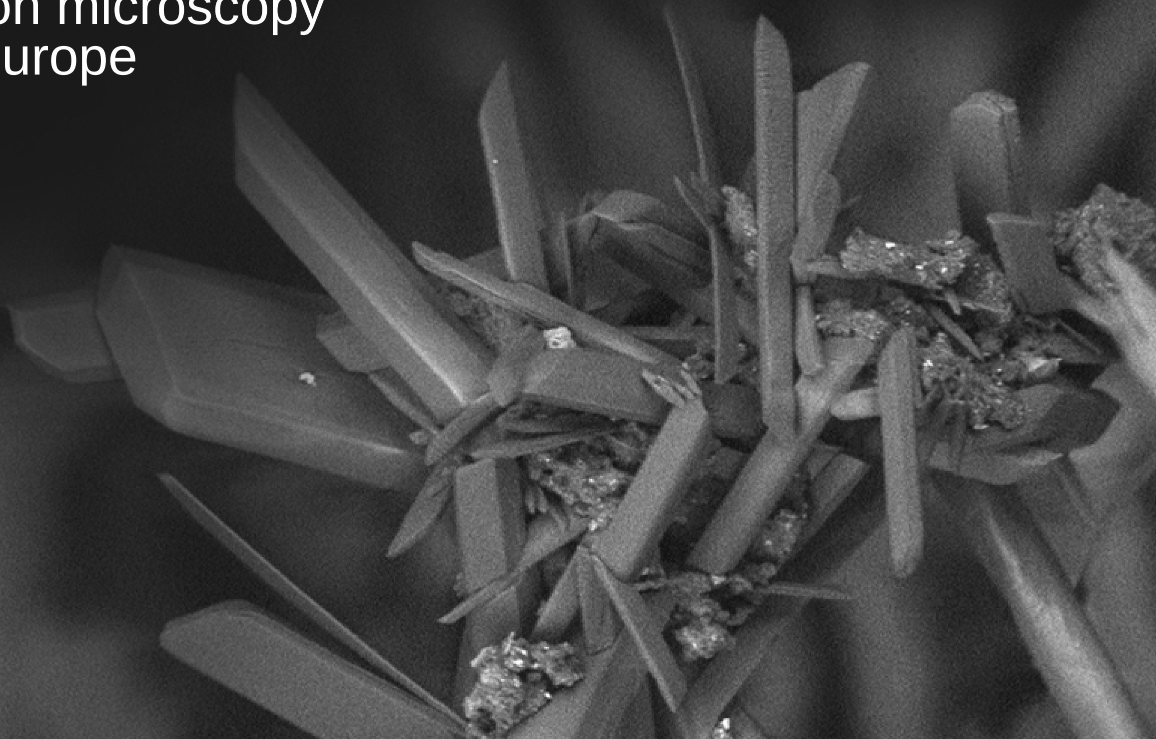
mats.eriksson@hht-eu.com

BRUKER

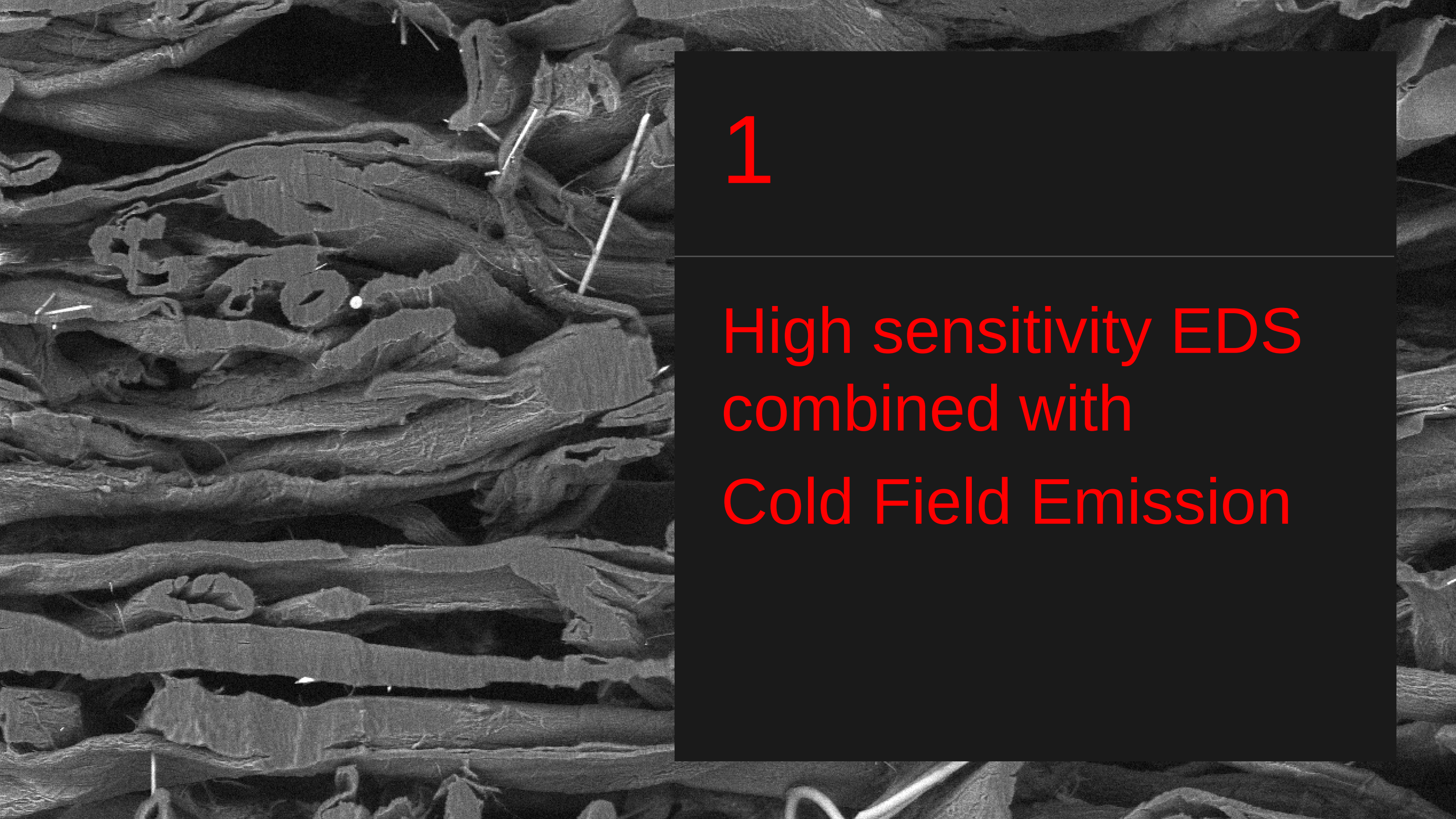
Innovation with Integrity

EDS on the nanoscale

Mats Eriksson
Department manager electron microscopy
Hitachi High-Technologies Europe



HITACHI
Inspire the Next



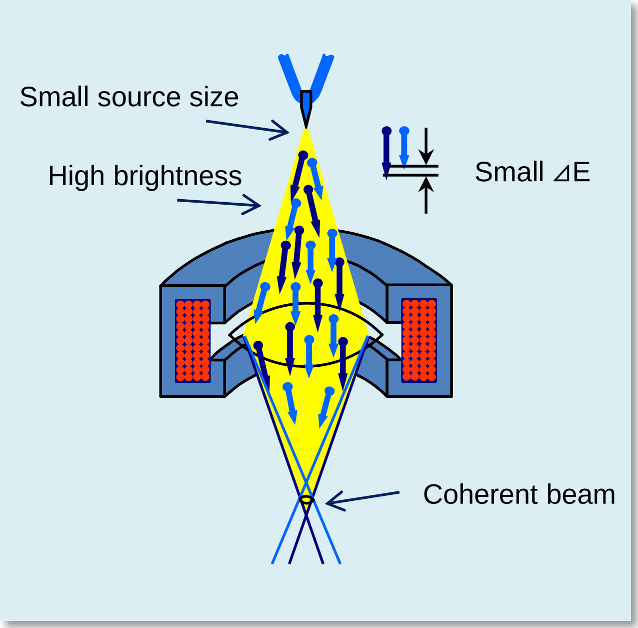
1

High sensitivity EDS combined with Cold Field Emission

Optical Properties of FE sources

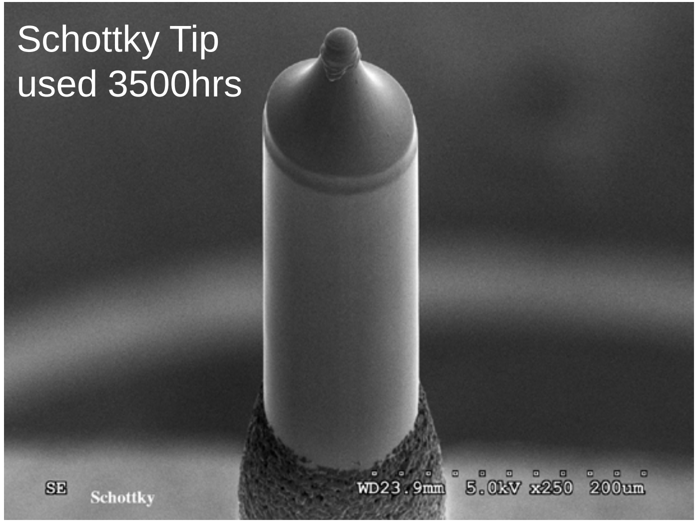
Very high density of electrons with small energy spread from a small source makes a very fine beam spot for high resolution imaging

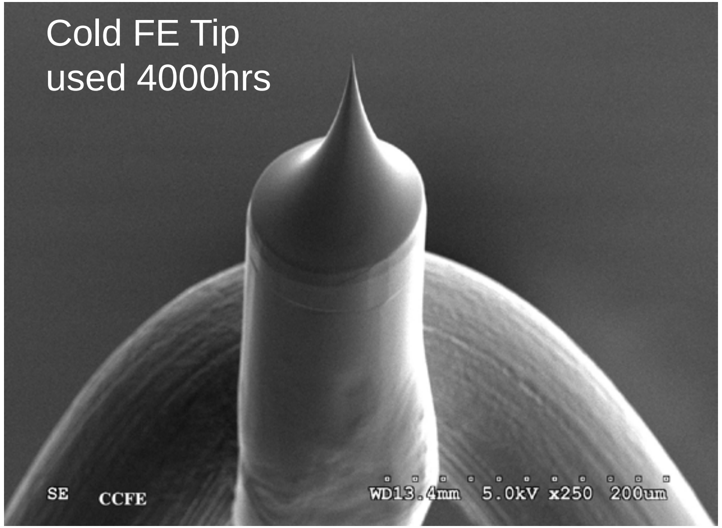
	Coherent beam Cold FE Gun	Schottky FE
Cathode	Cold cathode	Thermal cathode
Energy spread（⊿E)	**0.2～0.3eV**	0.6～0.8eV
Source size	**< 5nm**	< 30nm
Brightness	**2×10^9 A/cm^{2}sr**	2×10^8 A/cm^{2}sr
Flashing	**Flash free**	Flash free
Specimen current	**Over 20nA**	Over 100nA
Life time	**Over 5 years**	2 years



FE sources overview

Schottky and Cold FE Tips



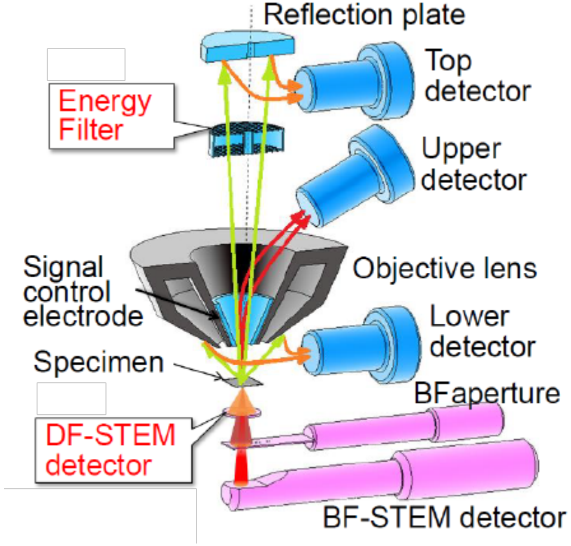


Small source size – fine beam
Small energy spread: 0.2~0.3eV
Higher brightness and resolution

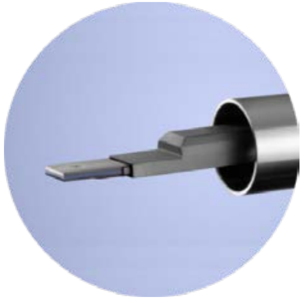
Images courtesy of Mark J. Grimson, Texas Tech

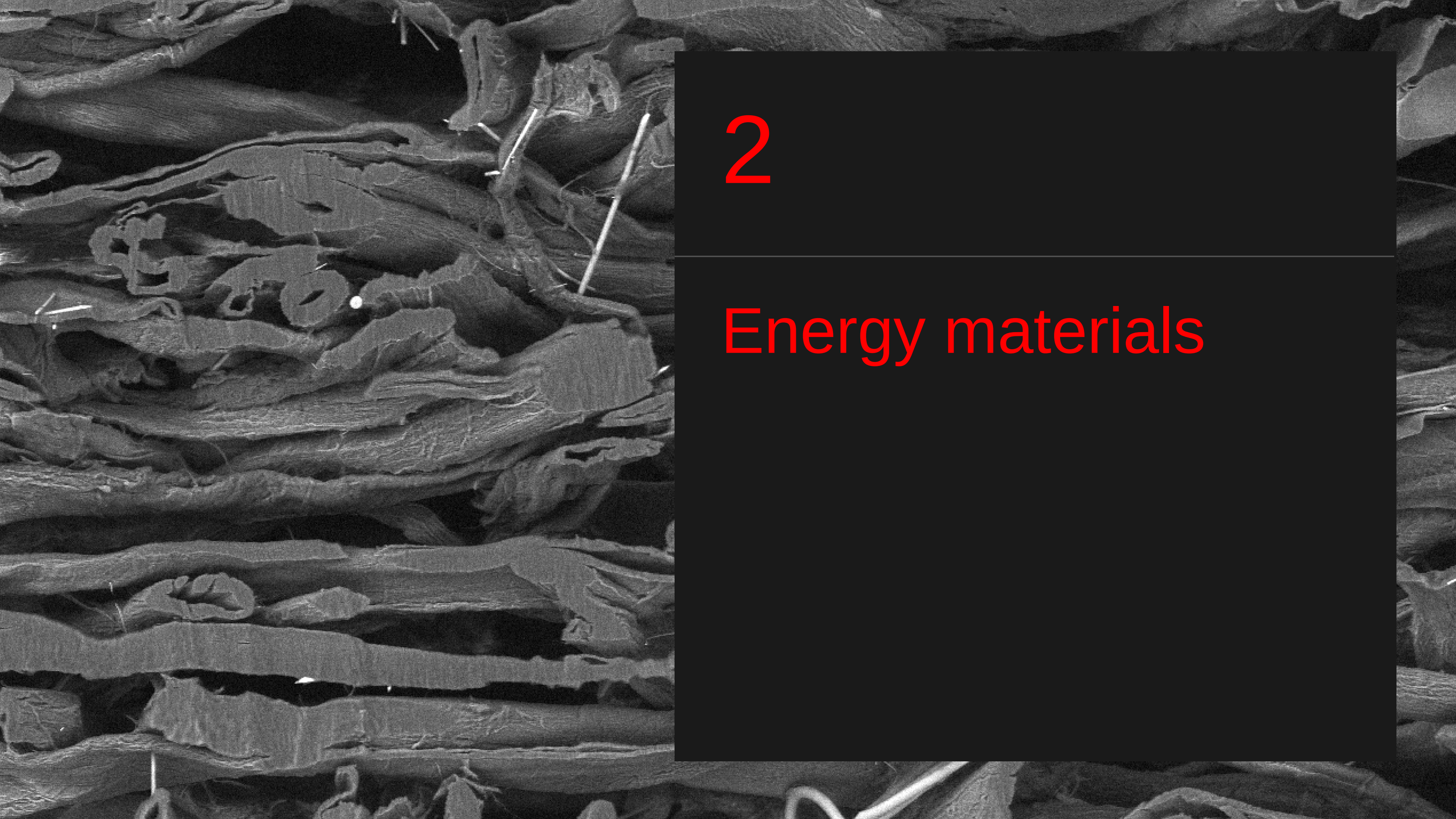
Suitable scanning electron microscope

Hitachi SU8230



- Coherent beam cold field emission gun
- Easy to operate at low dose with high S/N
- Immersion lens providing high efficiency SE and BSE collection through the lens
- Fits FlatQuad geometry well as BSE can be captured simultaneously using the in-lens SE/BSE detectors
- Flexible imaging in transmission mode using BF and DF detectors with variable collection angles



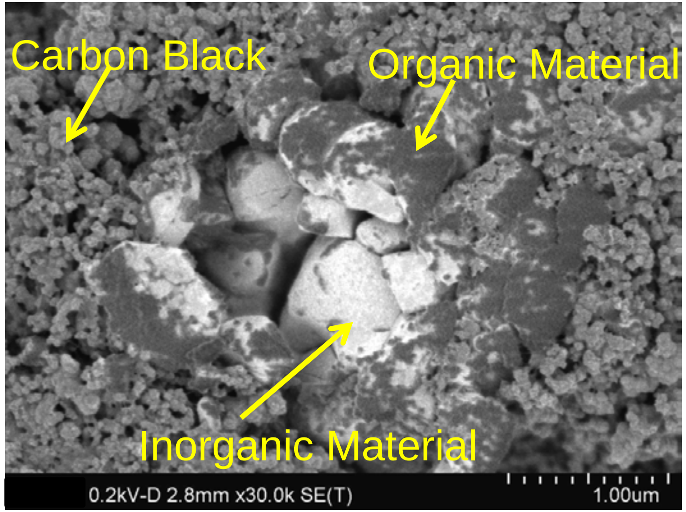


2

Energy materials

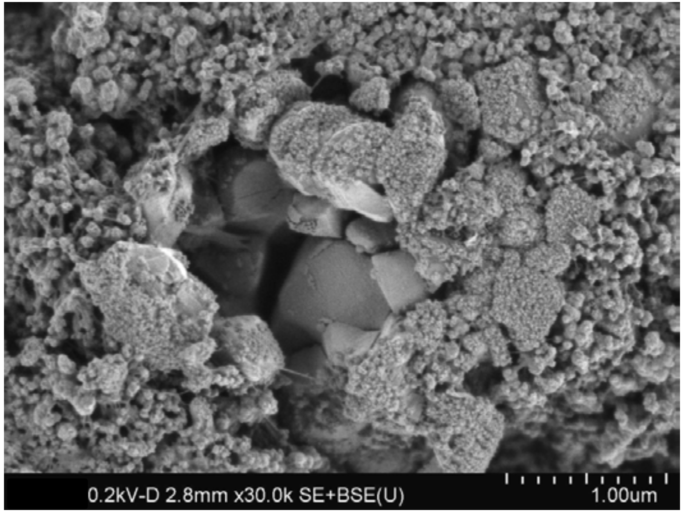
Low kV analysis for surface sensitivity

LIB Electrode: Material vs.Topographic Information



Vacc: 0.2kV, Mag.: x30k SE-Top

Material type shown by surface potential (voltage contrast)
Organic, inorganic and Carbon Black



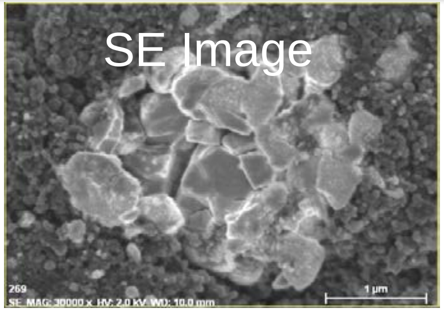
Vacc: 0.2kV, Mag.: x30k SE + BSE Upper

Enhanced topography image using mixed SE and BSE

Low kV analysis for surface sensitivity

LIB Electrode: Material vs.Topographic Information

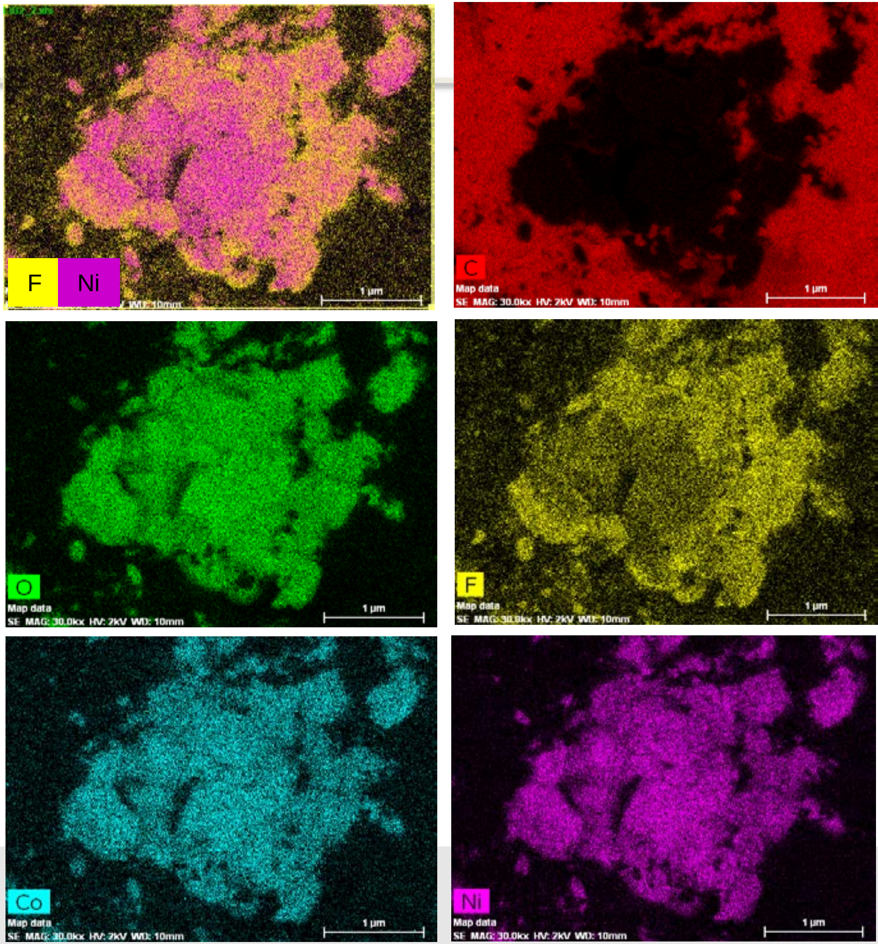
EDS: **Flat Quad 5060F**
Vacc: **2kV**
Mag.: 30kX
Acquisition time: **4min.**



60mm^2 large sensor and 1.1sr solid angle enabled fast and high spatial resolution

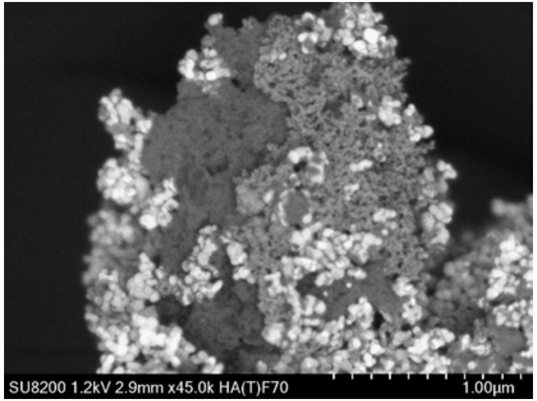
EDS mapping even at 2kV in 4 min.

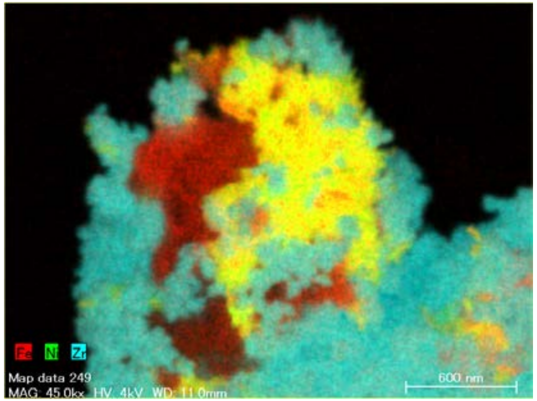
C: Carbon black
Co, Ni & O: Active material
F, O: Organic materials



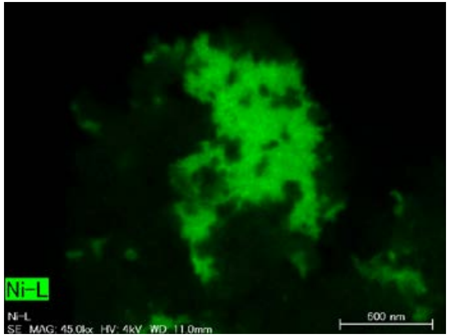
Low kV analysis for spatial resolution

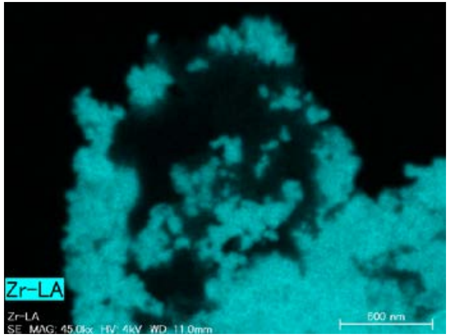
Catalyst : FeNi-ZrO2

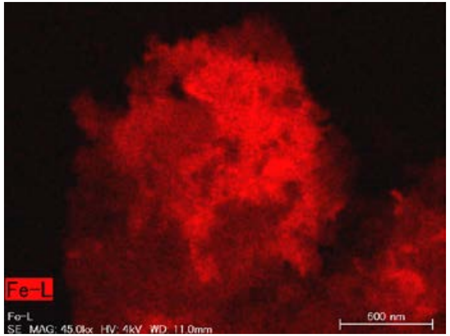




Energy filtered 1.2 kV BSE image, corresponds to EDS elemental map.







HV：1.2kV(SEM),
4 kV(EDS)
Duration:10min

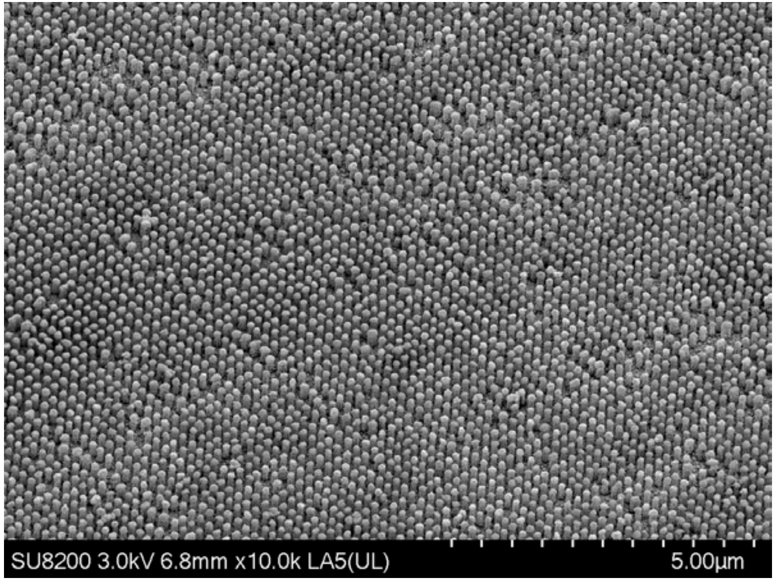
Sample courtesy : Prof. Kohsuke Mori, Osaka University

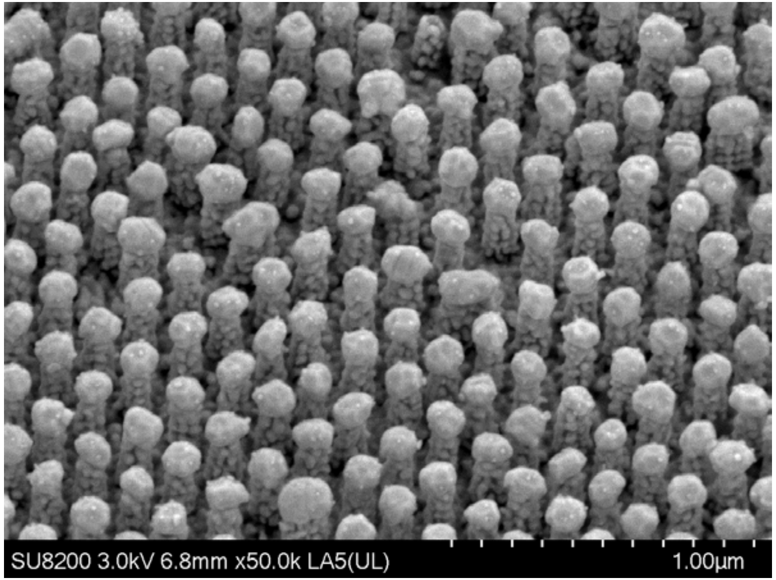
3

Nano Pillars

SU8200 Applications

Nano Pillar



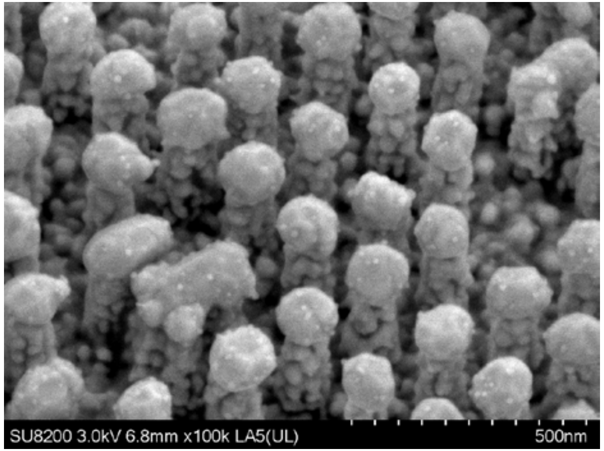


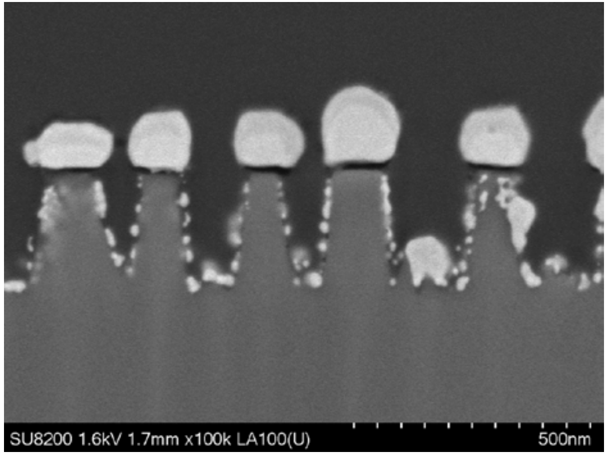
The above nano-pillar images were taken with our SU8200 as examples for researchers interested in imaging photonics and related materials. The gold (Au) particles in this dotted pattern formed into pillars on this silicon plate after chemical etching. Furthermore, the surface was coated with silver (Ag) to improve the specimen properties. These 100nm diameter nano-pillars were imaged using our “bird’s eye view” SEM function.

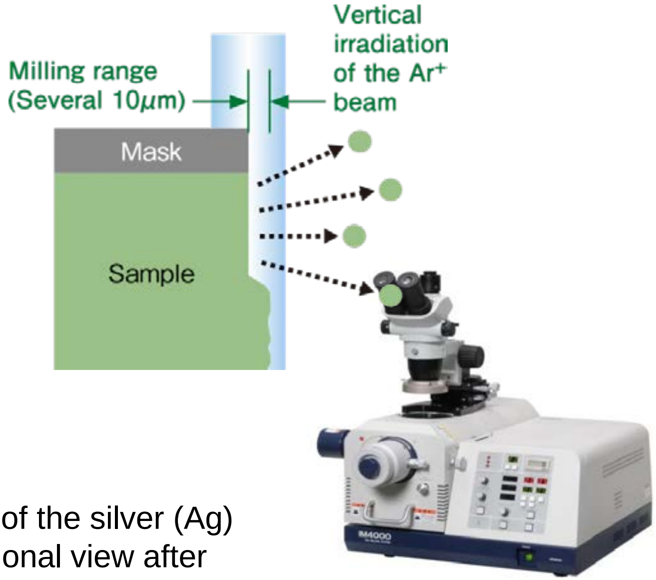
Sample courtesy: Prof. Masahiko Yoshino,
Department of Mechanical and Control Engineering, Tokyo Institute of Technology

SU8200 Applications

Nano Pillar





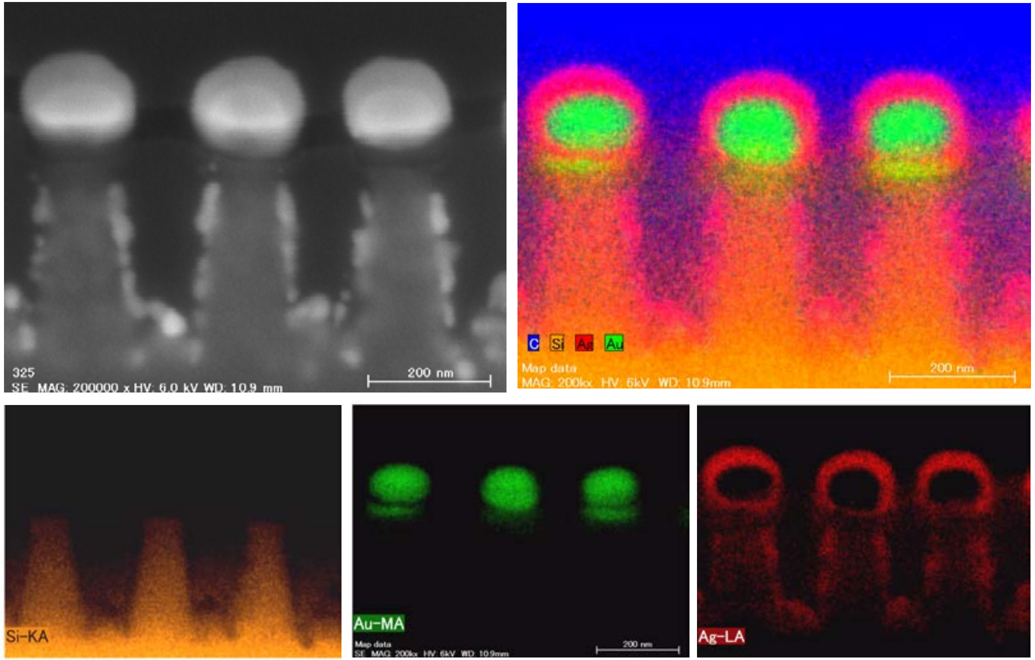


The image on the left has been enlarged to 100,000x which enables the observation of the silver (Ag) coating particles on the surface of each pillar. The image on the right is a cross-sectional view after milling through the pillars with our IM4000 broad beam ion milling unit. The image was taken using the BSE signal at a magnification of 100,000x at 1.6kV accelerating voltage. The silver (Ag) coating on the surface of the gold (Au) is clearly observed using the BSE signal for improved compositional information.

Sample courtesy: Prof. Masahiko Yoshino,
Department of Mechanical and Control Engineering, Tokyo Institute of Technology

SU8200 Applications

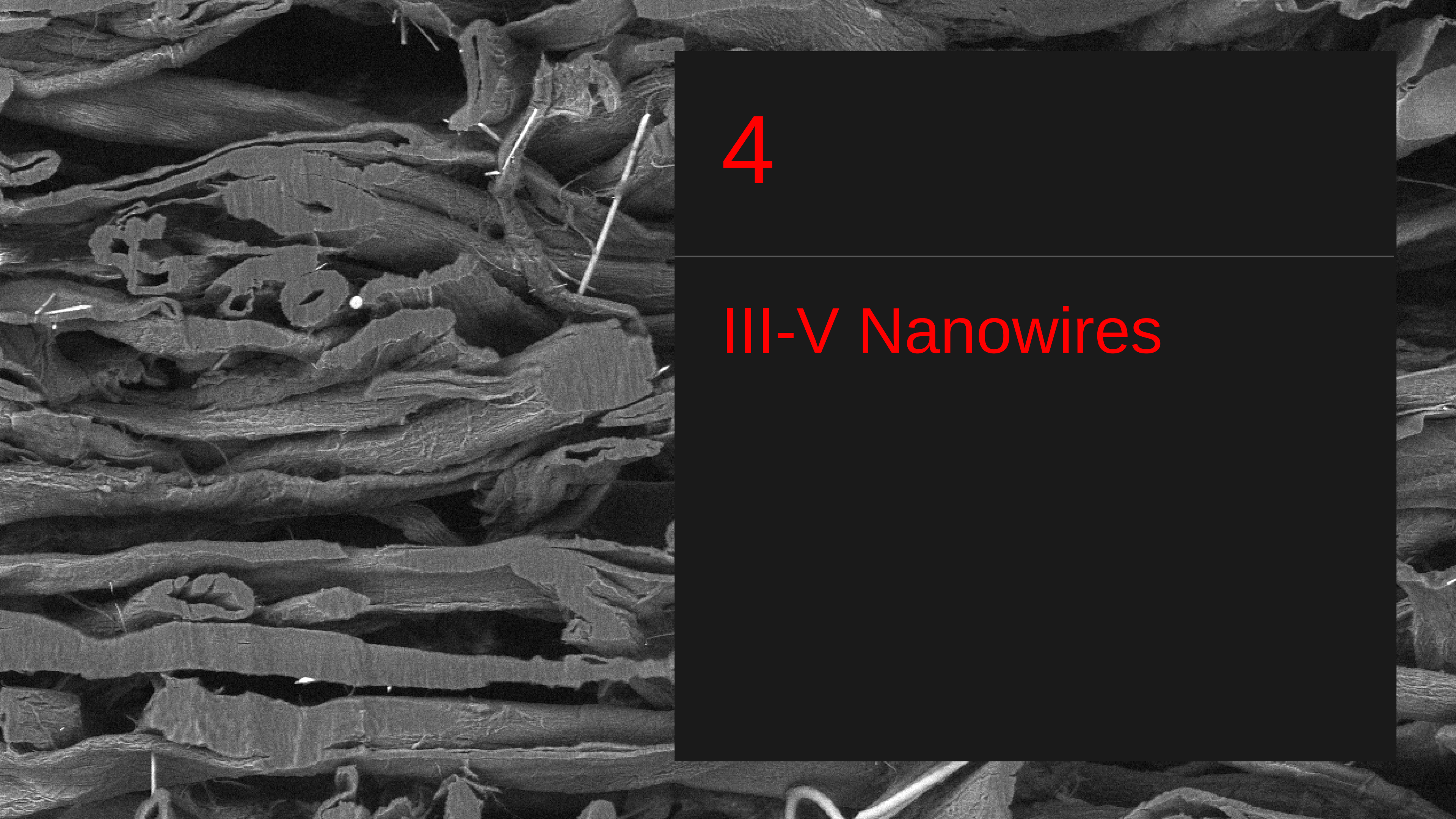
Nano Pillar



Left are EDS maps taken with a large active area SDD EDS detector at a magnification of 200,000x. The silicon (Si) plate pattern structure, gold (Au) particles, and 10nm diameter silver (Ag) coating around the nano-pillars were clearly revealed in ~5 minutes.

Acc. voltage: 6kV
Magnification: 200,000x
Analysis time: 313 sec.
EDS: Bruker FlatQUAD

Sample courtesy: Prof. Masahiko Yoshino,
Department of Mechanical and Control Engineering, Tokyo Institute of Technology



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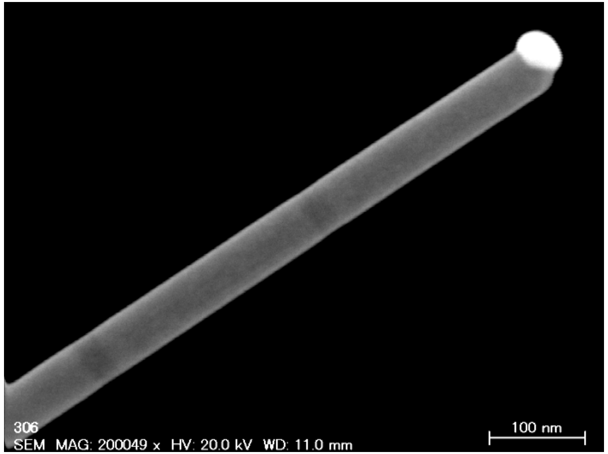
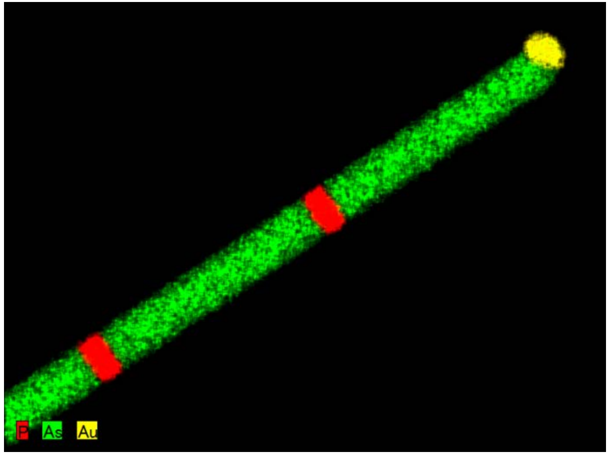
III-V Nanowires

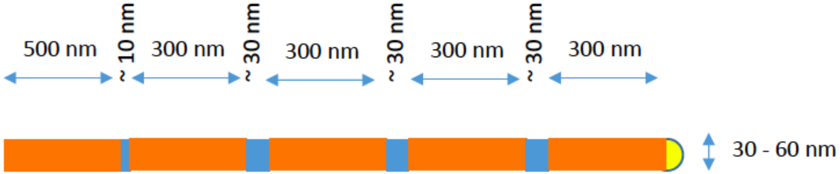
EDS on the nanoscale

InAs-InP Nanowires

- 🟧 InAs wurtzite
- 🟦 InP wurtzite
- 🟨 AuIn-alloy particle





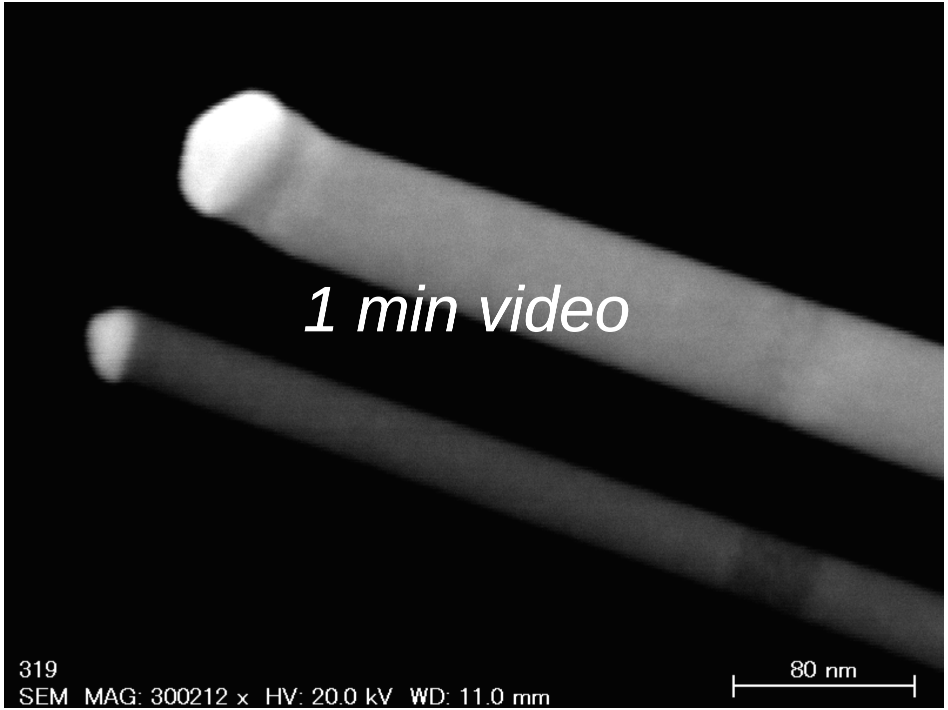


Accelerating voltage : 20 kV
Magnification : x200,000
Acquisition time : 300 sec.

Sample courtesy: Prof. Kimberly Dick Thelander, Dr. Sebastian Lehmann
Department of Solid State Physics, Lund University, Sweden

EDS on the nanoscale

InAs-InP Nanowires



1 min video

EDS on the nanoscale

GaAs-AlAs-AlGaAs Nanowires

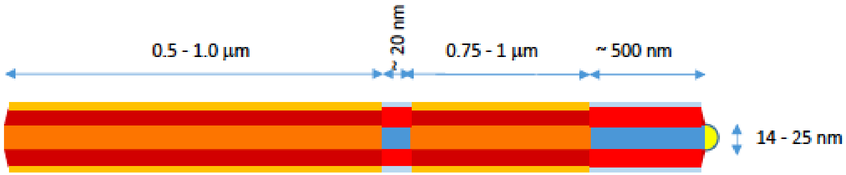
🟧 GaAs wurtzite

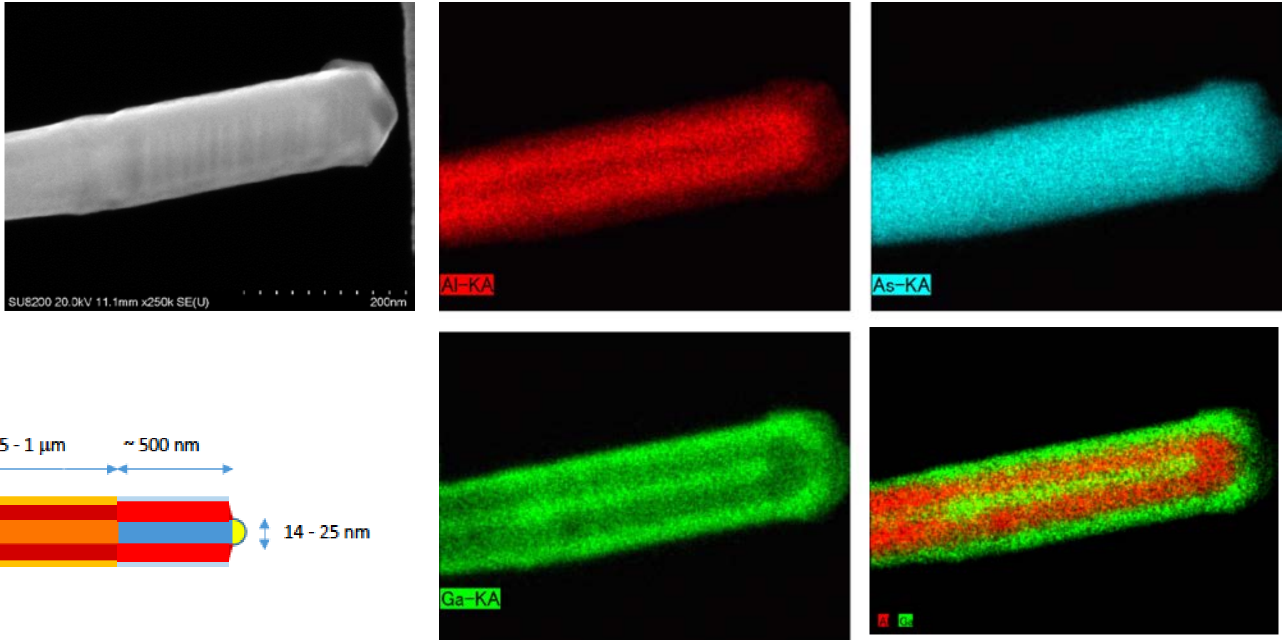
🟦 GaAs zinc blende

🟥🟥 AlAs wurtzite/zinc blende (shell ~ 20 nm)

🟨🟦 $Al_{0.2}Ga_{0.8}As$ wurtzite/zinc blende (shell ~ 5 nm)

🟨 AuGaAl-alloy particle





20 kV, x250,000, 326 sec.

Sample courtesy: Prof. Kimberly Dick Thelander, Dr. Sebastian Lehmann
Department of Solid State Physics, Lund University, Sweden

Thank you for your attention !