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New materials: their secondary electron emission and potential applications

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This presentation

- **Work at GSI, Germany**
- **Work at SSLS, Singapore**
- **Conclusions**

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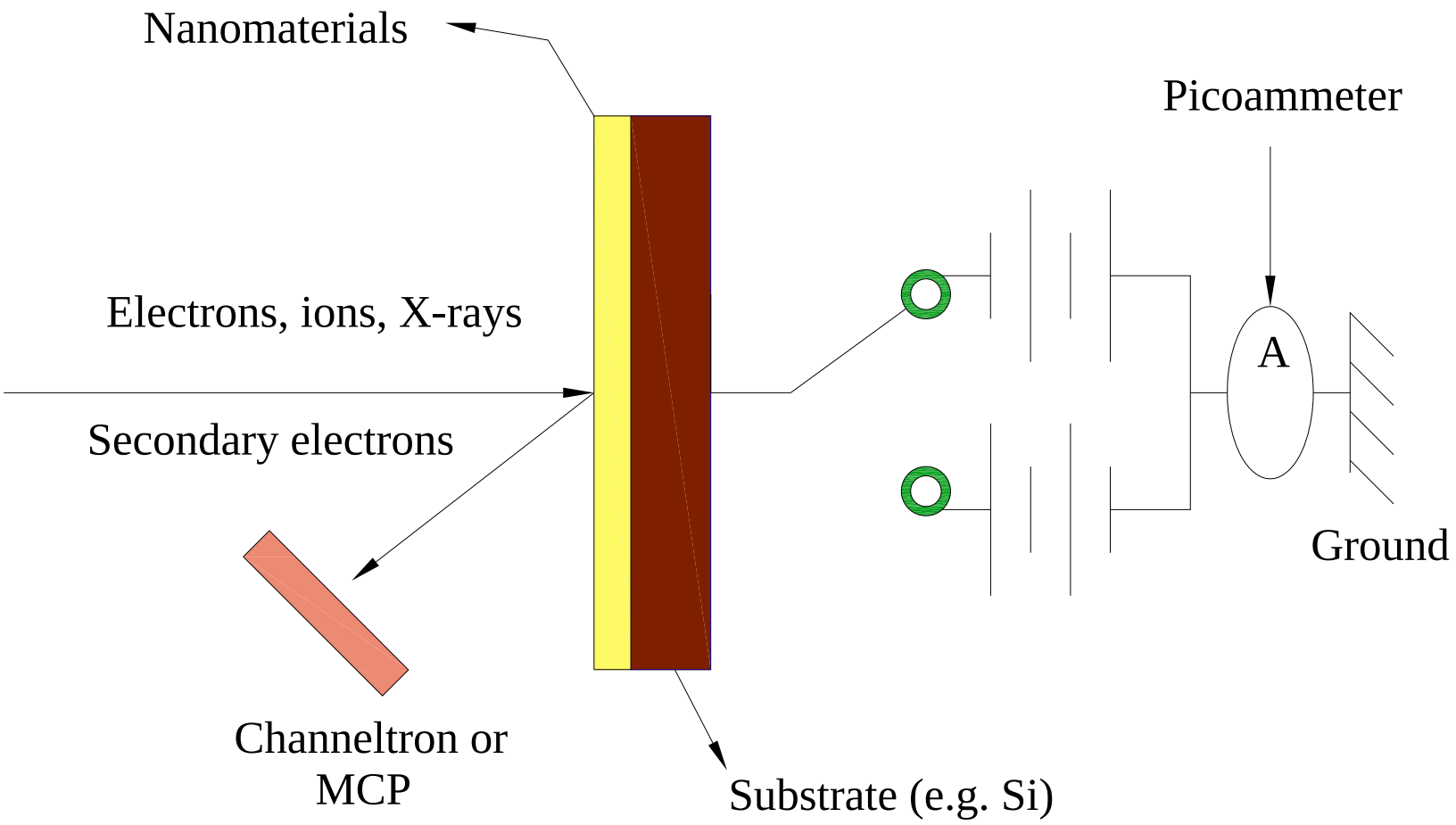
Collaborators

- **GSI, Darmstadt, Germany**
  B. Fischer, M. Heiss
- **INP, Krakow, Poland**
  Z. Stachura, J. Lekki, W. Polak
- **Pohang University, South Korea**
  Jinkyoung Yoo, Sung Jin An, Gyu-Chul Yi
- **NTU, Singapore**
  Lie Huang, Shu Ping Lau
- **CIBA, NUS, Singapore**
  Andrew Bettiol, Frank Watt
- **NUSNNI, NUS, Singapore**
  Gao Xingyu, Andrew Thye Shen Wee
- **SSLS, NUS, Singapore**
  M. Cholewa, H.O. Moser

New materials for detectors



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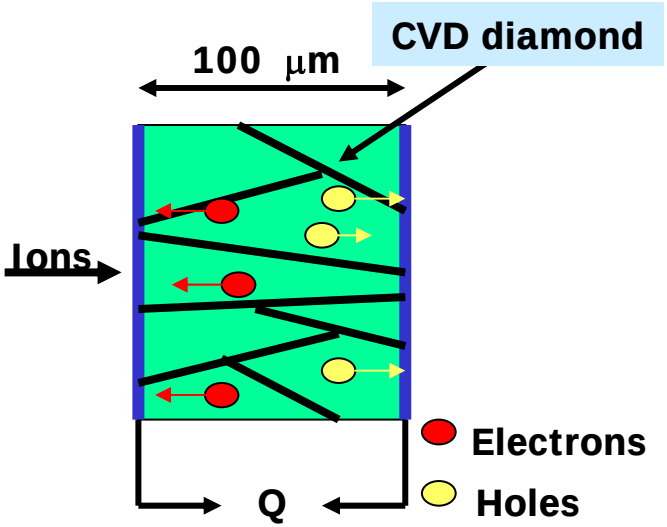
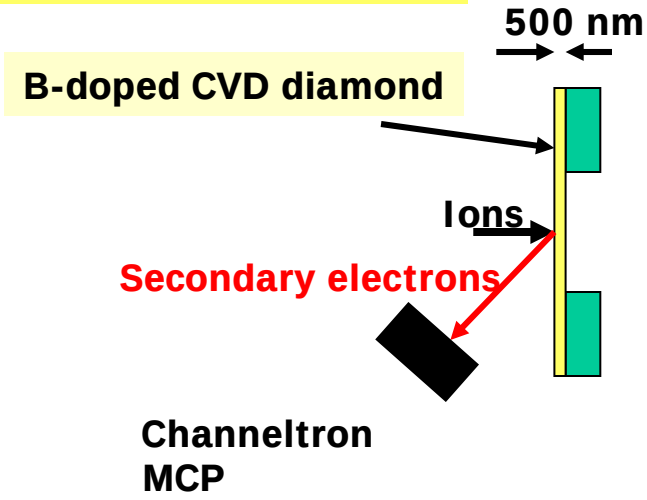
Diamond detectors at GSI





- 5.5 eV band gap
- 200 μm/ns
- e-h pairs
- 1 ns drift time
- 10^9 ions/s
- 2 GHz amplifier
- 29.3 ps ToF resolution
- bad energy resolution
- non-uniform surface
- resistance to damage
- Berdermann et al.

- secondary electrons
- 4.5 eV mean energy
- channeltron: 2 ns
- MCP: 300 ps
- ToF systems: 100 ps (?)
- 1 MHz with channeltron
- no energy resolution
- non-uniform surface
- resistance to damage 10^7 heavy ions/μm^2
- Cholewa et al.

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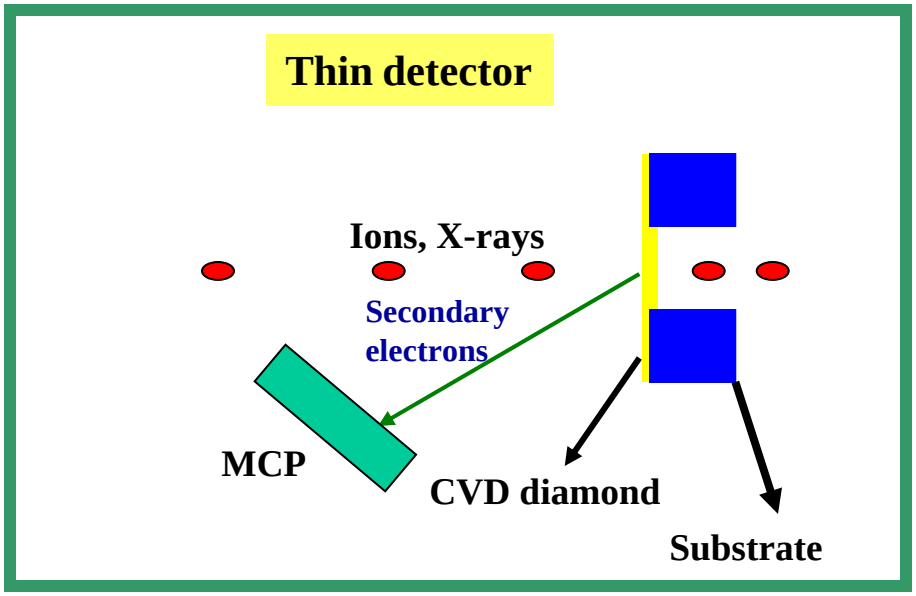
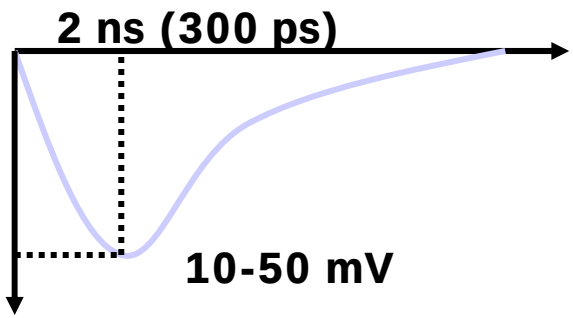
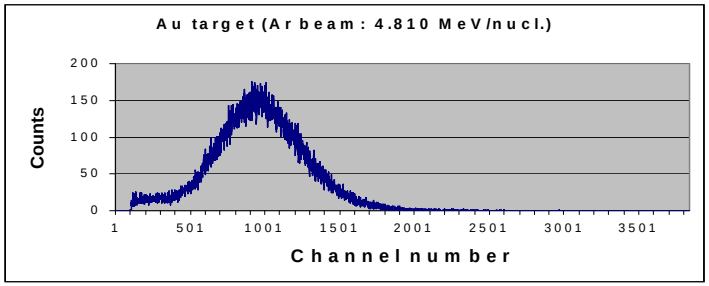
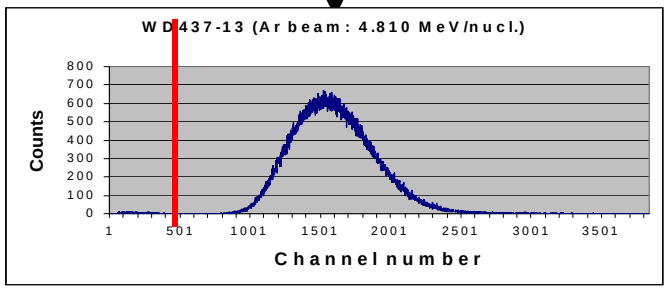
Boron-doped CVD diamond detector





Position (N, E)





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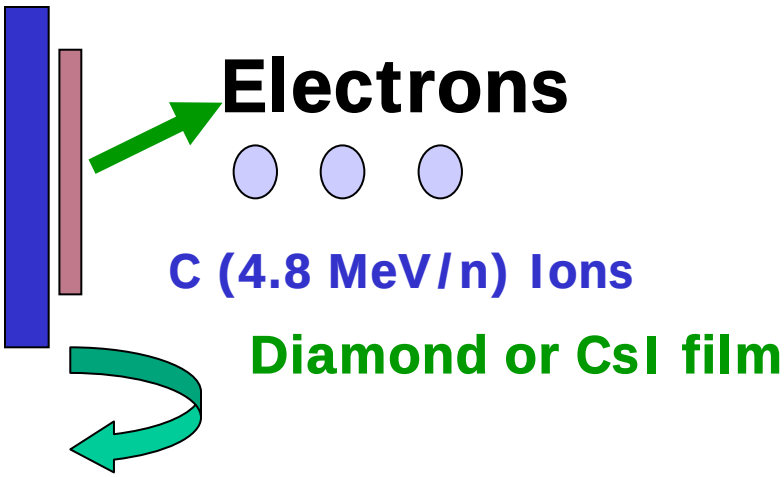
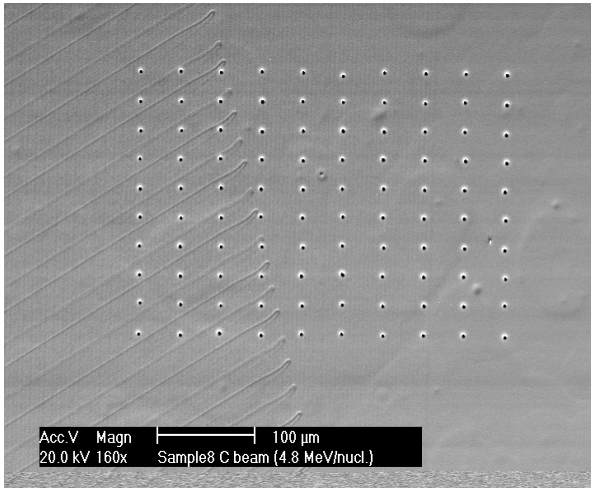
Efficiency (Xe, C)



Cr-39

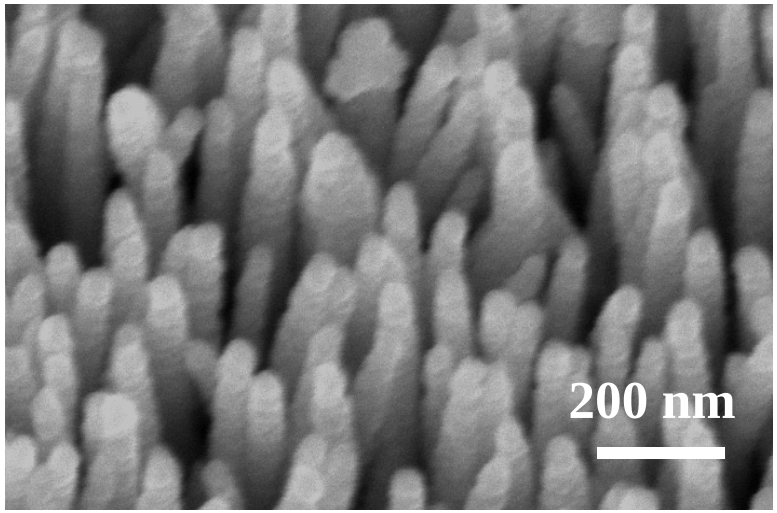


10x10

36 scans

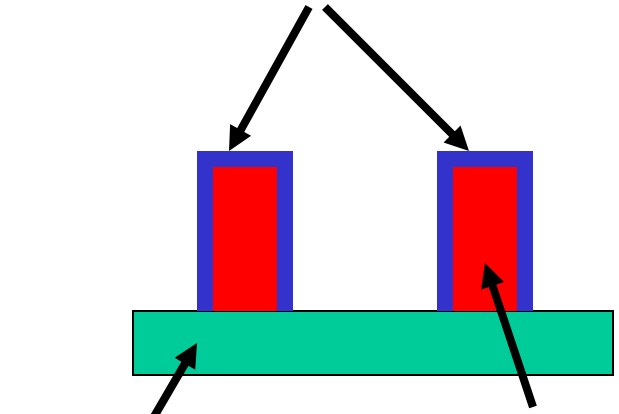
99.98 %

New materials for detectors



SEM image of the GaN/ZnO coaxial heterostructure

Au
Boron-doped CVD diamond
Si
Si with ZnO, GaN, AlN, MgO coating
Carbon nanotubes (CNTs)
CNTs with ZnO, MgO, AlN, GaN coating
ZnO nanorods
ZnO nanorods with AlN, GaN coating



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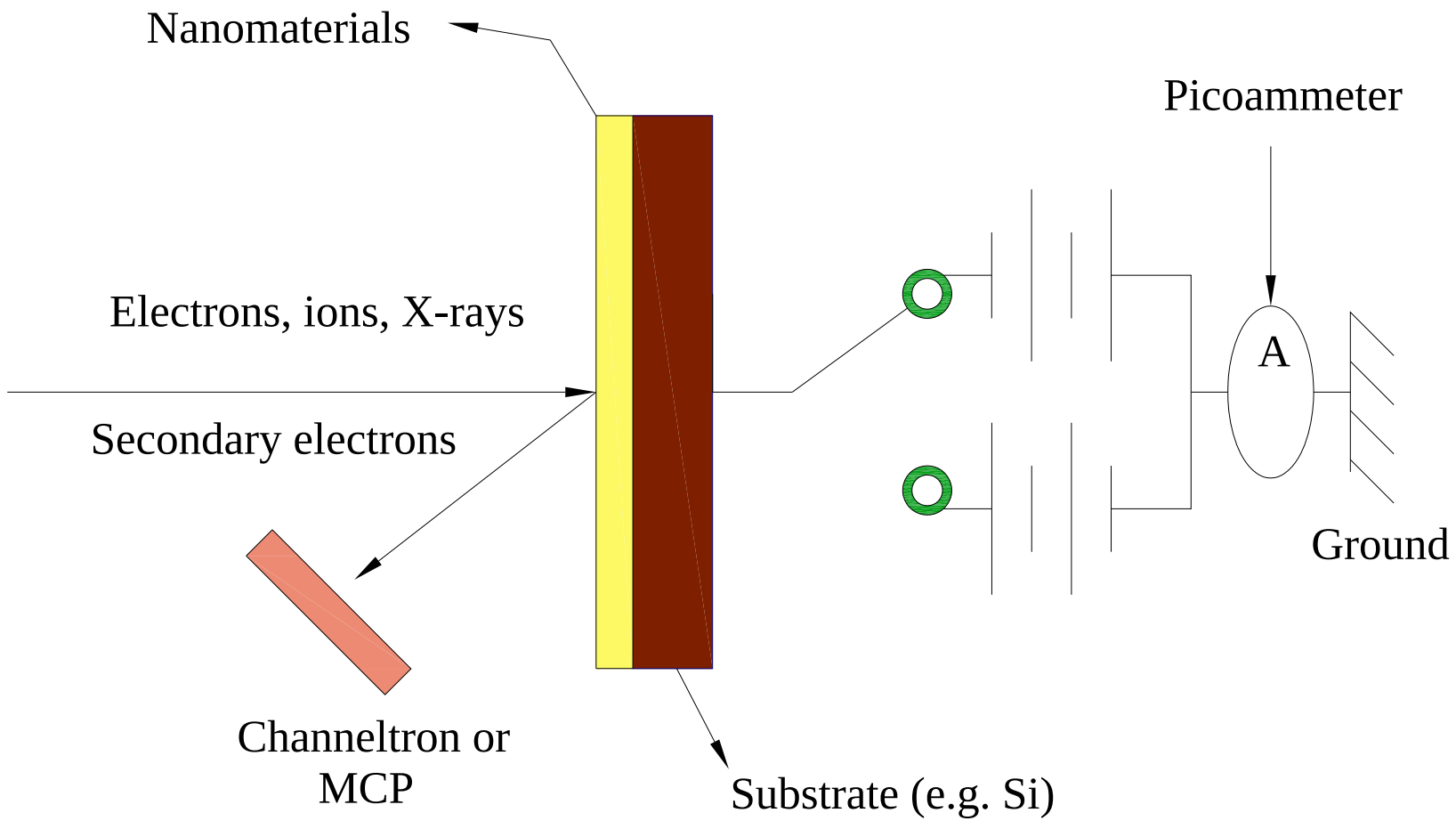
Sample preparation

1. ZnO nanoneedles were grown by catalyst-free MOCVD on Si substrates

1. Using diethylzinc (DEZn) and oxygen gas in the 400 – 500 °C range

1. Following the fabrication of ZnO nanoneedles, around 10 nm thick AlN or GaN layers were deposited by low pressure metal-organic vapor phase epitaxy (MOVPE) directly on the ZnO nanoneedles using trimethyl-Ga (TMGa) and trimethyl-Al (TMAl)), and ammonia (NH3) as precursors, respectively.

New materials for detectors



Marian Cholewa, Shu Ping Lau, Gyu-Chul Yi ,Yoo Jin Kyoung,
Adrian P. Burden, Lei Huang, Gao Xingyu,
Andrew T.S. Wee, Herbert O. Moser
United States Patent No. 7,388,201 (June 17, 2008)
"Radiation Detector Having Coated Nanostructure and Method"

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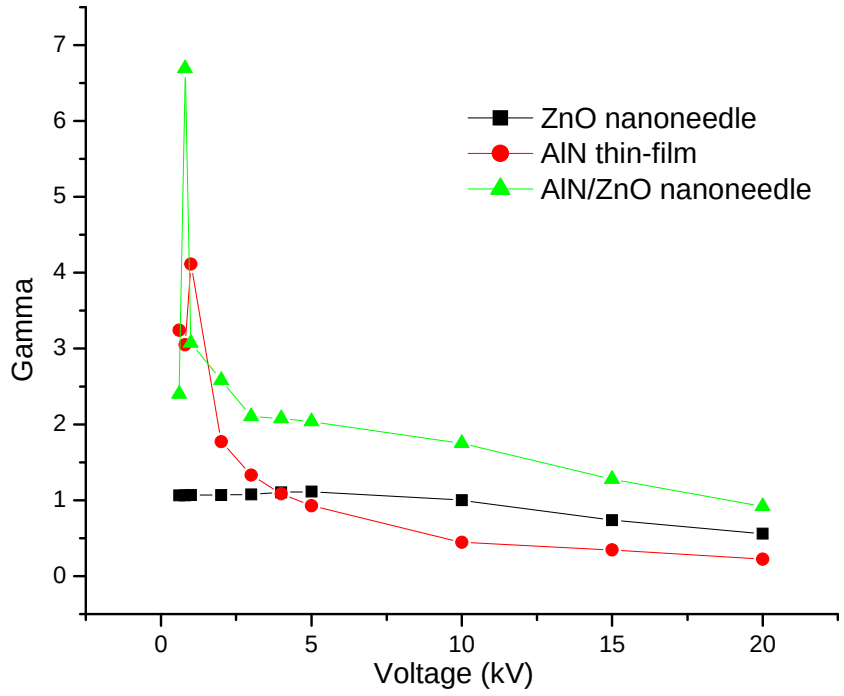
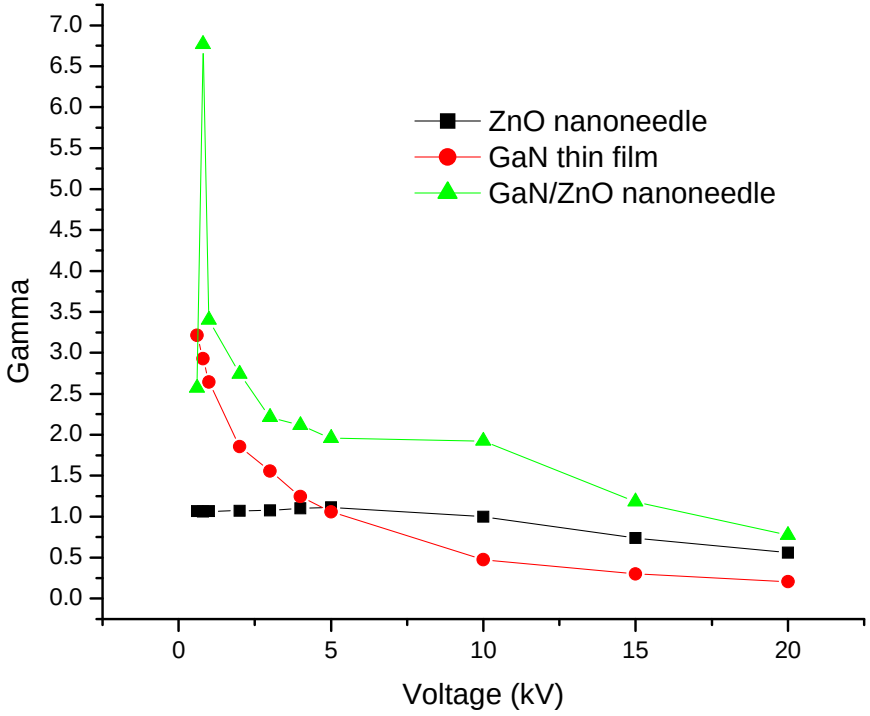
Electrons


ZnO nanoneedle
AlN thin-film
AlN/ZnO nanoneedle
Gamma
Voltage (kV)
0
1
2
3
4
5
6
7
0
5
10
15
20


ZnO nanoneedle
GaN thin film
GaN/ZnO nanoneedle
Gamma
Voltage (kV)
0.0
0.5
1.0
1.5
2.0
2.5
3.0
3.5
4.0
4.5
5.0
5.5
6.0
6.5
7.0
0
5
10
15
20

New materials for detectors

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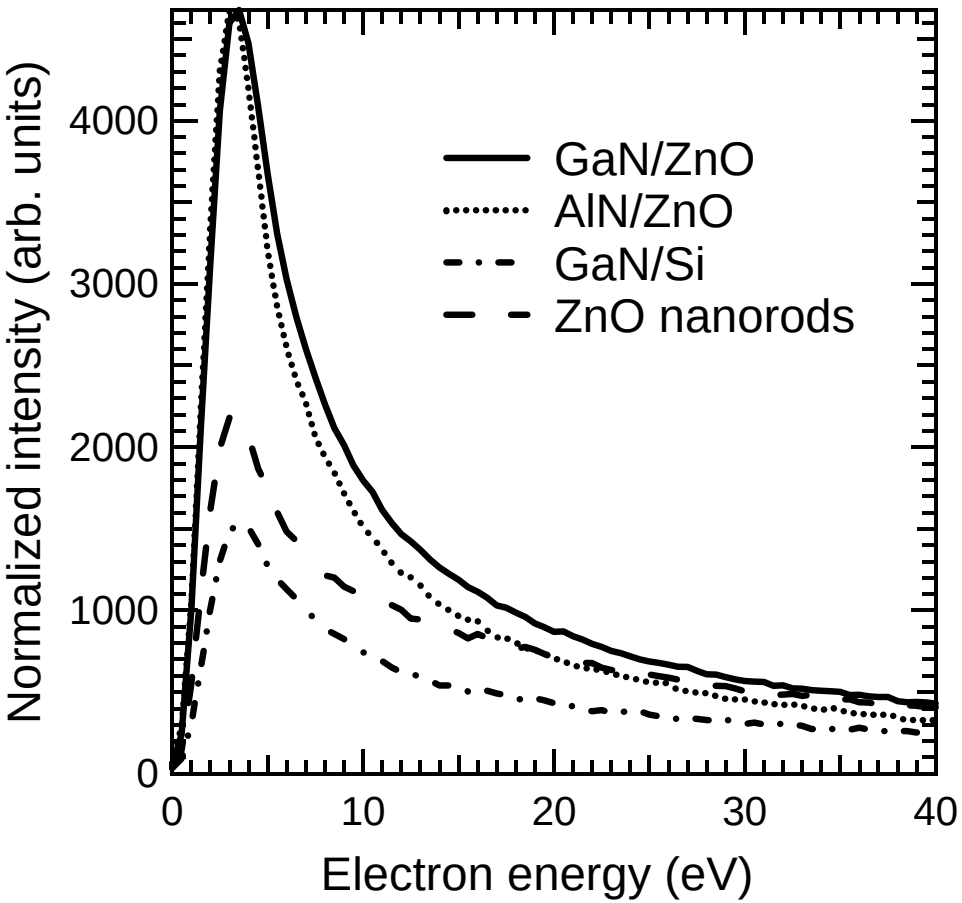
X-rays



SSLS
- **1 keV**
- **100 keV**

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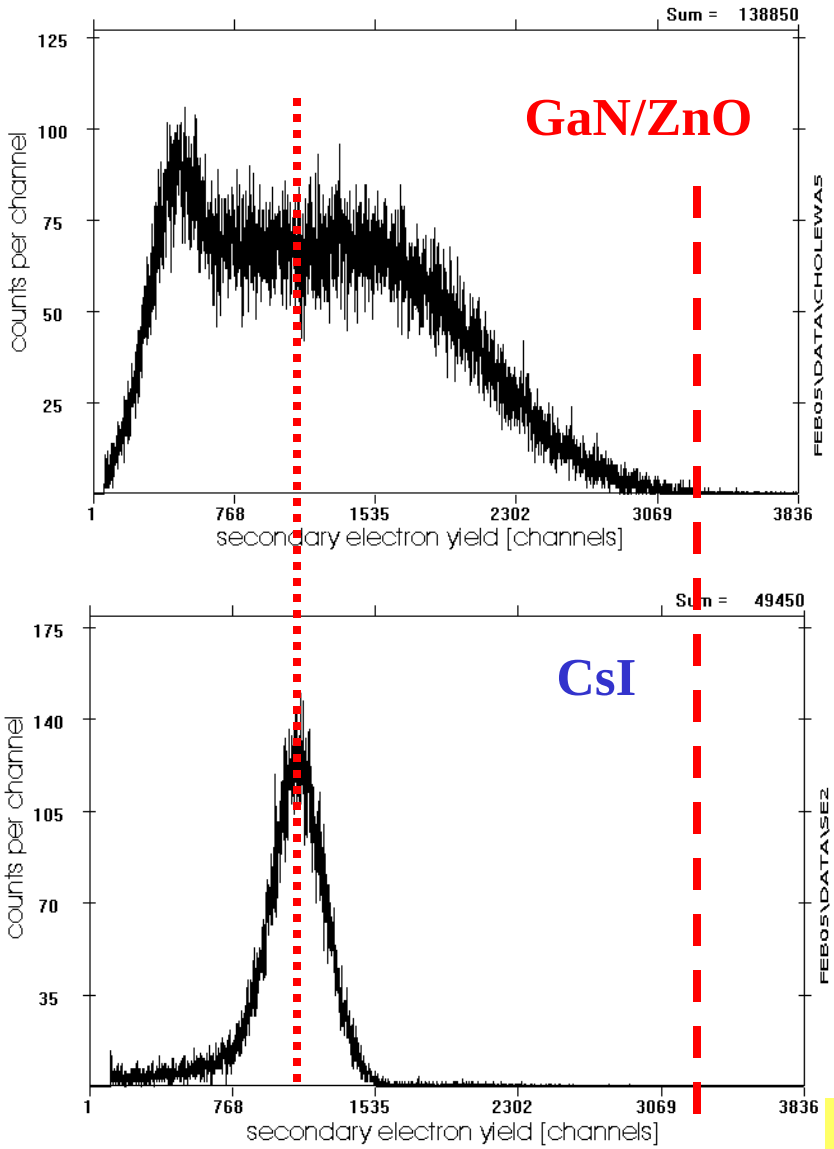
New materials for detectors



Ions

- **GSI, Germany**
- **4.8 MeV/nucleon Carbon ions**
- **1 μm diameter beam**

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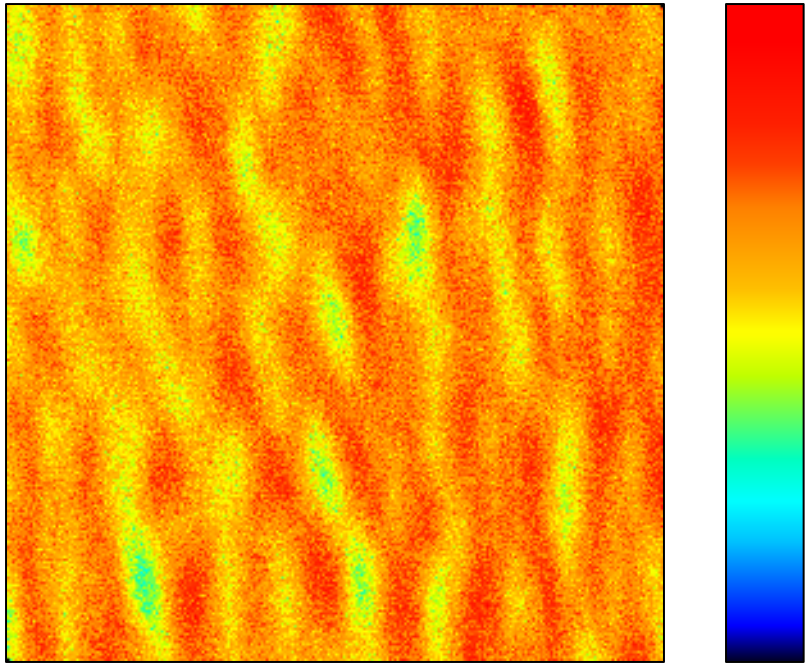
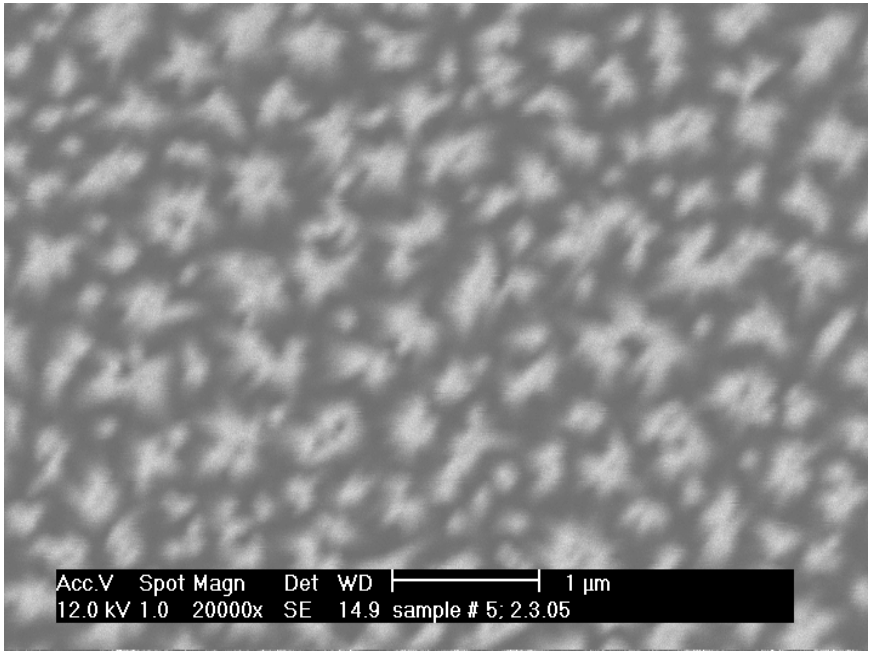
Ions & electrons



CIBA, NUS
2 MeV protons
200 nm resolution
5x5 μm^2 scan



GSI, Germany
SEM image
12 keV electrons
6x4 μm^2 scan

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Questions

1. How many electrons are being generated?
2. What is their spatial and energy distribution?
3. What is the secondary electron emission (SEE) yield as a function of type of radiation and energy?
4. Could we produce highly uniform materials?

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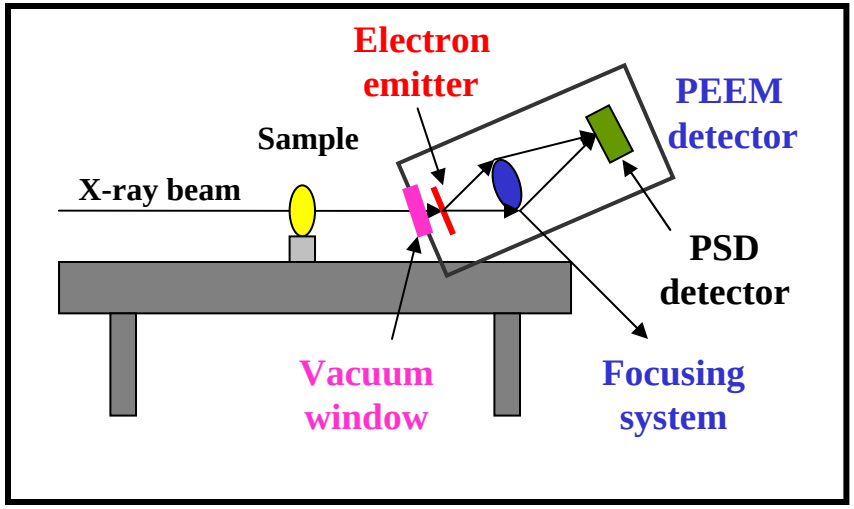
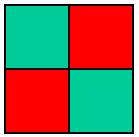
X-ray Electron Emission Microscopy (XEEM)



- **White beam**
- **20 nm resolution**
- **Sample size ~50 μm**
- **Estimated cost: 600 k$**
- **Proposal to ARC**

PEEM (Photon Electron Emission Microscopy) : 2 nm



1x1 μm^2
20x20 nm^2 (50x50 pixels)

Marian Cholewa & Bernd Fischer
International Patent: PCT/EP 03/02323; P179 (GSI 12283) **2003**
"Device for charged particle and photon detection" – DE 202 03 702.9.
Licence for the patent purchased by SIEMENS, Germany in 2008.

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Summary

Collaborators:

- **Germany, Poland, South Korea, Singapore**

Conclusions:

- **Boron-doped CVD diamond**
- **Nano-materials (GaN/ZnO, AlN/ZnO)**

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Thank you!

Report from MC

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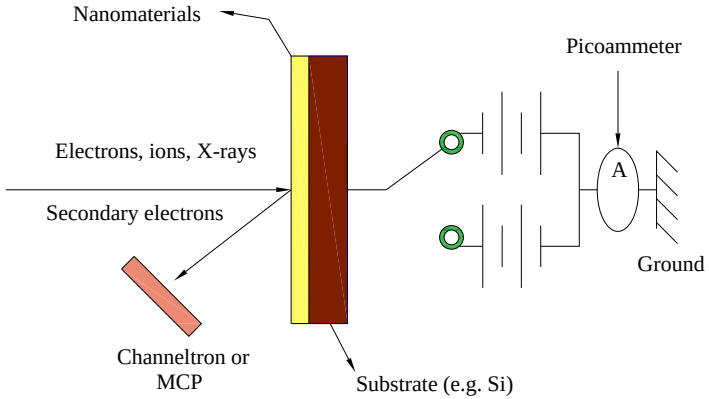
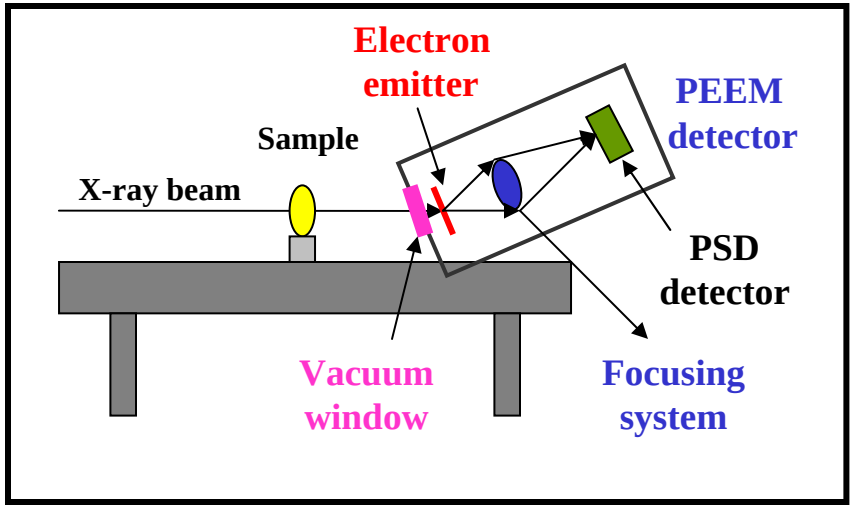
Proposals

ARC DP10 (Cholewa, Hall, Araujo, Wee)
DP1094734 (submitted in 2009) **- $A 449,407**
"Development and applications of new materials for high speed, high efficiency radiation detectors"





- **B-doped CVD diamond**
- **ZnO with GaN/AlN**

- **Efficiency (ca. 100%)**
- **Speed > 10 MHz**
- **Rise time from 2ns to 250 ps**

X-ray Electron Emission Microscope

Marian Cholewa & Bernd Fischer
International Patent: PCT/EP 03/02323; P179 (GSI 12283) **2003**
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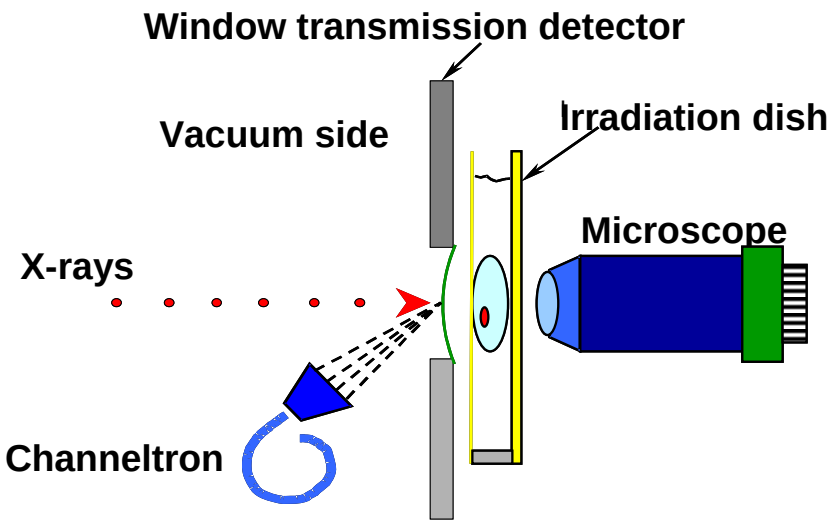
Single Cell X-ray Irradiation Facility



- Detection system (100%) & window (200 nm)
- Cell dish
- Cell visualisation system
- Computer controlled system
- 10,000 cells per hour

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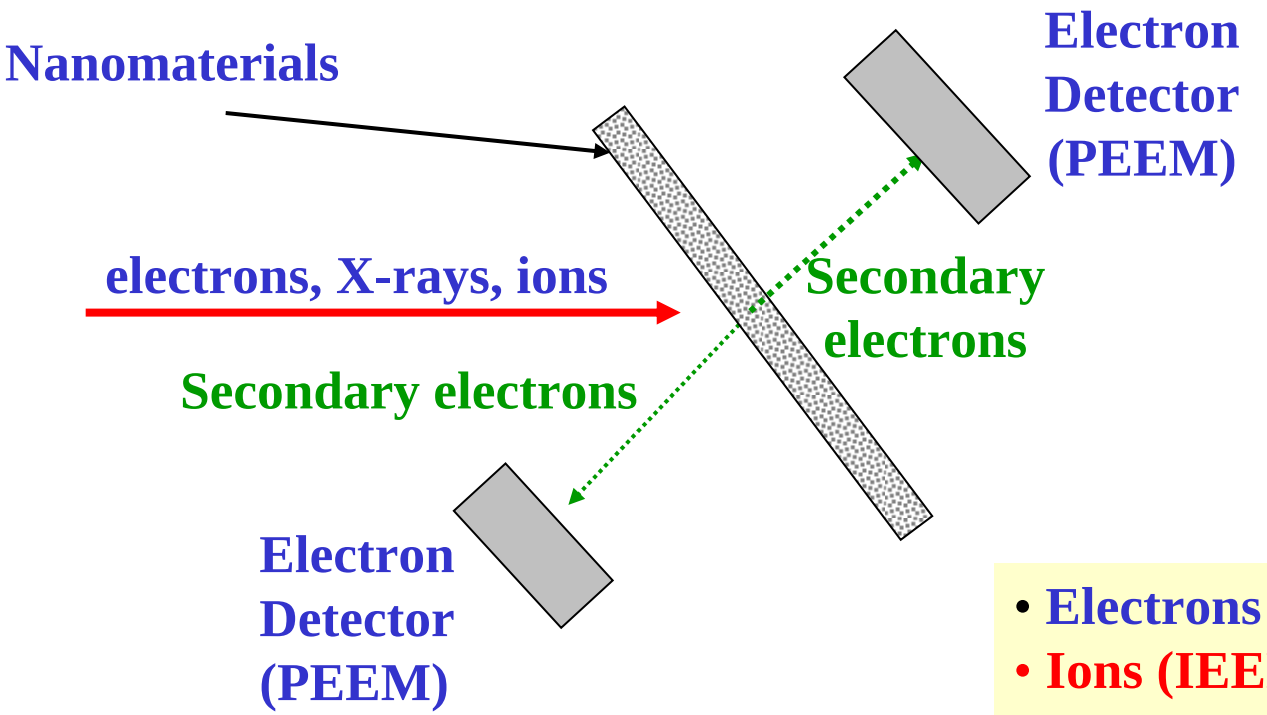
Imaging systems



- Electrons (PEEM): 10 nm
- Ions (IEEM): 20 nm
- X-rays (XEEM): 300 » 20 nm

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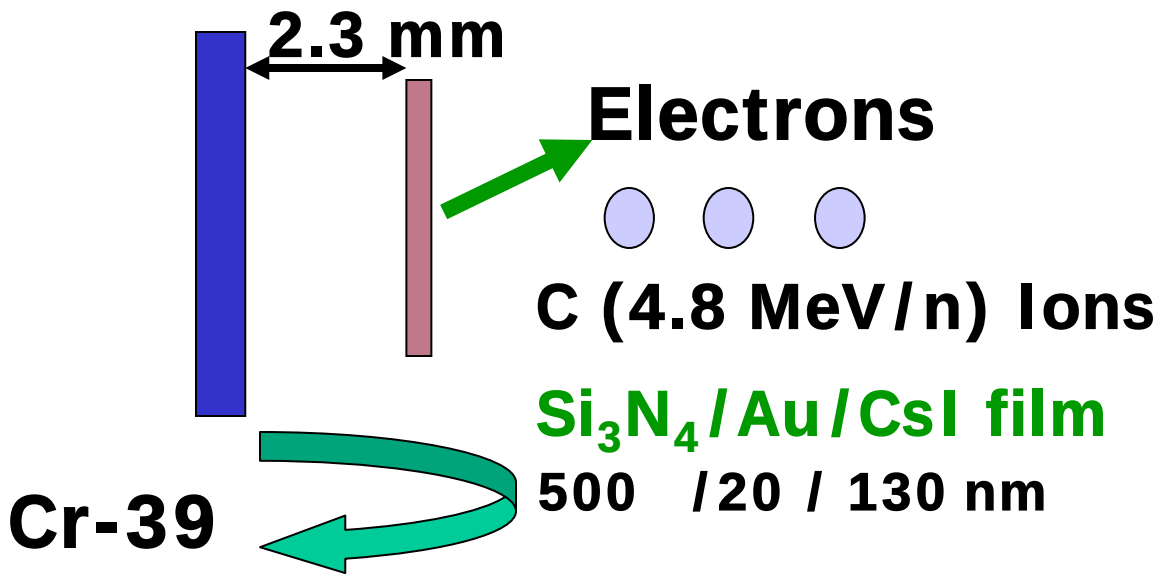
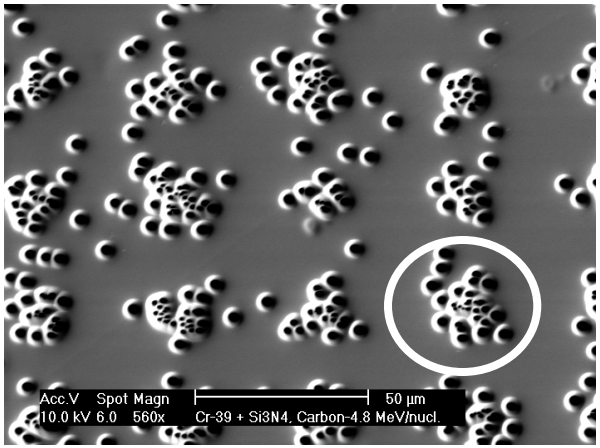
Scattering (Xe, C)





10x10
15 ions

TRIM (99.73%)
3σ : ± 9.1 µm

Exp: ± 15 µm

M. Cholewa et al , Nucl. Instrum. & Meth., B210 (2003) 296-301.