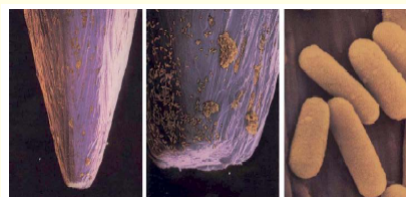


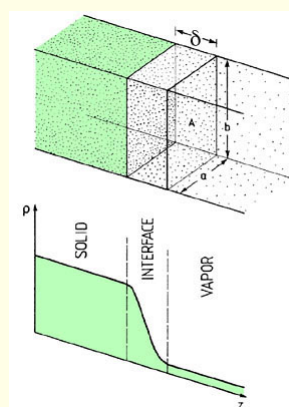
## Sissejuhatus pinnaanalüüsi meetoditele

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<http://staff.ttu.ee/~krustok>

## Mis on pind?



Nööpnõela pea erinevatel suurendustel



## Pinna spektroskoopia

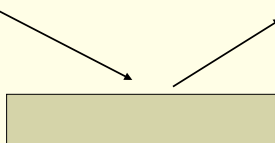
Võimaldavad saada informatsiooni pinna keemilisest koostisest (mõni Å ~ 10-d Å)

- Footonid, elektronid, ioonid või neutraalsed molekulid.

Allikast  
(primaarne kiir)

Sample

Spektromeetrise  
(sekundaarne kiir)



1-keV elektronid tungivad umbes ~ 25 Å sügavusele, sama energiaga fotonid tungivad aga ~ 10<sup>4</sup> Å

## Põhilised pinna analüüsi meetodid:

**X-ray Photoelectron Spectroscopy (XPS)**

**Ultraviolet Photoelectron Spectroscopy (UPS)**

**Auger Electron Spectroscopy (Auger)**

**Secondary Ion Mass Spectroscopy (SIMS)**

Electron Energy Loss Spectroscopy (EELS)

Rutherford Backscattering Spectrometry (RBS)

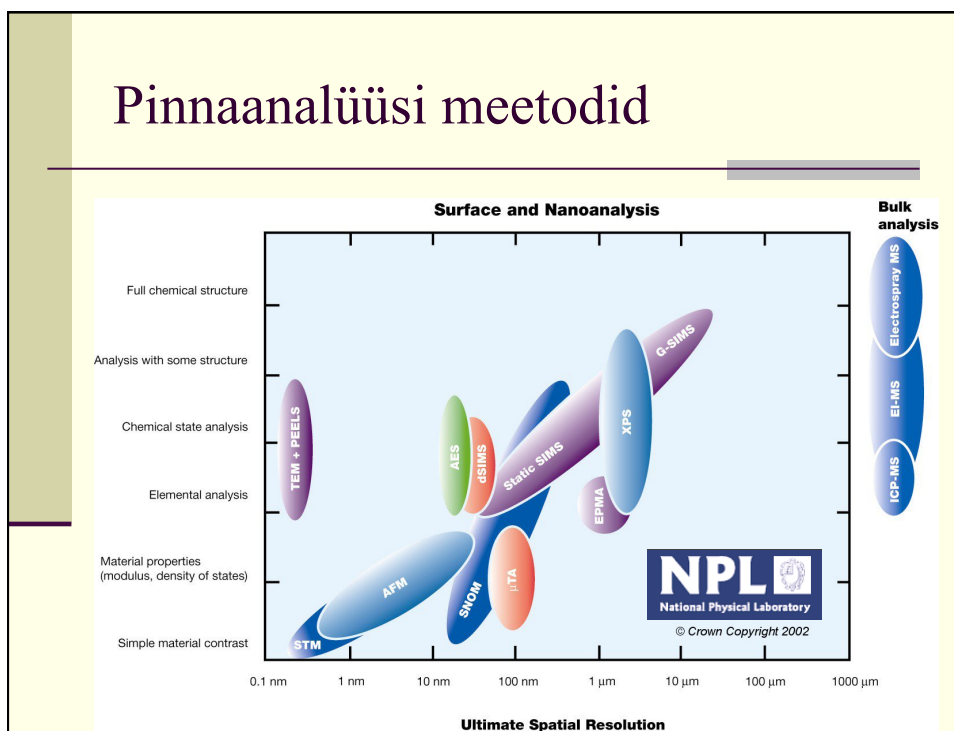
## Pinnaanalüüsi meetodid

Method and Common Acronym	Primary Beam	Secondary Beam
X-ray Photoelectron Spectroscopy (XPS), or Electron Spectroscopy for Chemical Analysis (ESCA)	X-ray photons	Electrons
Auger Electron Spectroscopy (AES)	Electrons, or X-ray photons	Electrons
Ultraviolet Photoelectron Spectroscopy (UPS)	UV photons	Electrons
Secondary Ion Mass Spectrometry (SIMS)	Ions	Ions
Laser Microprobe Mass Spectrometry (LMMS)	Photons	Ions
Electron Microbe (EM)	Electrons	X-ray photons

## Pinnaanalüüsi meetodid

Analytical Technique	Signal Measured	Elemental Range	Depth Resolution	Surface info.
<b>SIMS</b> (secondary ion mass spectrometry)	Secondary Ions	H-U	5 - 30 Å	Chemical composition Chemical structure
<b>TOF-SIMS</b> (time-of-flight SIMS)	Secondary Ions	H-U, Large Organic Molecules / Cluster Ions	2000 Å (Scanning Mode)	Adsorbate bonding
<b>TEM</b> (transmission electron microscopy)	Transmitted Electrons X-Rays	Na-U EDX	N/A	
<b>FE-SEM, EDX</b> (field emission SEM)	Backscattered or Secondary Electrons and X-Rays	Na-U	1 - 5 micrometres	
<b>ISS</b> (ion scattering spectroscopy)	Ions	H- U	monolayer	atomic structure chemical composition
<b>AES/SAM</b> (Auger electron spectroscopy, scanning Auger microscopy)	Auger Electrons	Li-U	1 - 5 nm	chemical composition
<b>ESCA/XPS</b> (electron spectroscopy for chemical analysis, X-ray photoelectron spectroscopy)	Photoelectrons	Li-U	1 - 10 nm	chemical composition chemical structure
<b>RAIRS</b> (reflection-absorption infra-red spectroscopy)	IR photons	organic, some inorganics	monolayer	Adsorbate bonding
<b>STM</b> (scanning tunnelling microscopy)	-	solid surfaces	upper most atoms	physical topography
Analytical Technique	Signal Measured	Elemental Range	Depth Resolution	Surface info,

## Pinnaanaluüsi meetodid



## Primaarse kiire energiad

**UPS**

$h\nu < 100 \text{ eV}$   
tüüpiliselt 10-45 eV

**XPS**

$100 \text{ eV} < h\nu < 2000 \text{ eV}$

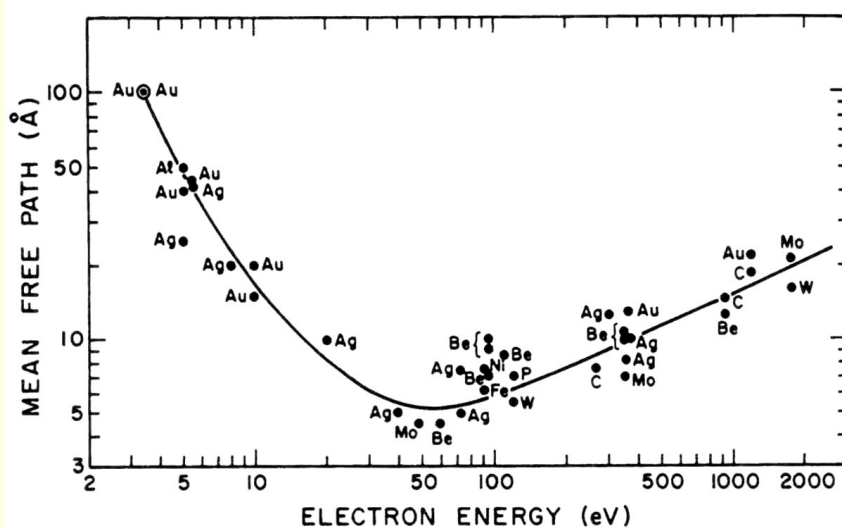
**Fotoelektron spektroskoopia (PES),**  
mis kasutab sünkrotronkiirgust

$5 \text{ eV} < h\nu < 5000 \text{ eV}$

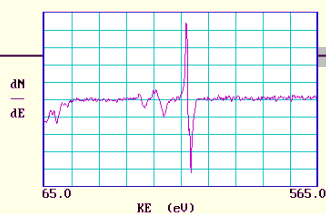
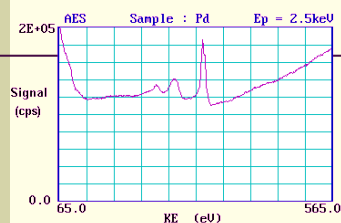
## Primaarse kiire allikad

UPS	He gaaslahenduse lamp 21.2 eV
XPS	Mg $K_{\alpha}$ = 1253.6 eV Al $K_{\alpha}$ = 1486.6 eV Ti $K_{\alpha}$ = 2040 eV
PES	Sünkrotronkiirgus 5 – 5000 eV

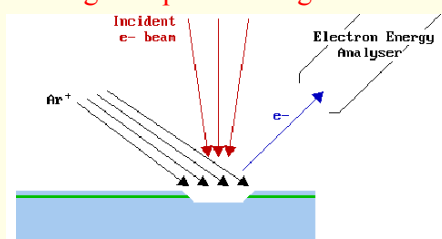
## Elektronide sissetungimise sügavus



## Auger Electron Spectroscopy (AES)

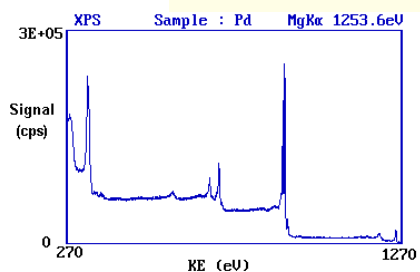
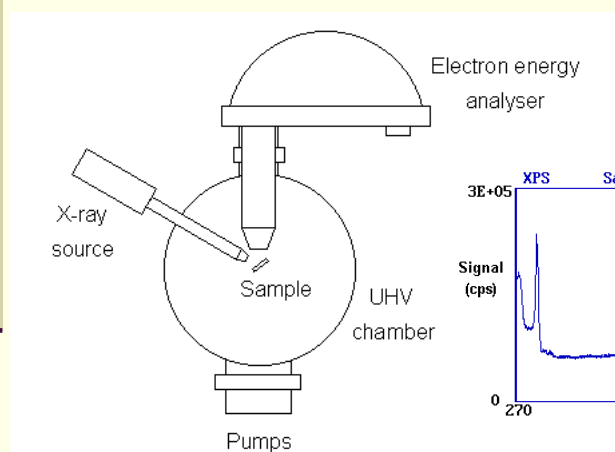


### Auger Depth Profiling



Pinda pommitatakse fokuseeritud elektronkiirega, mõõdetakse emiteerunud Auger elektronide kineetilist energiat

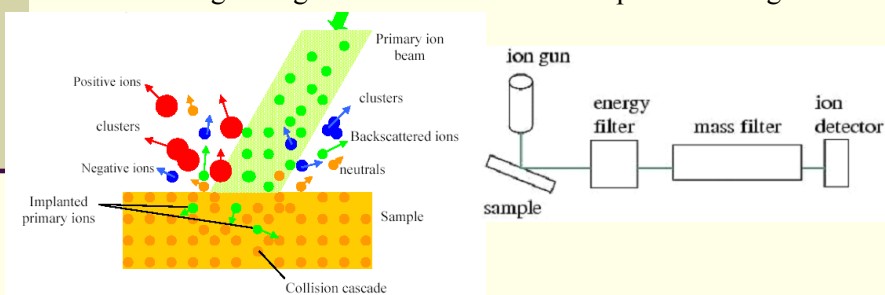
## X-ray photoelectron spectroscopy (XPS)



## Secondary Ion Mass Spectroscopy (SIMS)

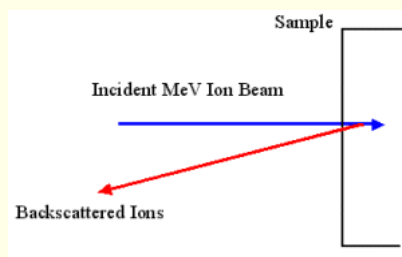
➤ **Ioonid energiaga 1-15 keV** pommitavad objekti pinda

➤ **Sekundaarsed ioonid** kannavad negatiivset, positiivset või neutraalset laengut ning neid analüüsitakse massispektromeetriga.

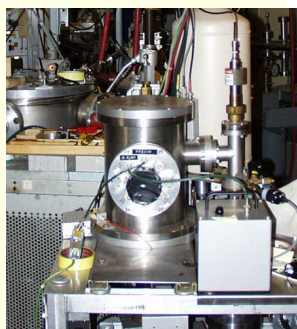


## Rutherford Backscattering Spectrometry (RBS)

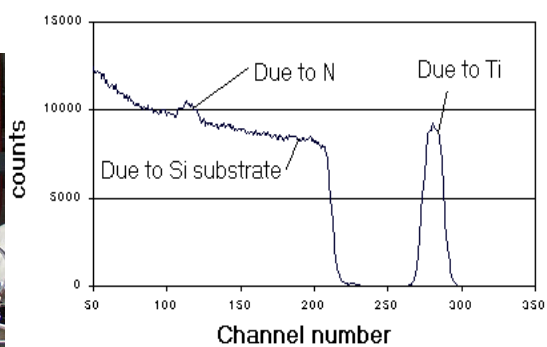
$\text{He}^+$  ioonidega (energia  $> 2 \text{ MeV}$ ) pommitatakse pinda. Osaliselt hajuvad ioonid pinnakihi tagasi. Neid ioone analüüsitakse tahke keha detektoriga. Võib saada nii pinna elementkoostise kui ka jaotuse sügavusse.



## Rutherford Backscattering Spectrometry (RBS)



RBS aparatuur



RBS spekter TiN kihist räni pinnal

## Rutherford Backscattering Spectrometry (RBS)

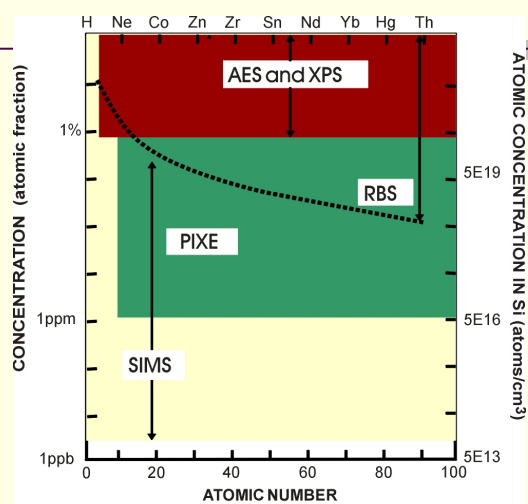
### Detekteerimise piirid:

$z < 20$	1-10 at%
$20 < z < 70$	0.01 – 1 at%
$z > 70$	0.001 at%

**Lahutusvõime sügavusse:** 20 – 200 Å



## Kokkuvõtte pinnaanalüüsi meetoditest



XPS X-ray Photoelectron Spectroscopy  
 AES Auger Electron Spectroscopy  
 RBS Rutherford Backscattering  
 SNMS Plasma-based Sputtered Neutral Mass Spectrometry  
 SIMS Secondary Ion Mass Spectrometry