Measurement of electron blur

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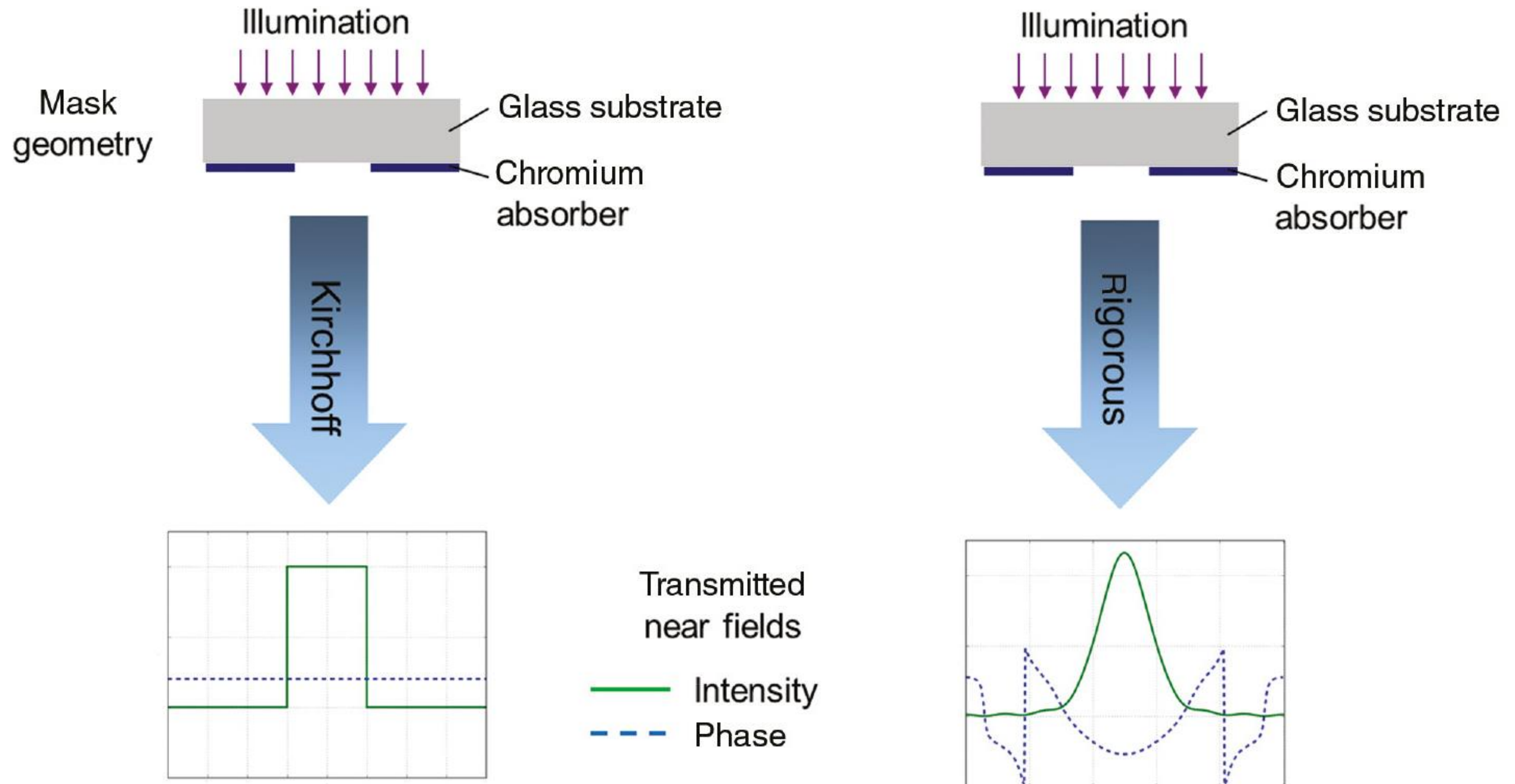
What is image blur

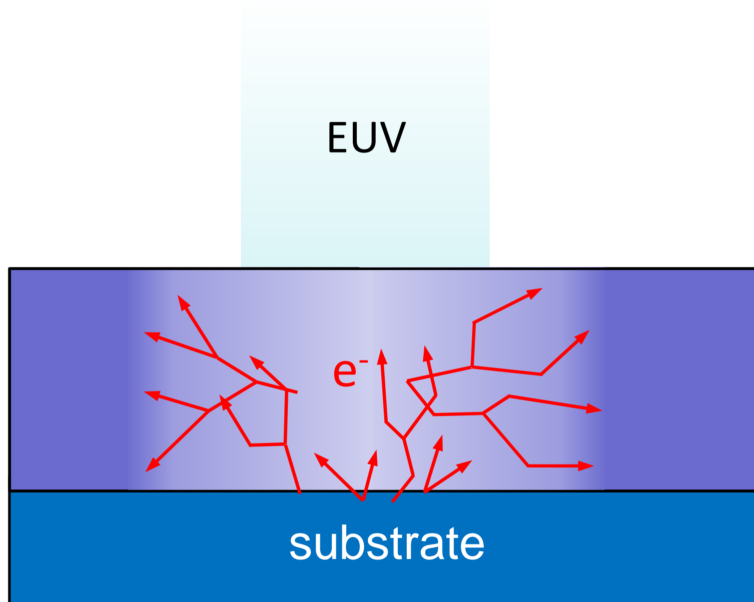
Blur due to imaging

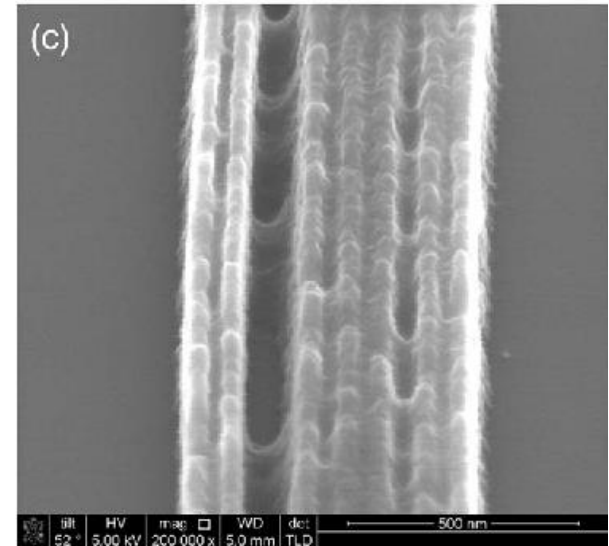


Erdmann et al., Adv. Opt. Techn. **6**, 187 (2017)

What is blur

Electron blur

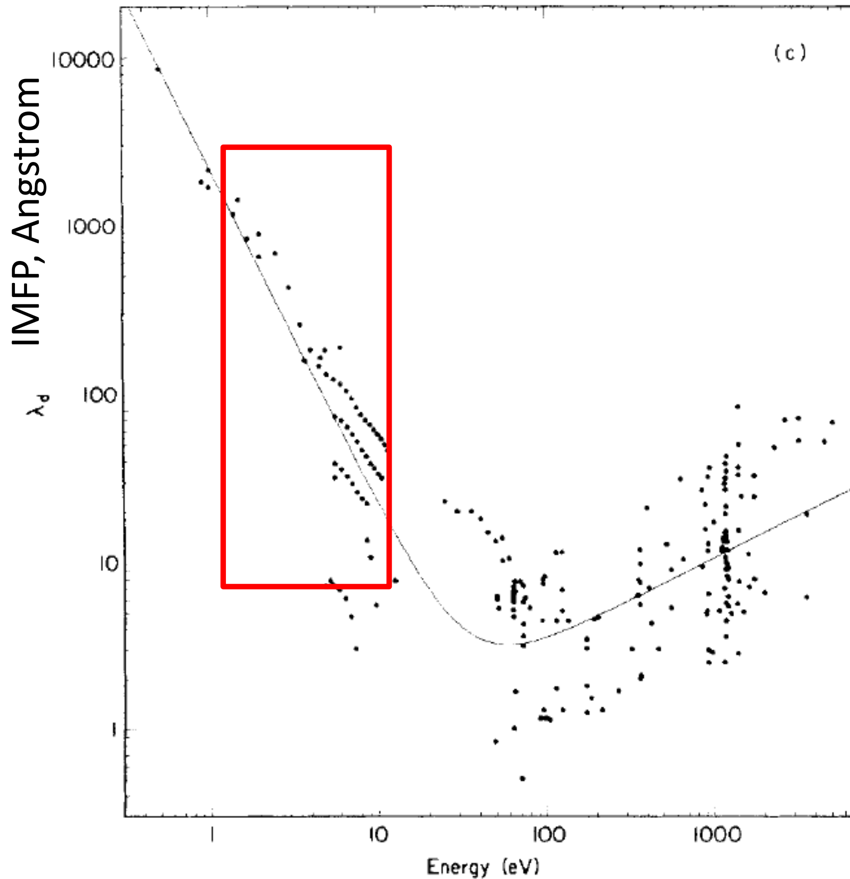




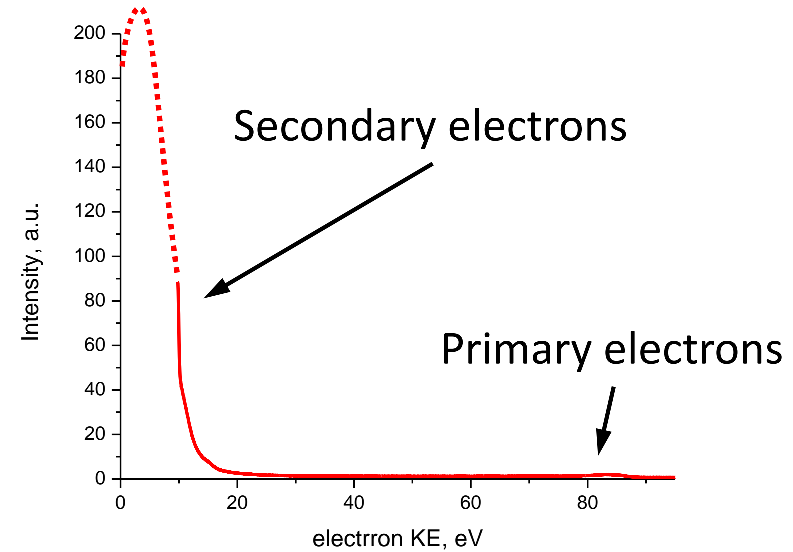
- Only **10 – 30 %** of EUV photons will be absorbed by 30 nm resist film
- Remaining **70 – 90 %** will be absorbed by substrate/underlayer

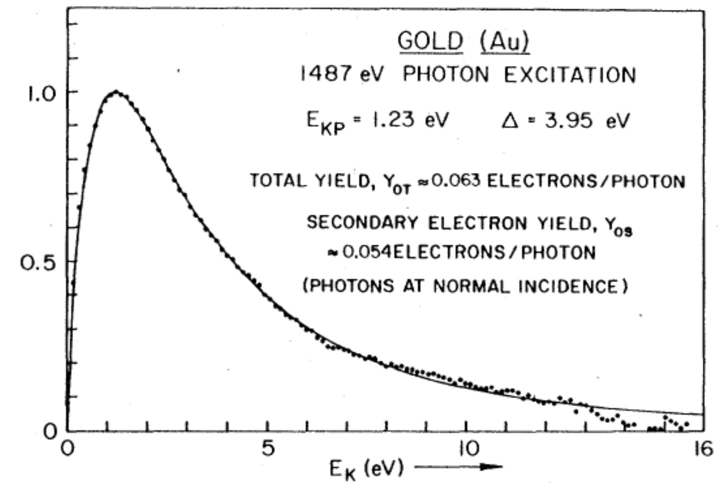
Importance of secondary electrons

Universal curve

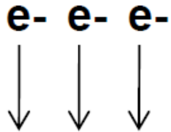


Seah and Dench, Surf. Interface Anal. **1**, 2 (1979)





Henke et al., PRB **19**, 3004 (1979)



Direct determination of electron blur

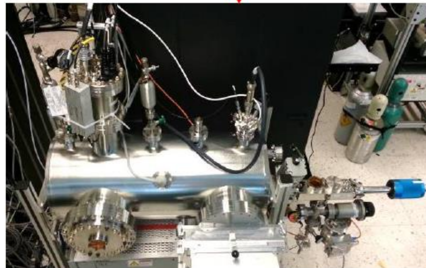
Vary Dose & Voltage

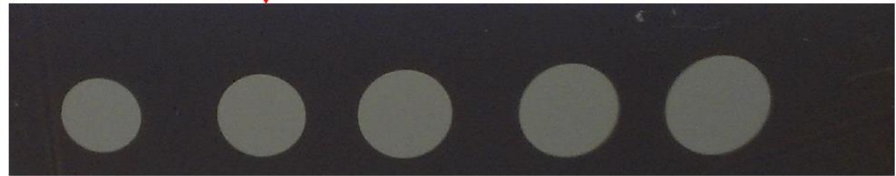
e- e- e-

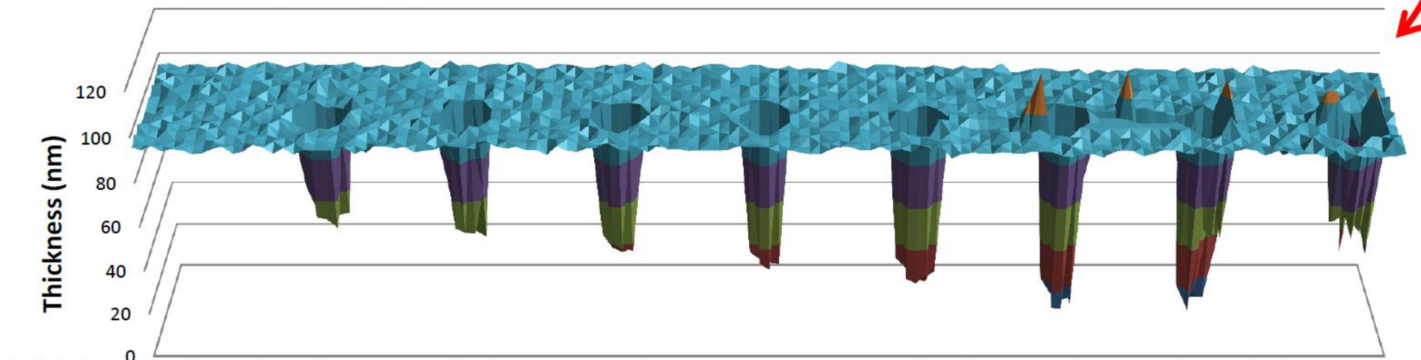
Bake and Develop

Thickness Loss (Ellipsometry)

Expose (vary energy and dose) → Bake and develop → Ellipsometry for thickness measurement







Thickness lost is where sufficient reactions occur – not final stopping point of electrons

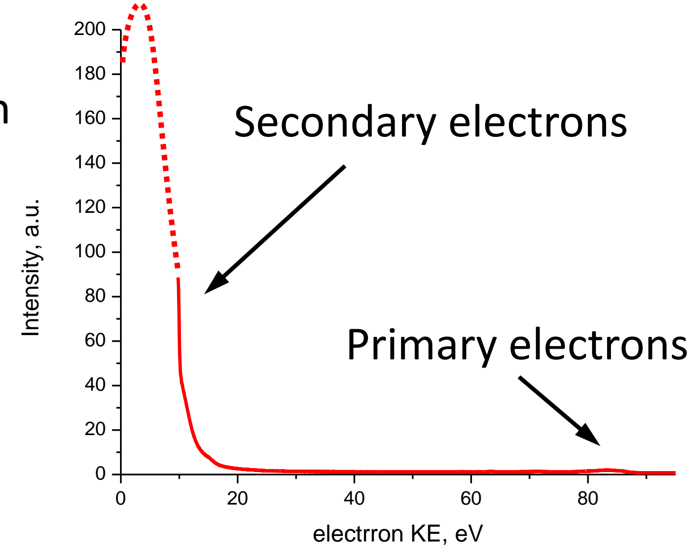
Possible problems: Hard to work with low KE electrons

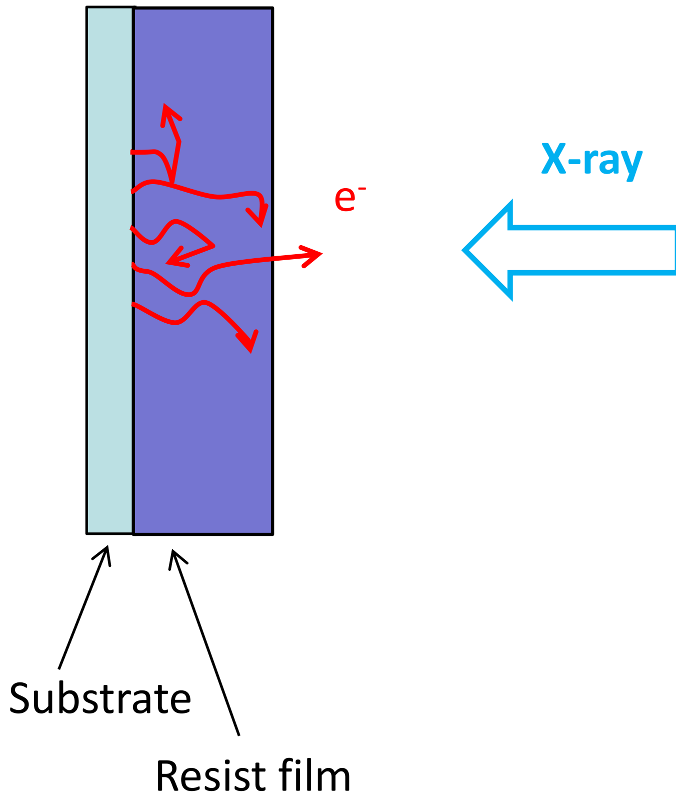
G. Dendeaux et al., EUV Litho workshop, 2013

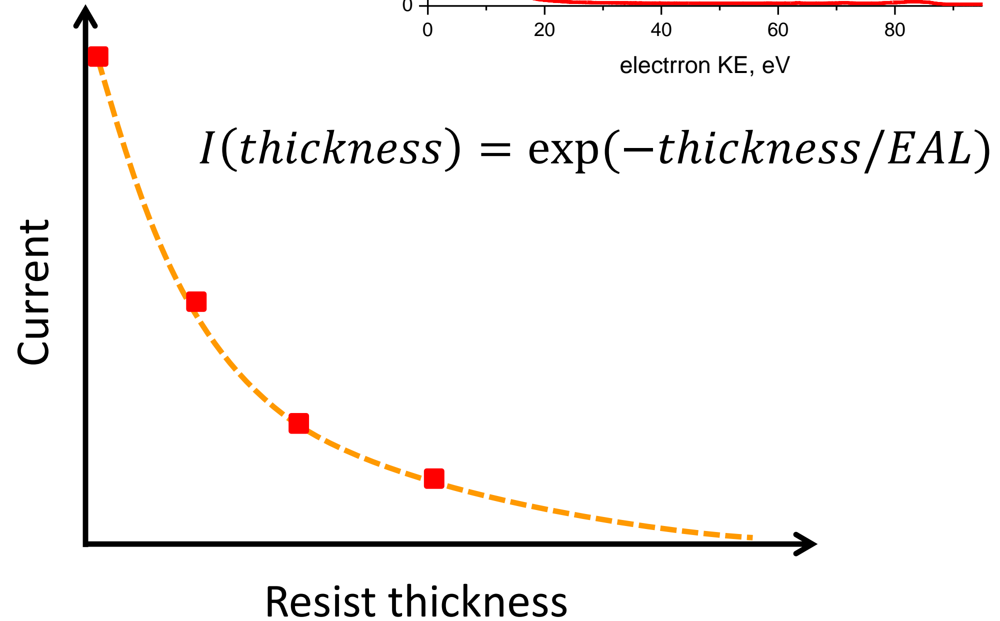
Indirect determination of electron blur

Assumption : Chemistry is mostly (secondary) electron driven

How far electrons can penetrate in a resist film?







$$I(thickness) = \exp(-thickness/EAL)$$

Electron attenuation length (EAL) – is the distance, at which number of electrons is dropped to 1/e of initial.

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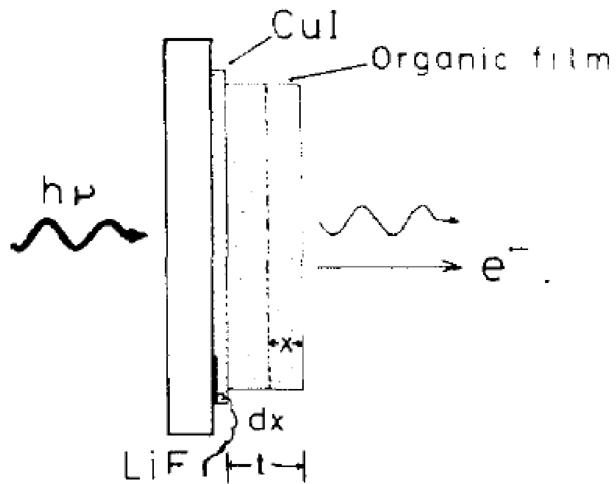
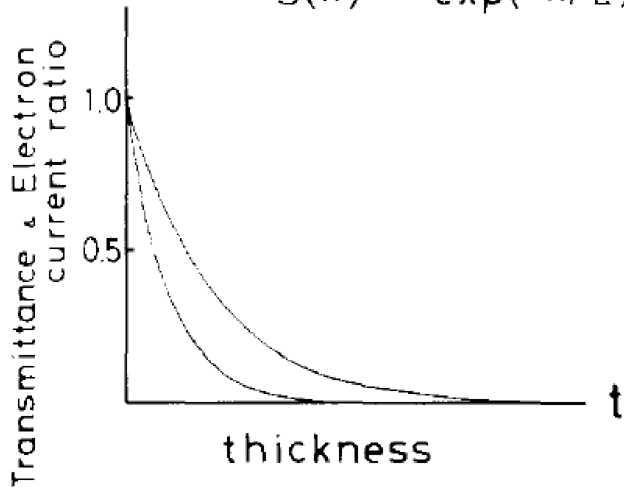
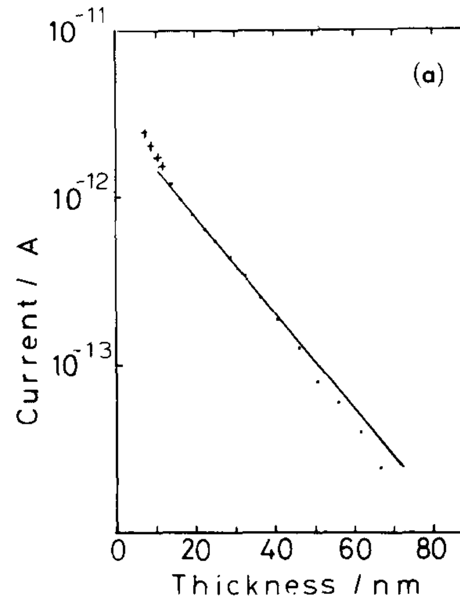
Electron attenuation length



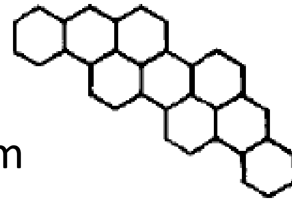
$S(x) = \exp(-x/L)$



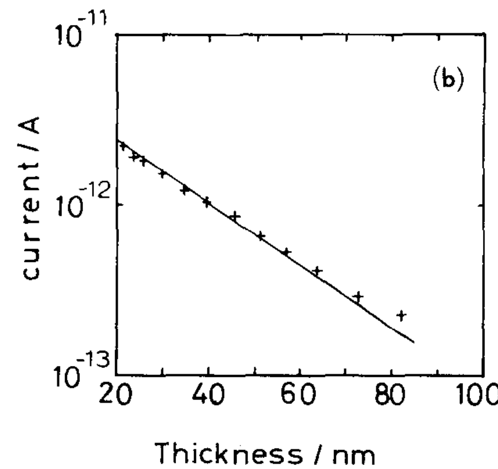
eKE = 7.8eV



Violanthrene A

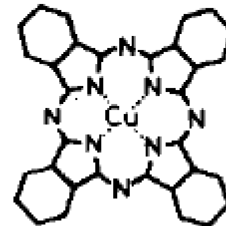


EAL = 1.3 nm



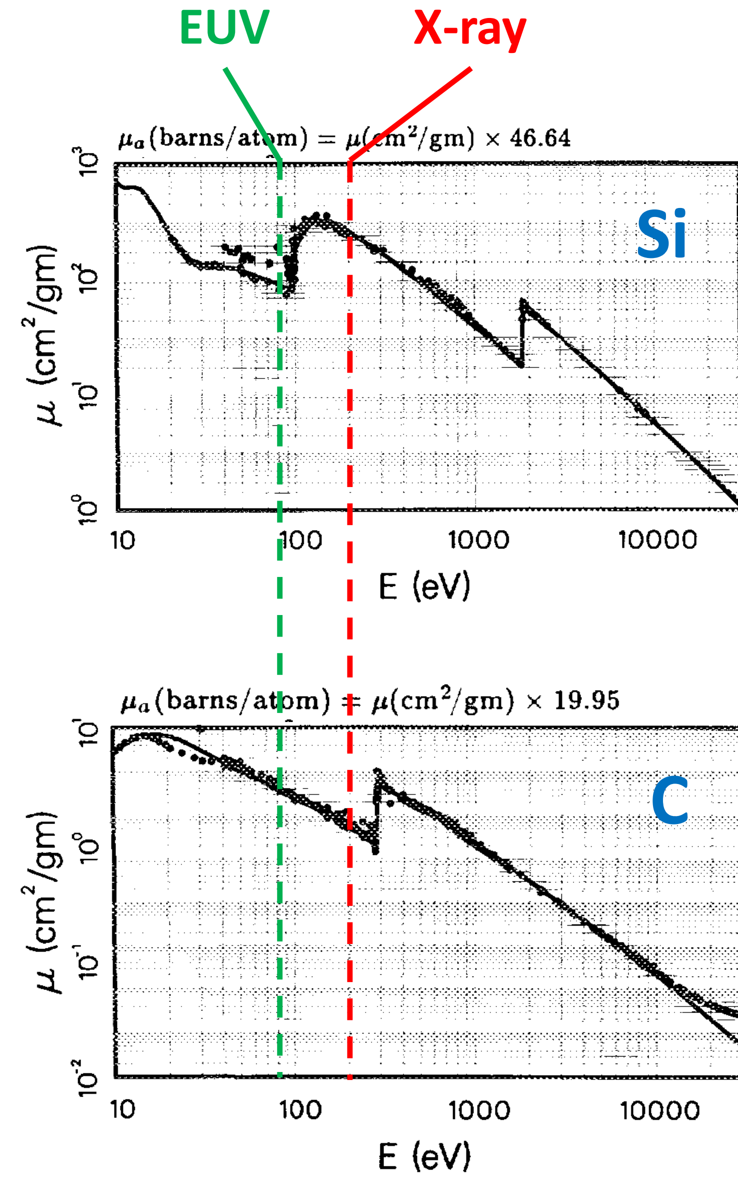
Cu-phtalocyanine

EAL = 2.7 nm



Hino et al., J. Chem. Phys. **67**, 4139 (1977)

Why X-rays?

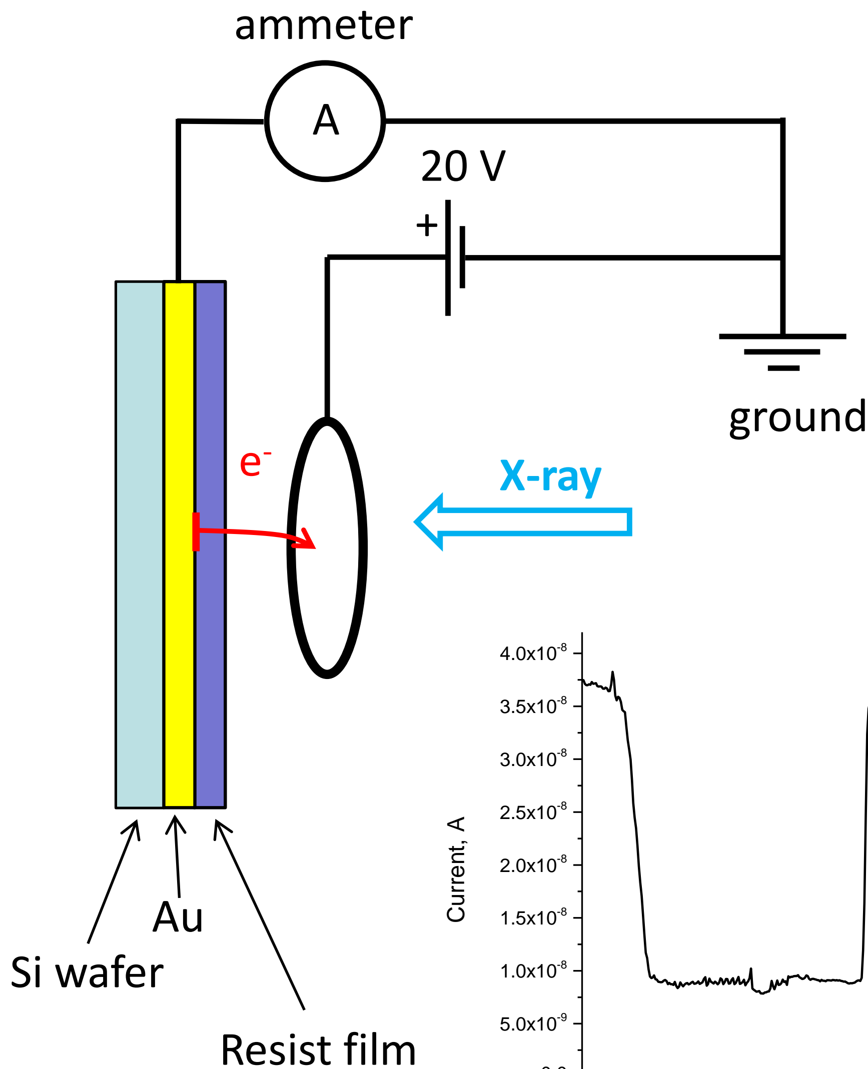


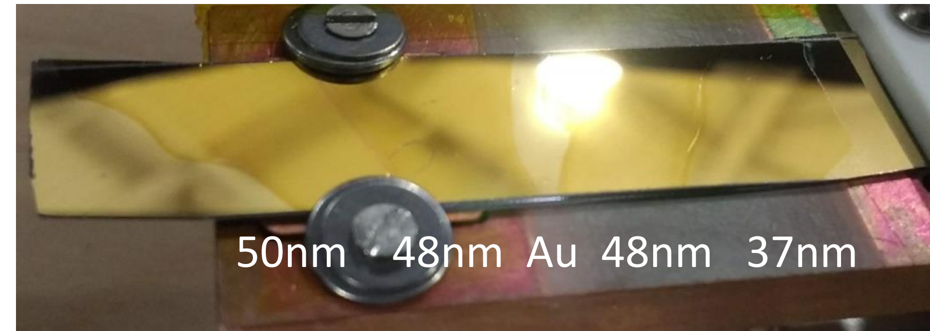
Material	Cross-section 92eV	Cross-section 193eV
Silicon	0.3 Mb	3.6 Mb
Carbon	0.6 Mb	0.11 Mb

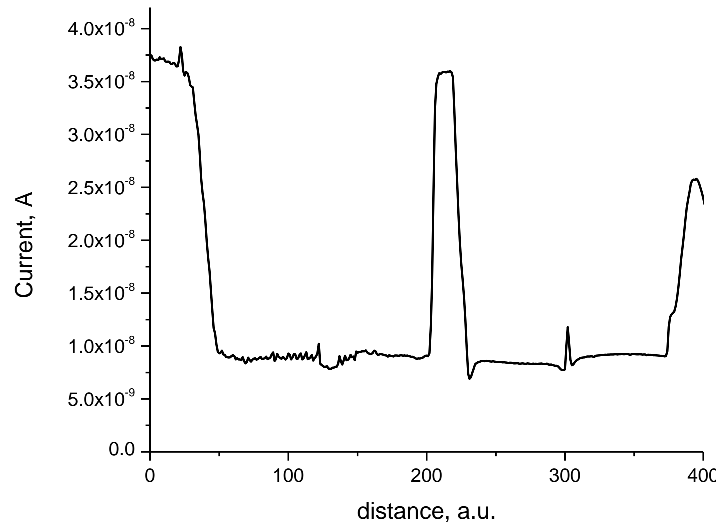
Carbon (polymer) is almost transparent for X-rays, therefore electrons are generated by substrate

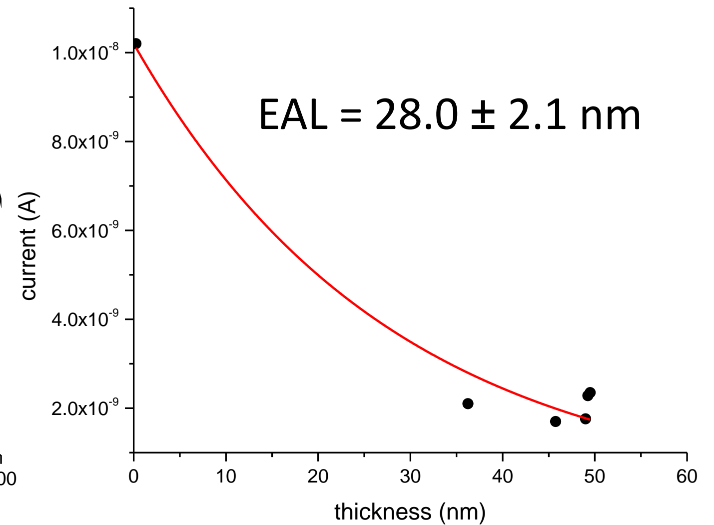
Atomic Data and Nuclear Data Tables, Vol. 54, No. 2, July 1993

Measurement using gold underlayer









Au 4f KE = 93 eV

Measurement directly from silicon wafer

20 V

ammeter

A

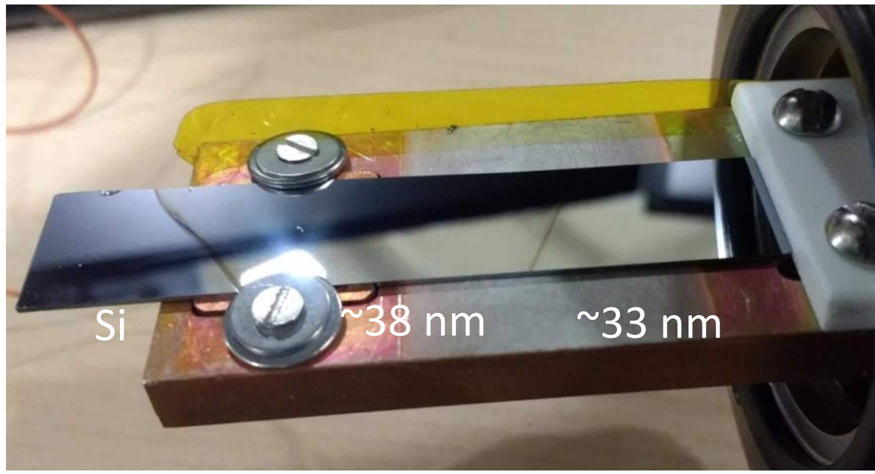
ground

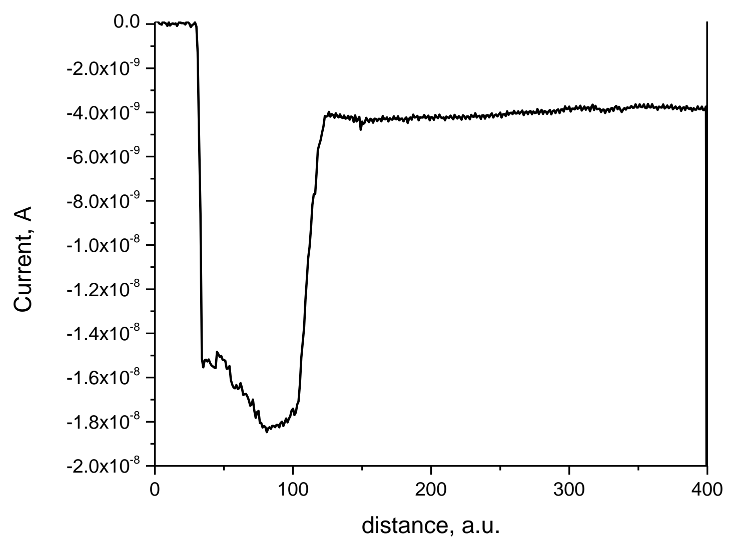
e⁻

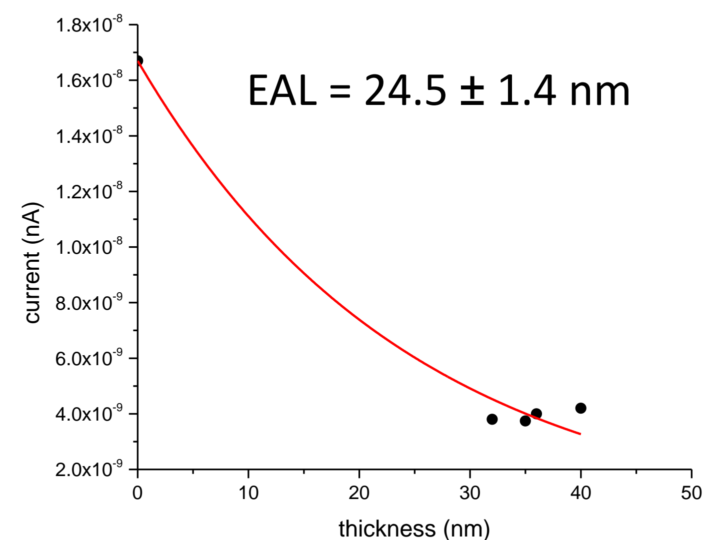
X-ray

Si wafer

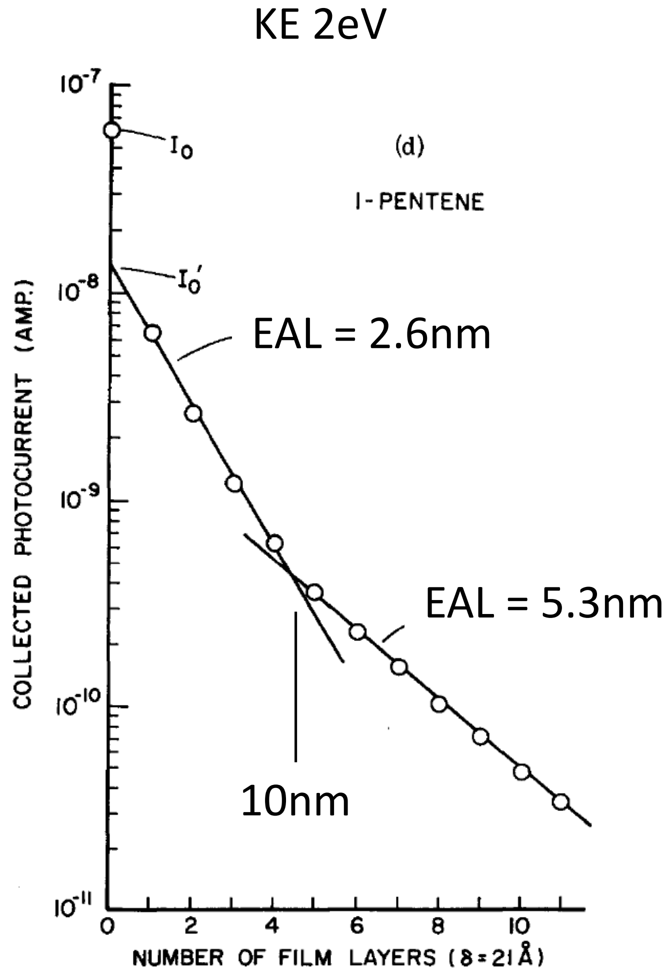
Resist film

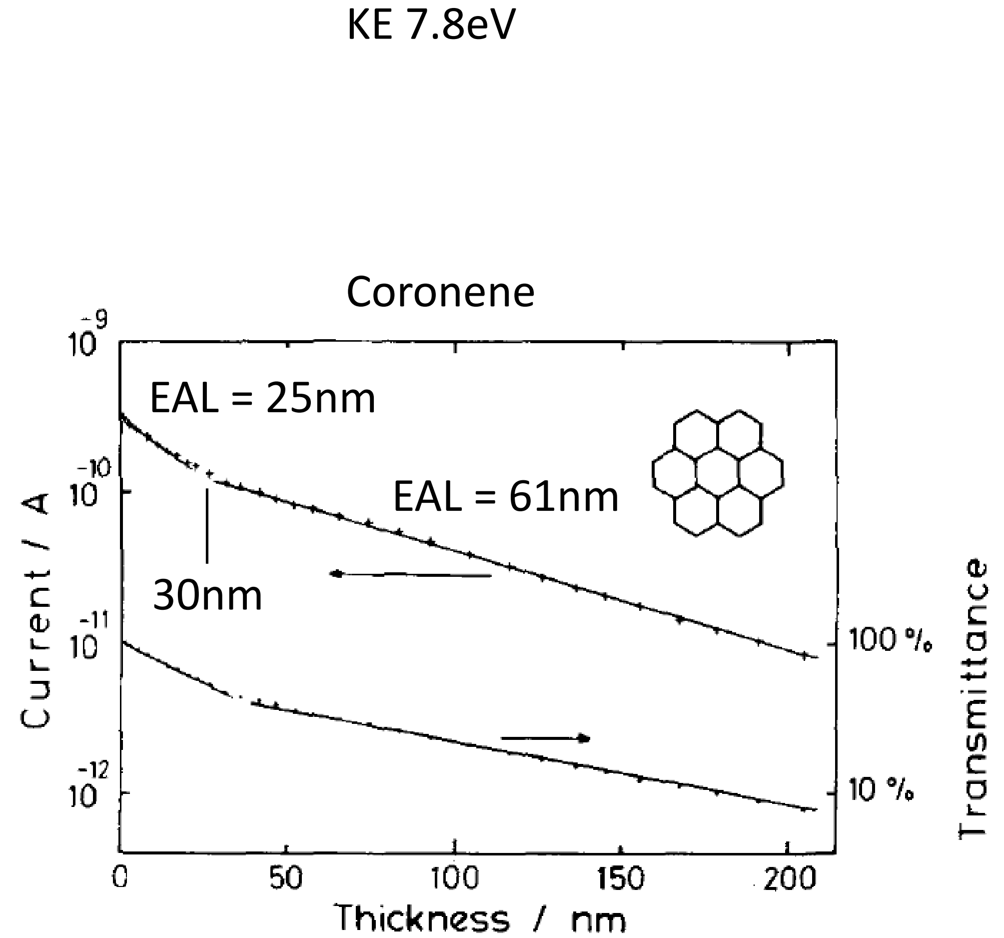






EAL can be thickness dependent





Chang, Berry, J. Chem. Phys. 61 (1974) 2727

Hino, Sato, Inokuchi, J. Chem. Phys. 67 (1977) 4139

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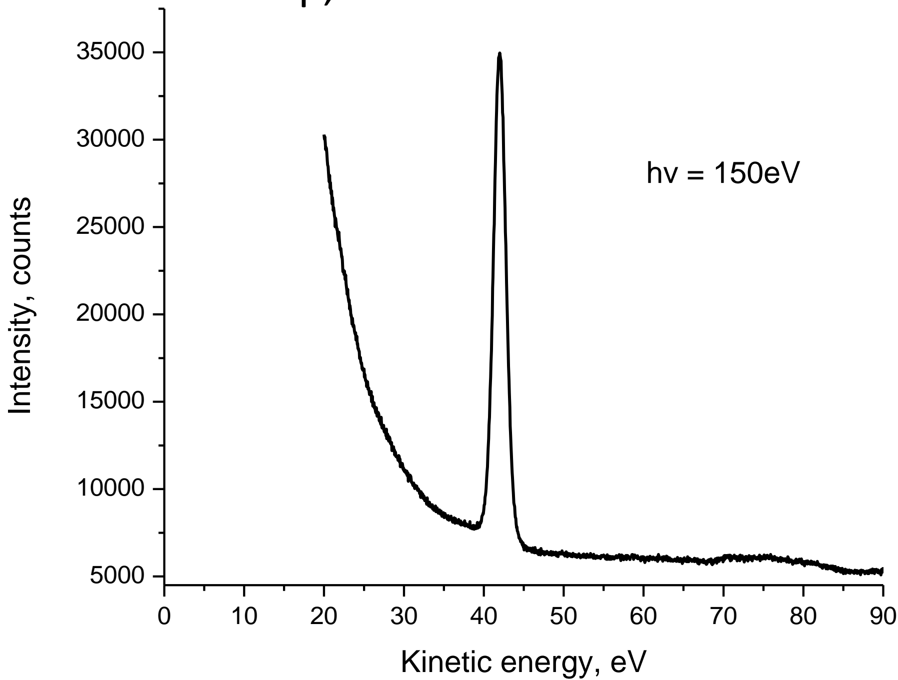
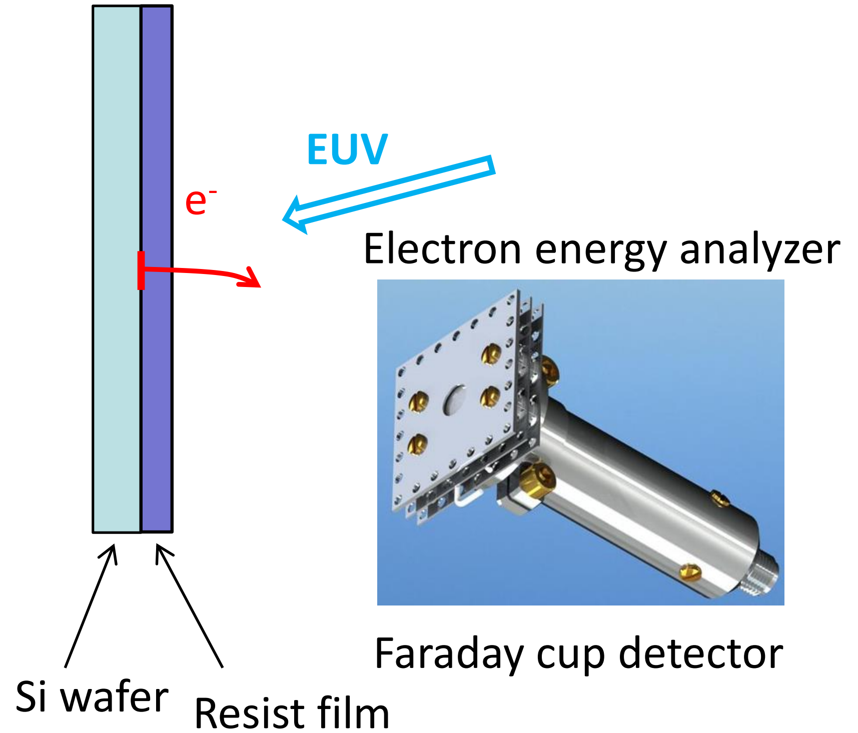
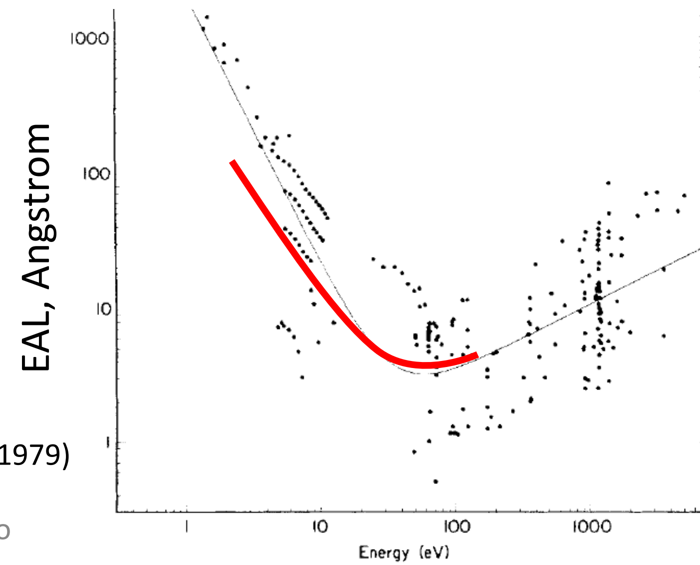
More advanced experiment

Si 2p binding energy 110eV







Seah and Dench, Surf. Interface Anal. **1**, 2 (1979)

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Conclusions

- Described sources of electron blur
- Importance of low kinetic energy secondary electrons
- Direct and indirect ways to measure electron blur
- Electron attenuation length (EAL)
- Demonstrated first results of EAL determination

Thank you for attention