SLAC-PUB-
April 20, 2004

Instrumental Effects in Secondary Electron Yield and Energy Distribution Measurements†*

Robert E. Kirby
Physical Electronics Group
The Stanford Linear Accelerator Center
Stanford University, Stanford, CA 94309

†Work supported by the U.S. Department of Energy under contract number DE-AC03-76SF00515 (SLAC).

*Presented at the **31st ICFA Advanced Beam Dynamics Workshop on Electron-Cloud Effects**, April 19-23, 2004, Napa, Ca.

Contributors to SEY at SLAC, 1978-2004

- Ed Garwin, Earl Hoyt, Frank King, Bob Kirby, SLAC
- Takashi Momose, KEK
- Osamu Aita, Osaka Prefecture Univ.
- Frederic Le Pimpec and Mauro Pivi, CERN
- Pilar Prieto, Univ. Autonoma Madrid
- Ali Nyaiesh, Brighton University
- Erhard Kisker, KFA Jülich

Effects

- Secondary "primary" electrons generated inside the source
- Secondary electrons generated inside RFA analyzer or from the chamber
- Surface modification by incident electrons (desorption, carburization, oxidation, damage)
- Substrate effects
- Near-zero energy

Energy Distribution (ED) of Secondary Electrons

TiN/Al

~ 60% 0-40 eV
~ 35% 41-295 eV
~ 5% 295-310 eV

"True"

Re-diffused primaries

Elastics

Normalized Intensity

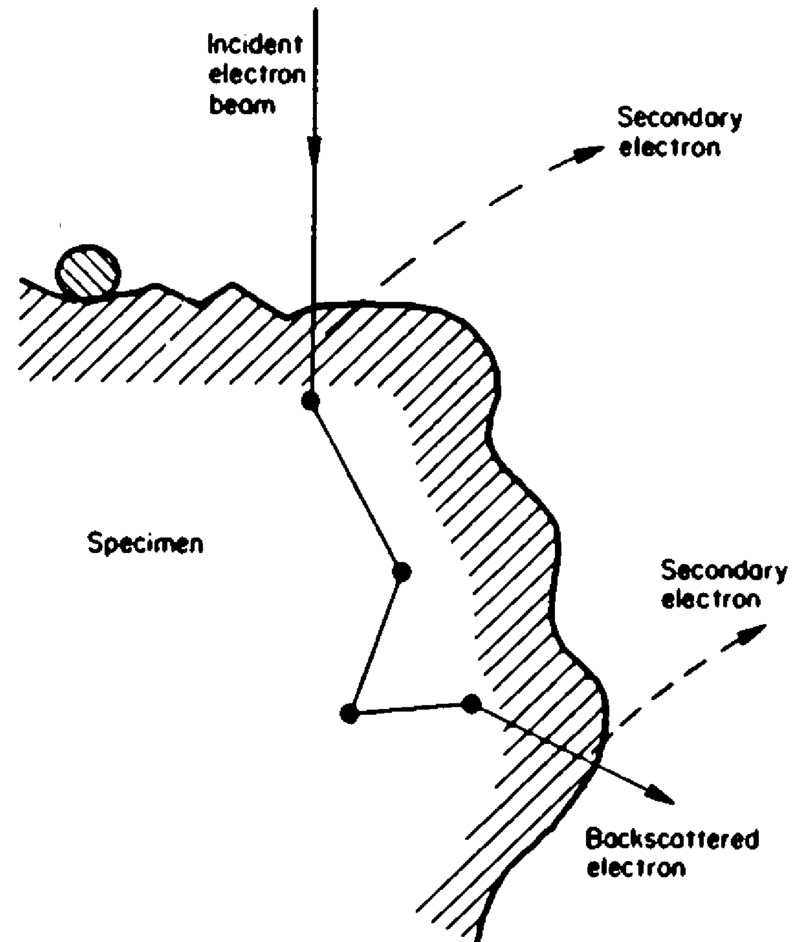
1

0

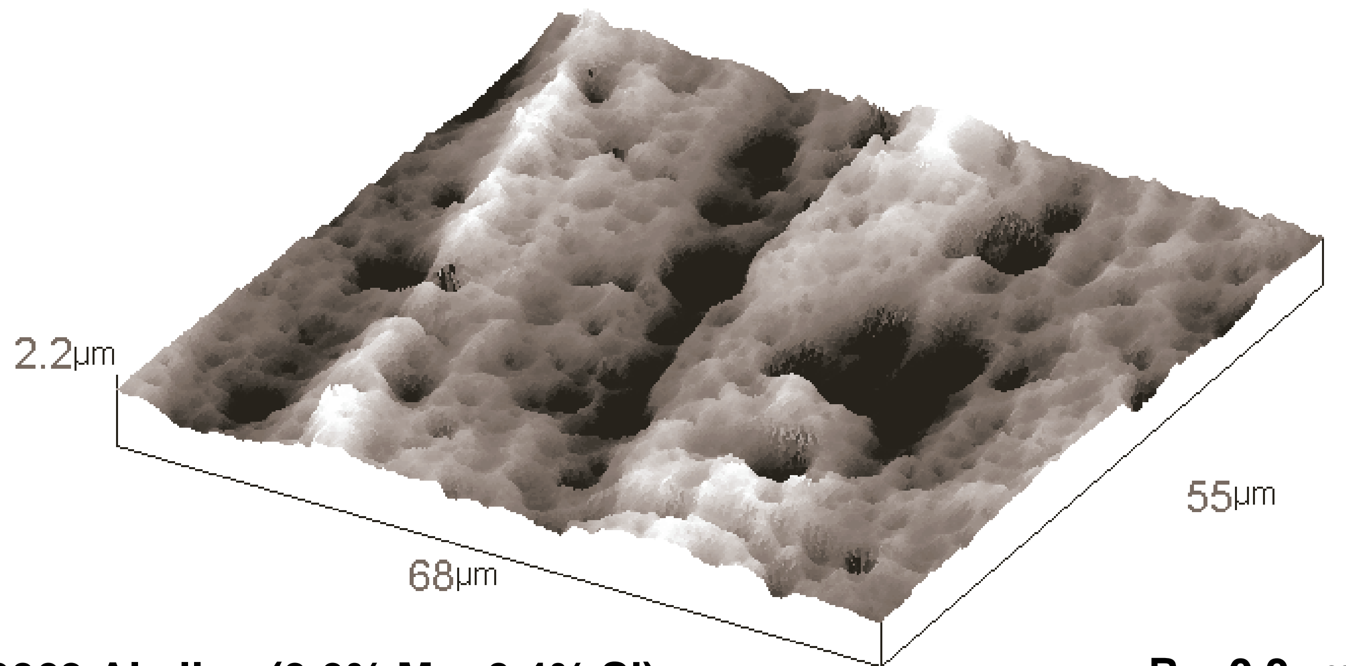
0 100 200 300

Primary Electron Energy (eV)

Secondary Electron Generation



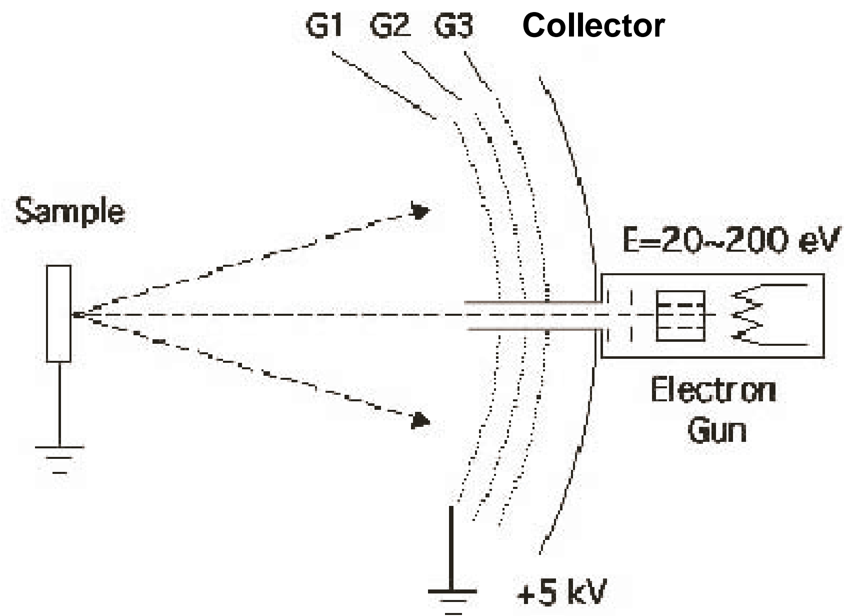
Extruded-Al Beam Chamber Topography



6063 Al alloy (0.6% Mg, 0.4% Si)

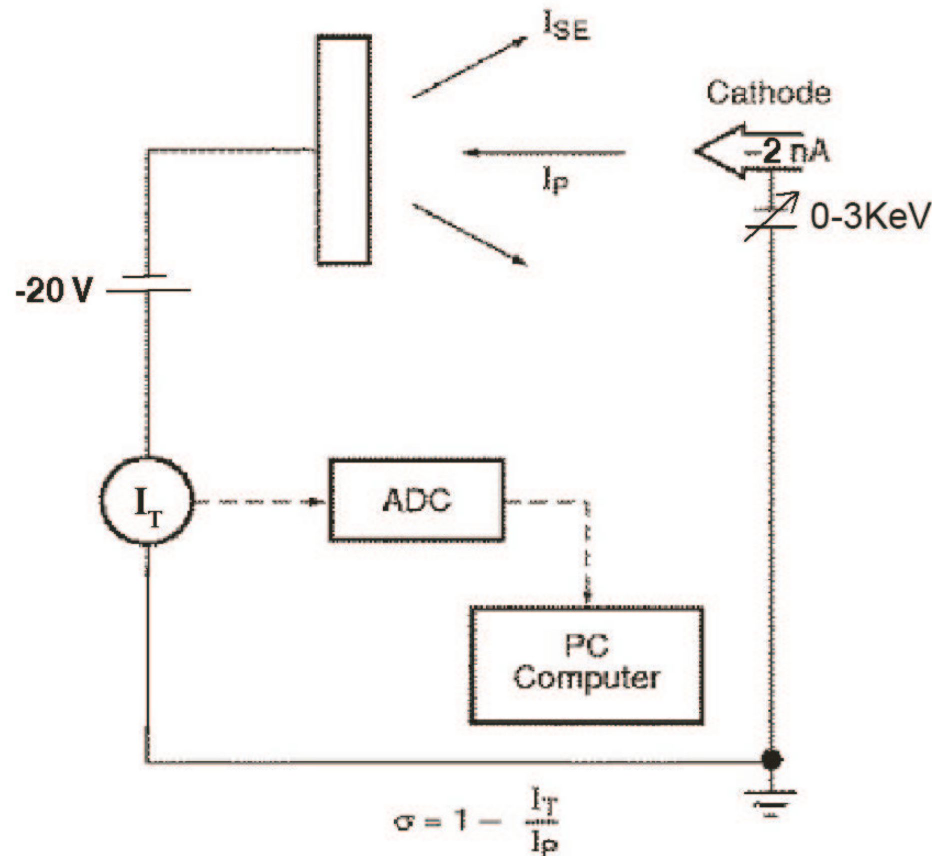
R_A=0.3µm

SEY Measurement - RFA



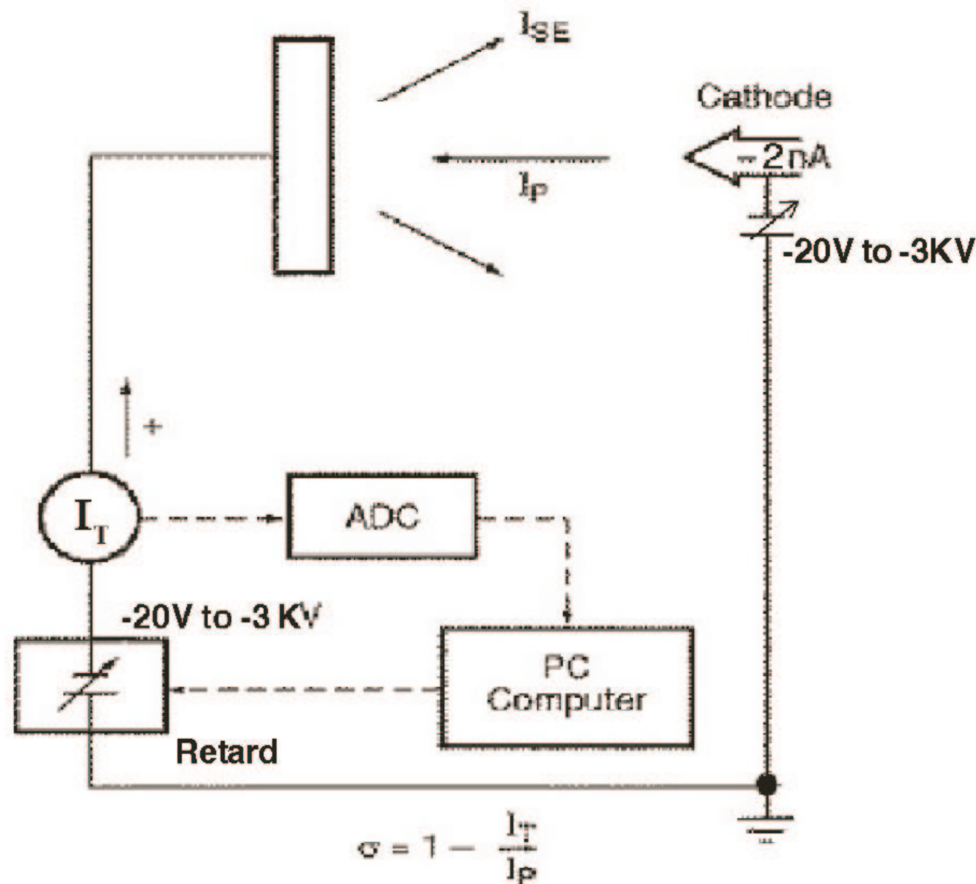
Strengths: Angular and energy distribution measurements possible
Weaknesses: Grid/collimator tertiaries; gun space charge

SEY Measurement - Sample Current



Strengths: Angular measurements; no stray secondaries (with -20V)
Weaknesses: Yield does not include elastics; gun space charge; tertiaries from surrounding chamber

SEY Measurement - Sample Retard



Strengths: Simple equipment (no space charge limit with gun);tertiaries rejected after -20V

Weaknesses: No angular measurements; yield does not include elastics

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Secondary “Primary” Electrons

Sputter-Cleaned Nb

Retarding field, V_{Cath}= -1500

Yield

2.00

1.50

1.00

0.50

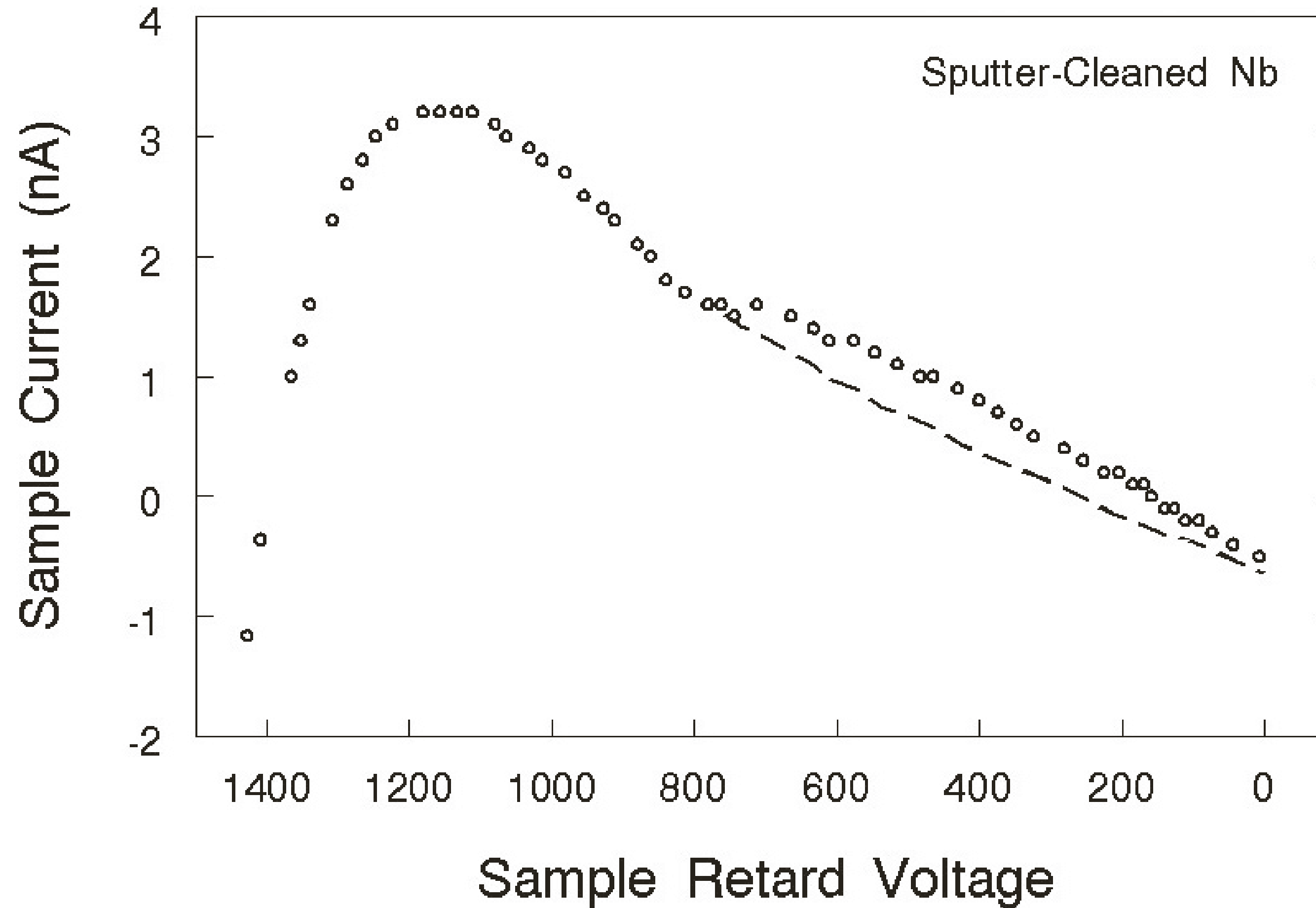
0.00

0 200 400 600 800 1000 1200 1400 1600

Primary Electron Energy

From Garwin et al, J. Appl. Phys. 59,3245(1986)

Secondary "Primary" Electrons



Beam Current Profile

FC Aperture = 0.25 mm

1

Cathode Electrons

FC Current (nA)

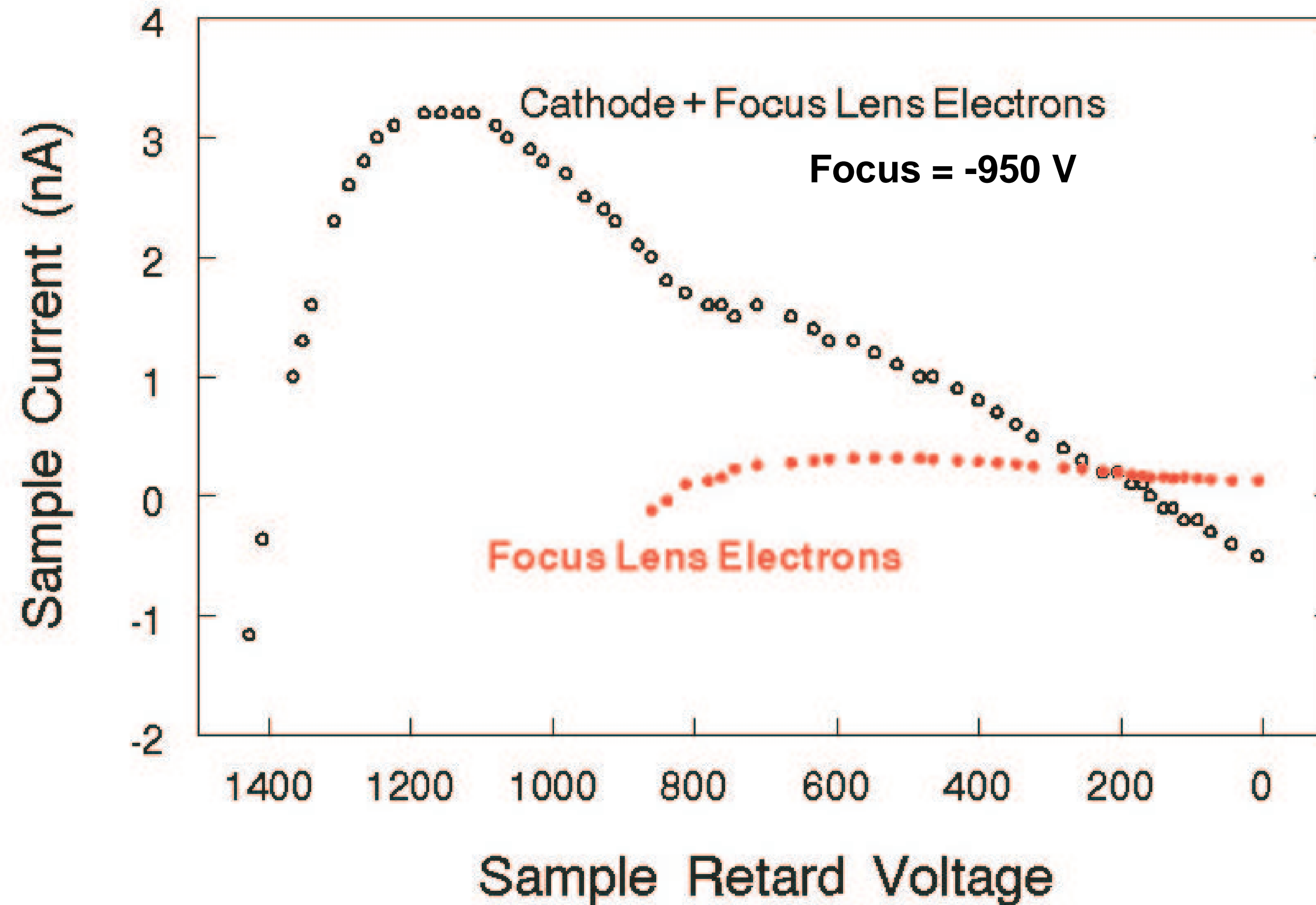
Focus Lens
Electrons

0

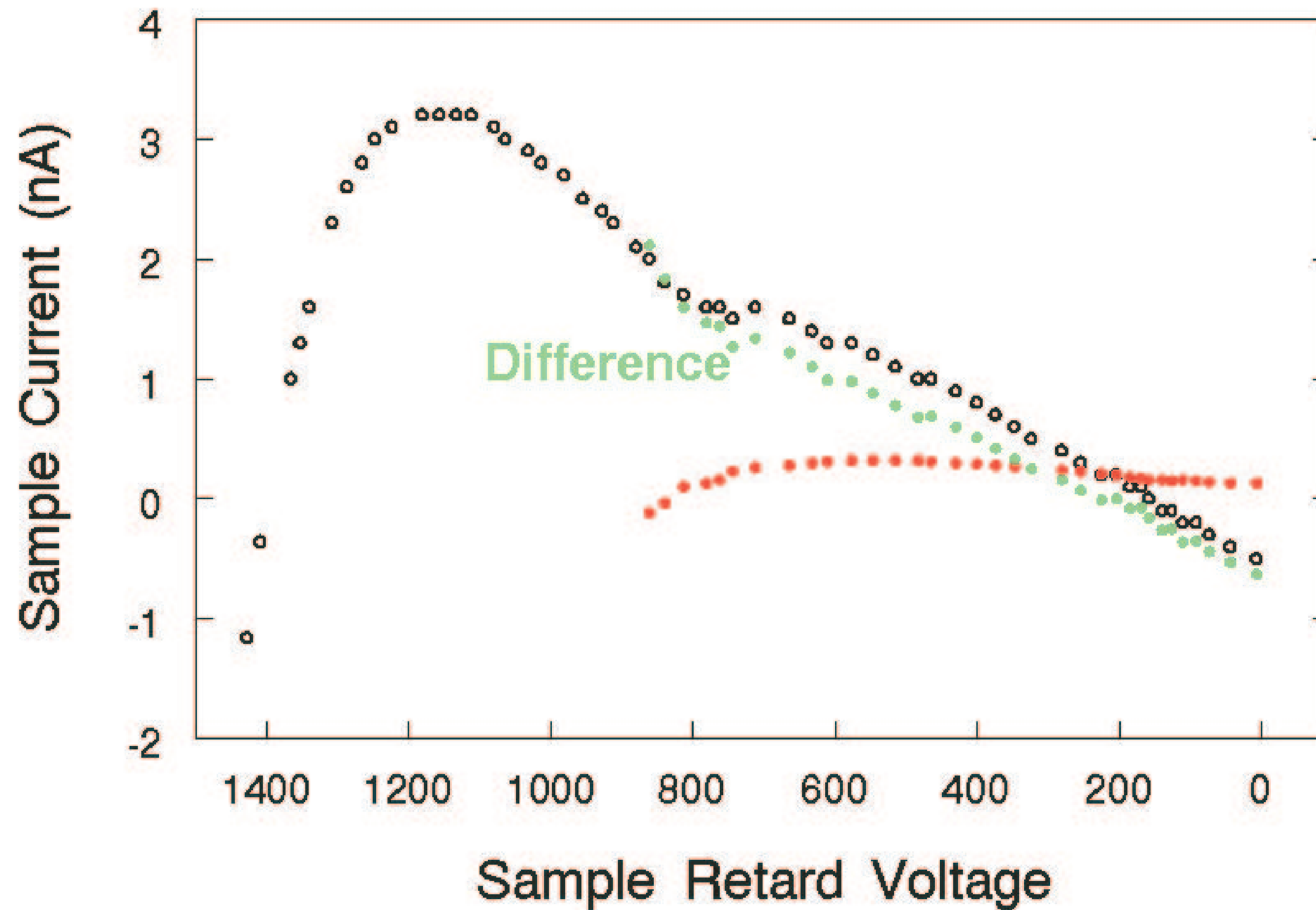
10

Beam Width (mm)

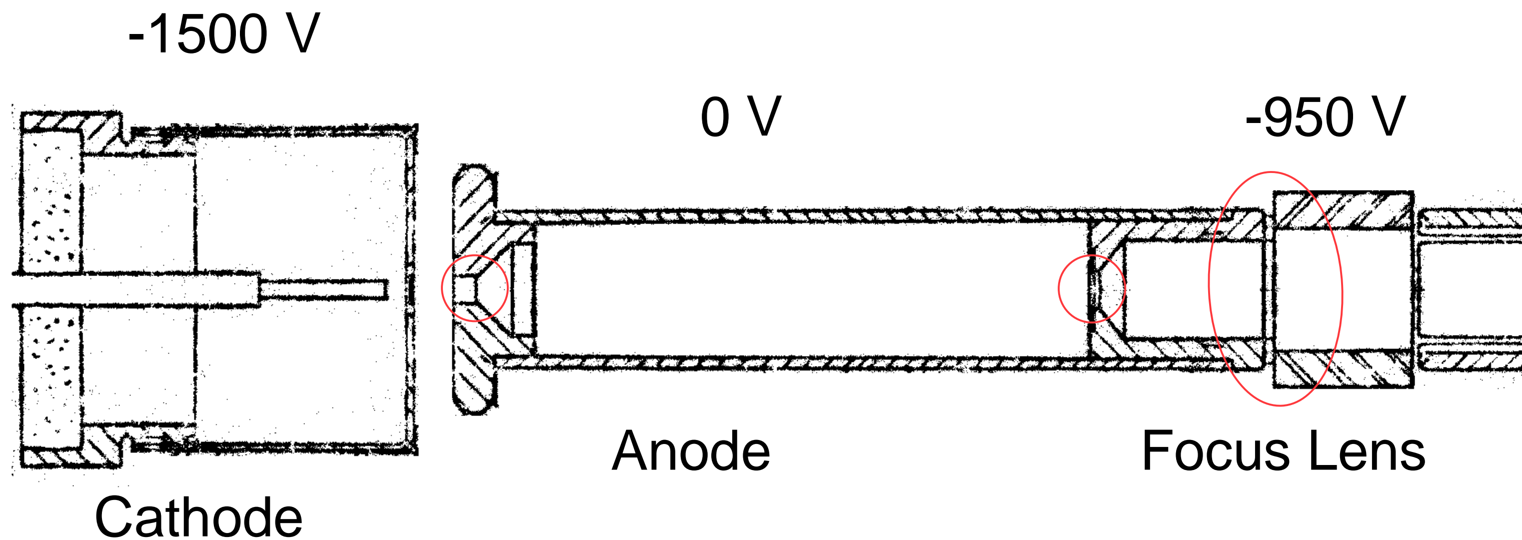
Secondary “Primary” Electrons



Secondary "Primary" Electrons

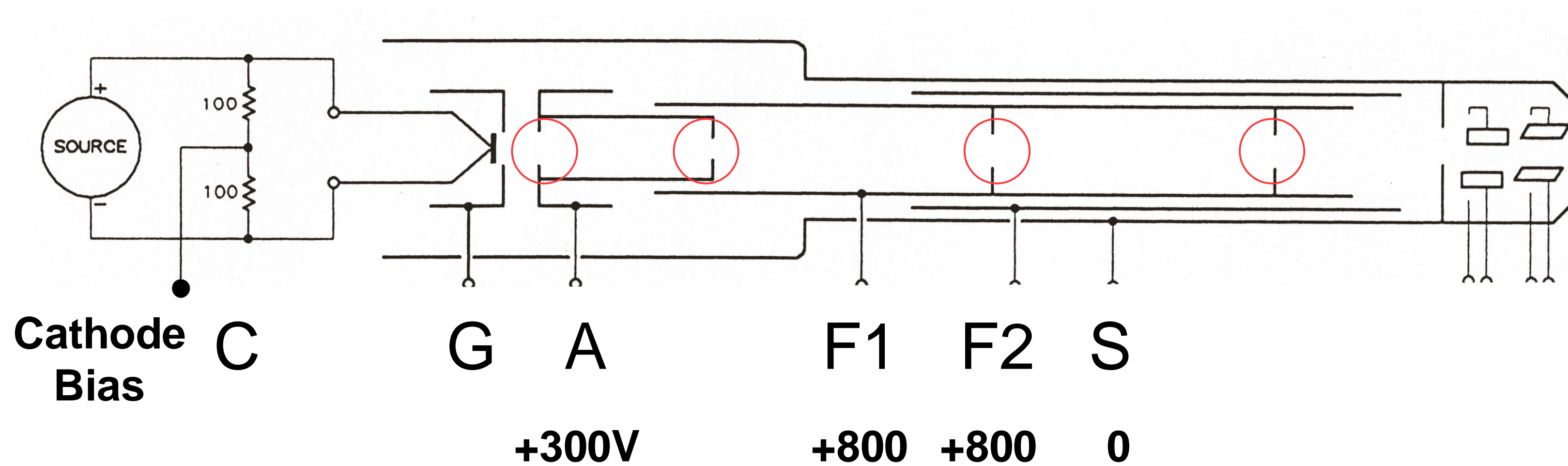


Unipotential Electron Gun



Simple electronics, but space charge problem below 200 eV

Fixed Element Voltages



Good performance to < 10 eV, expensive, complex design

Secondary "Primary" Electrons

POCO Graphite

Anode = +300 V

Anode = +500 V

Yield

1.00

0.75

0.50

0.25

0 500 1000 1500 2000 2500 3000

Primary Electron Energy

Secondary “Primary” Electrons??

Yes, but from the 0 V shield!

Gold (110)

Focus 1 = +800 V

Focus 1 = +900 V

0-80 eV

Yield

2.00
1.50
1.00
0.50

0 500 1000 1500 2000 2500 3000

Primary Electron Energy

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“Environmental” Tertiaries

Sputter-Cleaned Al With Native Oxide (~1.8 nm)

○ Vary Cathode Bias (- 20 V On Sample)

● Fixed Cathode Bias (Retard on Sample)

Yield

3.00
2.50
2.00
1.50
1.00

0 100 200 300 400

Primary Electron Energy (eV)

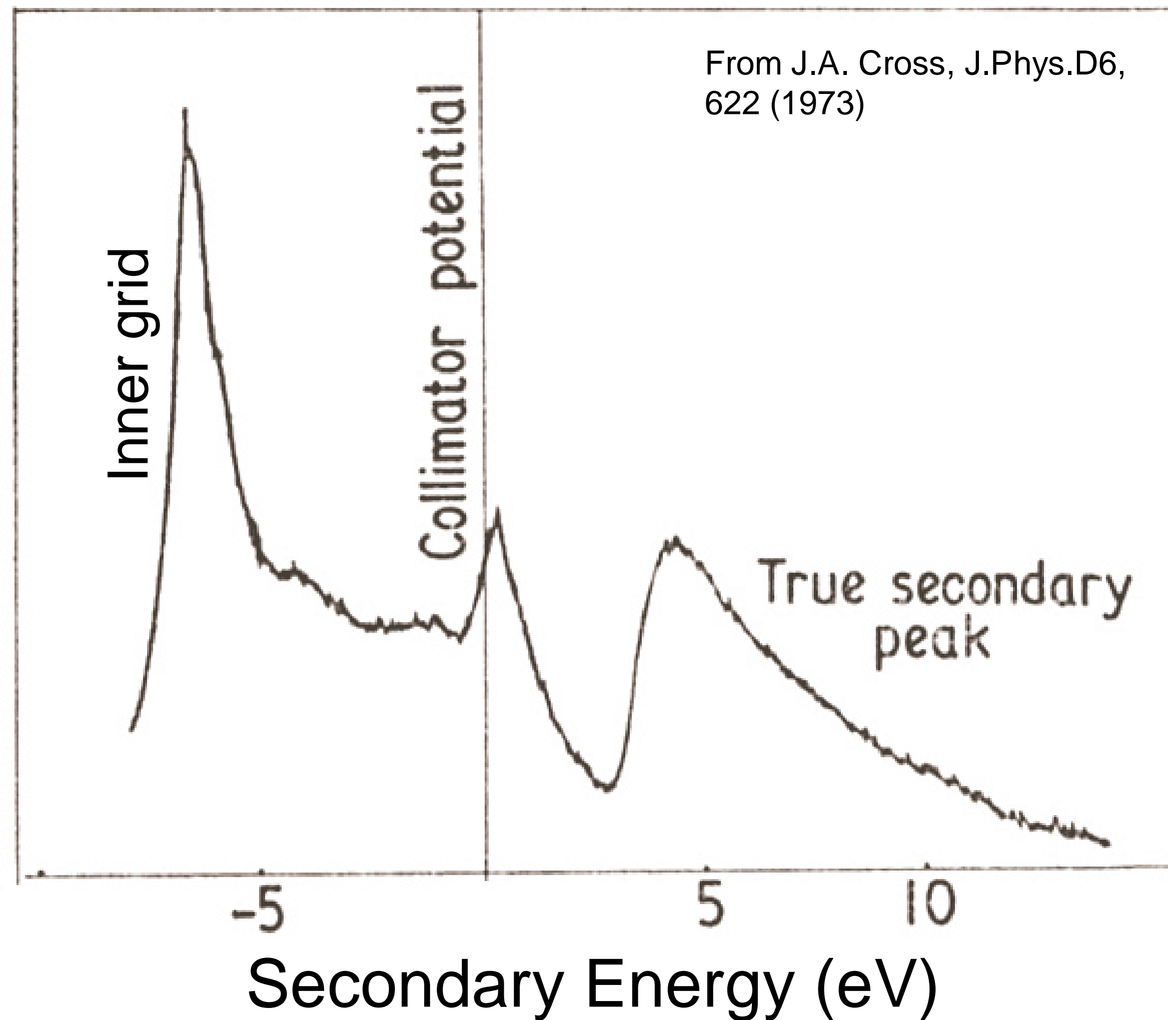
100 80 60 40 20 0

Retard Voltage (V)

Sample Current (nA)

5
4
3
2
1
0

RFA Tertiary Electrons



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Causes of Electron-Induced SEY Reduction

- Electron desorption of surface gases, particularly importantly barrier-reducing water and hydrocarbons
- Dissociation of aromatic HCs to low-yield polymerized carbon
- Electron-reduction of high-yield oxides
- Electron-activated grain boundary diffusion of carbon in the presence of hydrogen

Carbon Grain Boundary Diffusion

- Observed on aluminum covered with native oxide and thin γ-alumina
- Surface carbon was produced from electron reduction of CO, both from gas phase and from Al bulk, up the grain boundaries
- Co-adsorption of H_2 increased the surface concentration of CO at hydroxyl sites

From Garwin et al, SLAC Pubs. 392 (1968) and 2716 (1981).

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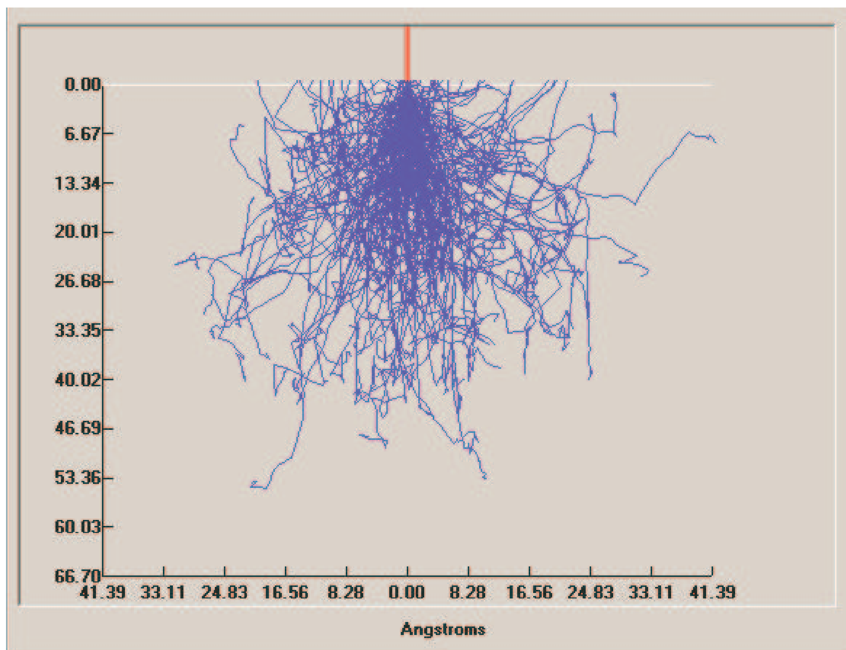
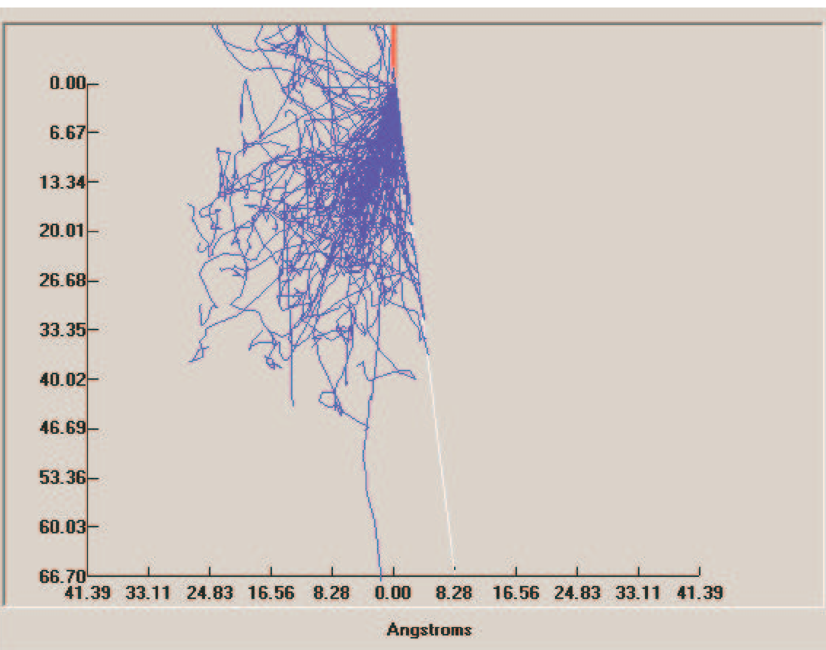
Primary Electron Range (TiN)

(All axes in angstroms)



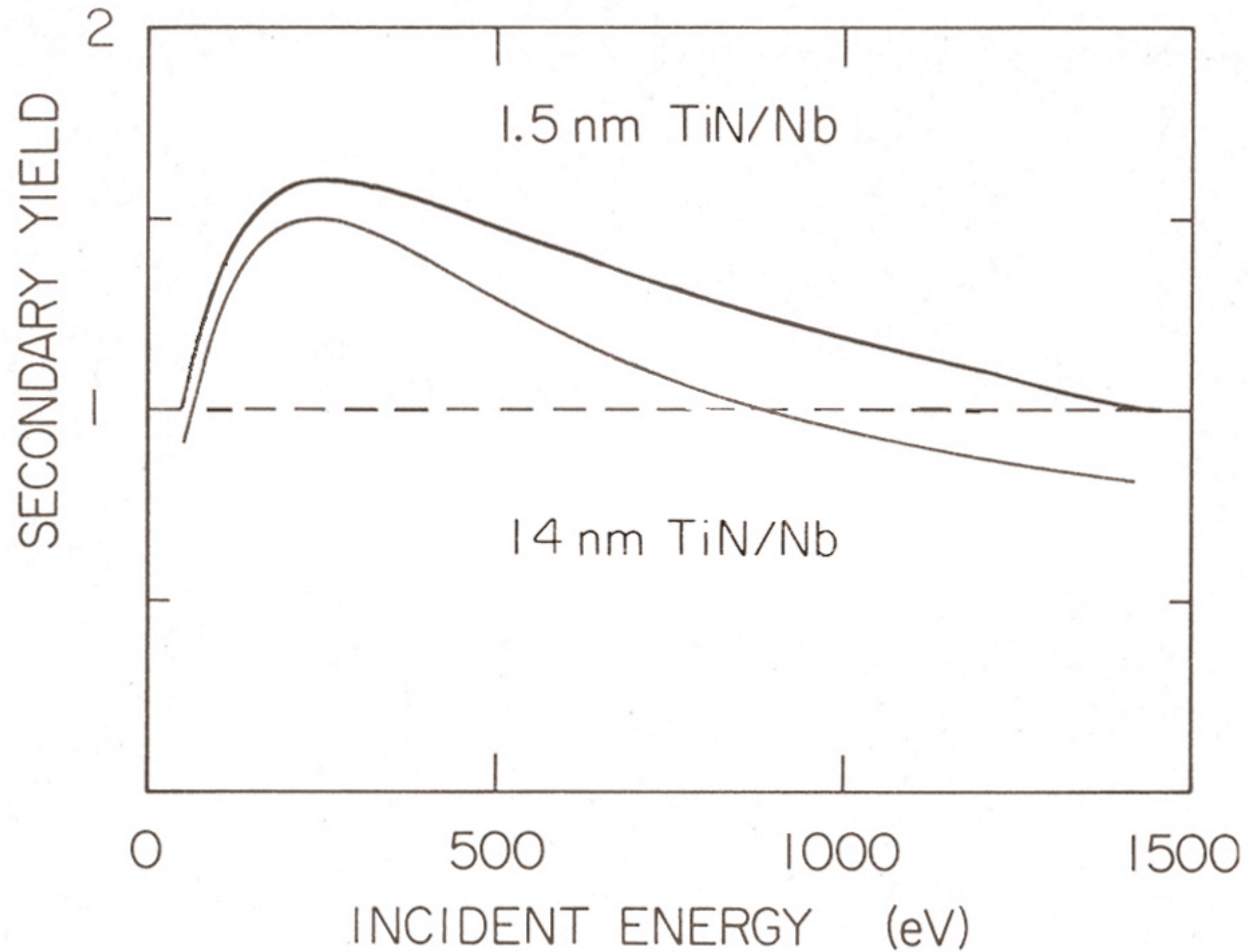


$\theta = 0^o$

$\theta = 83^o$

$E_p = 500$ eV

Substrate Effect



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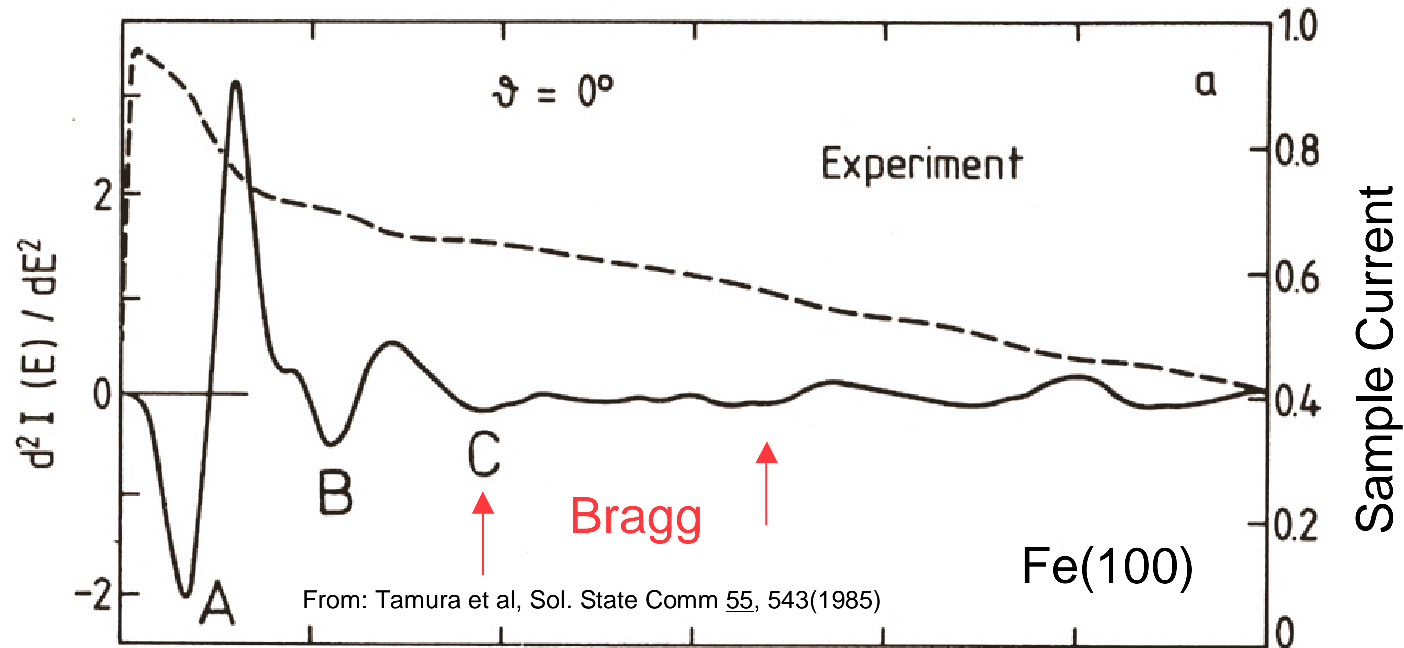
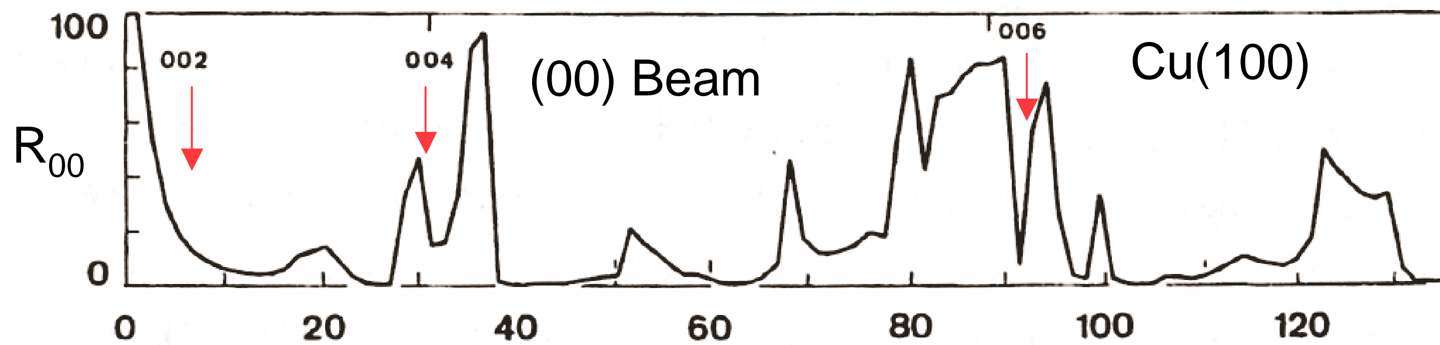
Yield From Sputtered (But Disordered) Surfaces

Elastic Reflection





From: G.Capart, Surf. Science 26, 429 (1971)