SLAC-WP- 044
April, 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 LePimpec 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 detector or from chamber
- Surface modification by incident electrons (desorption, carburization, oxidation, damage)
- Substrate effects
- Near-zero energy

Energy Distribution (ED) of Secondary Electrons

Secondary Electron Generation

Extruded-Al Beam Chamber Topography

SEY Measurement - RFA

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

SEY Measurement - Sample Current

Strengths: Angular measurements, no stray secondaries, low cost

Weaknesses: Yield does not include elastics, gun space charge

SEY Measurement - Sample Retard

Strengths: Simple equipment, no space charge limit with gun

Weaknesses: No angular measurements, yield does not include elastics

Effects

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

Secondary “Primary” Electrons

Secondary “Primary” Electrons

Beam Current Profile

FC Aperture = 0.25 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, complex design

Secondary “Primary” Electrons

Secondary “Primary” Electrons??

Yes, but from the 0 V shield!

Effects

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

“Environmental” Tertiaries

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

○ Vary Cathode Bias
(- 20 V On Sample)

● Fixed Cathode Bias
(Retard on Sample)

RFA Tertiary Electrons

Effects

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

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).

Effects

- Secondary “primary” electrons generated inside the source
- Secondary electrons generated inside detector or from chamber
- Surface modification by incident electrons (desorption, carburization, oxidation, damage)
- **Substrate effects**
- Near-zero energy

Substrate Effect

Primary Electron Range (TiN)

(All axes in angstroms)

$\theta = 0^\circ$

$E_p = 500 \text{ eV}$

$\theta = 83^\circ$

Effects

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

Elastic Reflection

Yield From Sputtered (But Disordered) Surfaces