10-12-2018

Electron Yield Measurements of Multilayer Conductive Materials

Gregory Wilson
Utah State University

Matthew Robertson
Utah State University

Jordan Lee
Utah State University

JR Dennison
Utah State Univesity

Electron Yield Measurements of Multilayer Conductive Materials

Gregory Wilson and JR Dennison

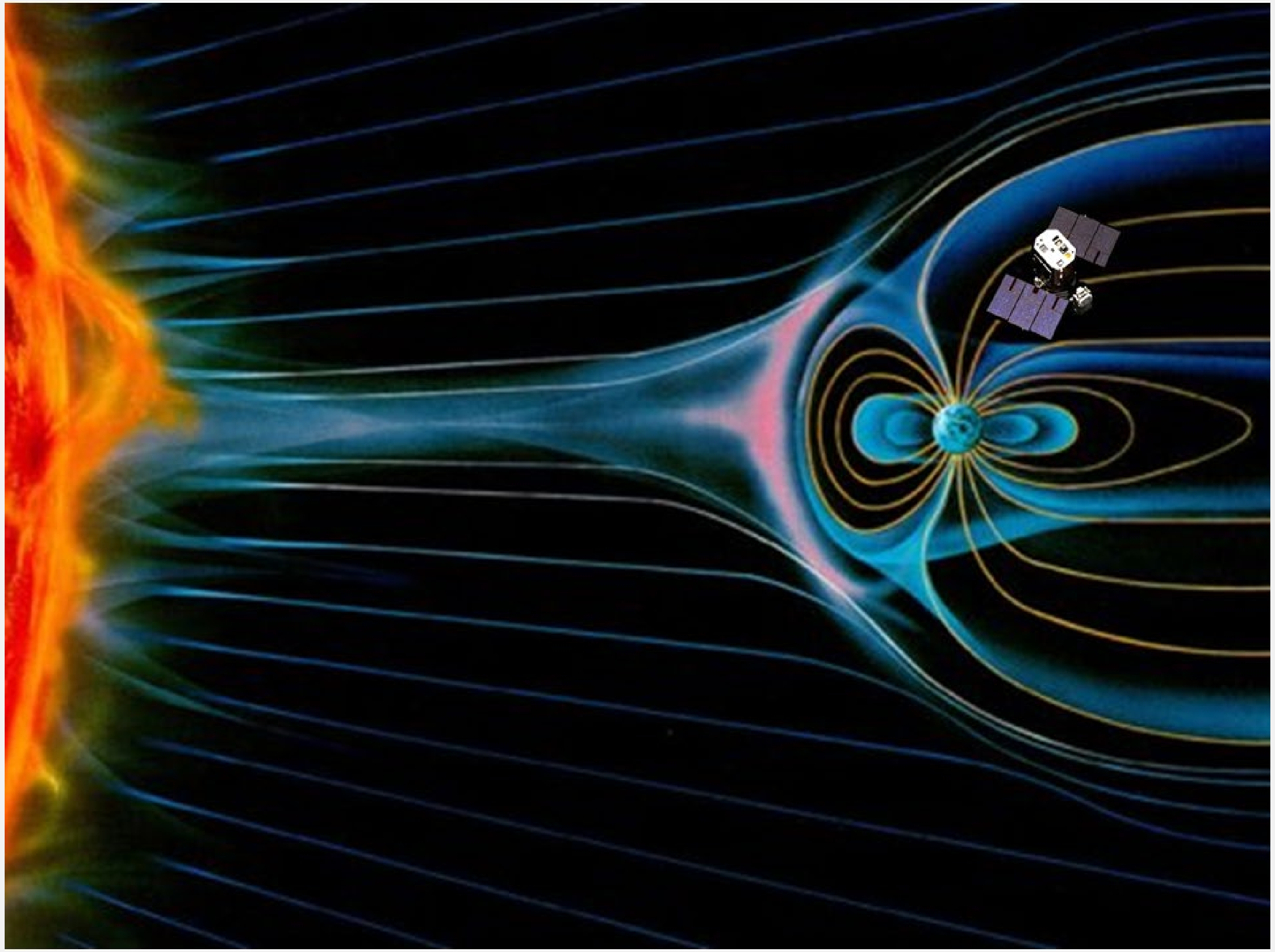
Utah State University

National Technical Systems

UTAH STATE UNIVERSITY
MATERIALS PHYSICS GROUP

Introduction

- Space is a harsh and complicated environment
- Depending on the orbit, different energetic species dominate the environmental effects
- Spacecraft charging is the leading cause of spacecraft failure due to the space environment

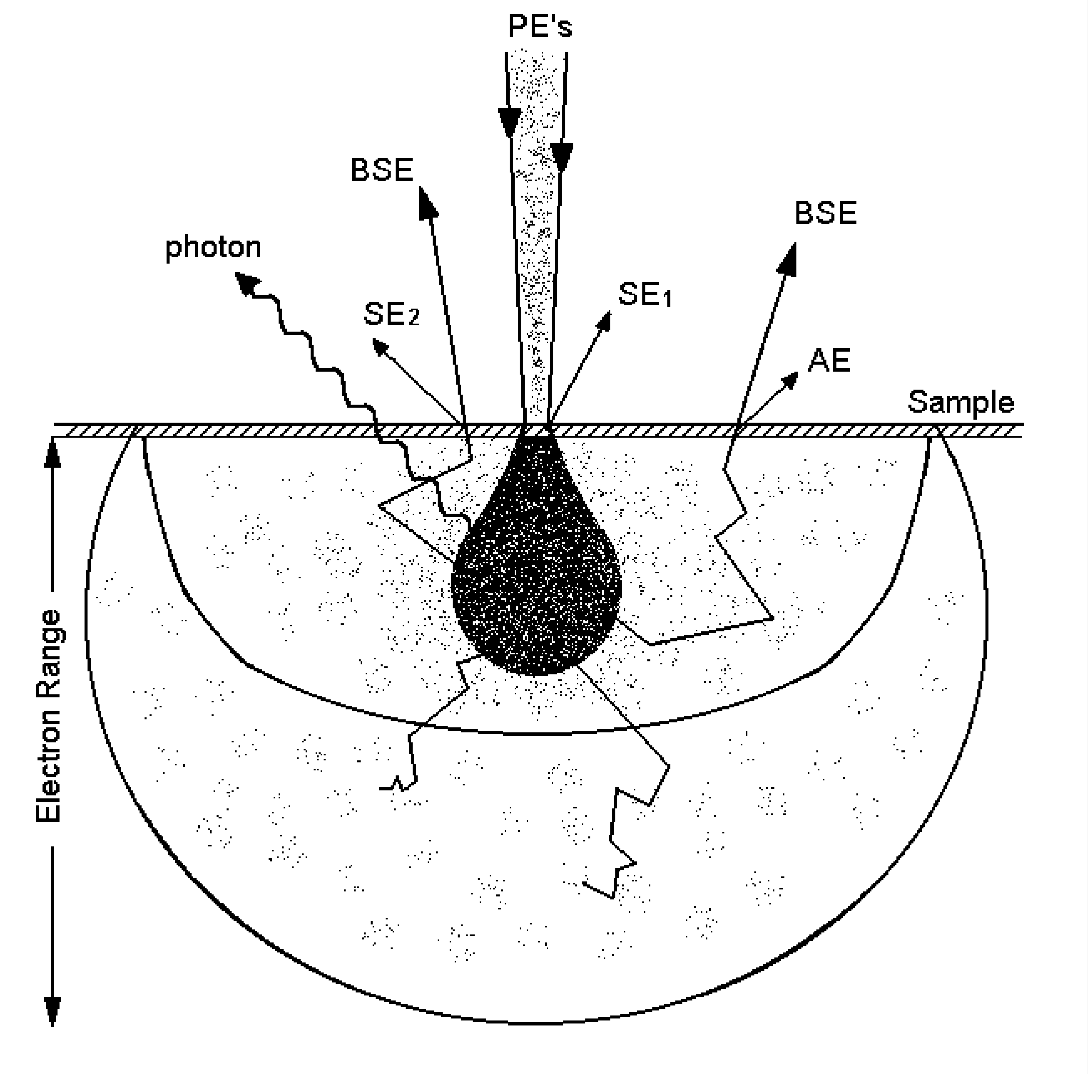


Introduction

- When different parts of a spacecraft have different potentials electrostatic breakdown can occur
- Differences in potential are due to electron interactions with the material
- Understanding these interactions is essential to model and mitigate spacecraft charging

Theoretical Background

- The three main phenomenon required to model spacecraft charging are the electron **range**, **yield** and **conductivity**.
- The **range** is the maximum distance an electron can penetrate a material
- The **yield** is the ratio of emitted electrons to incident electrons
- The **conductivity** determines how long it takes embedded charges to travel through a material

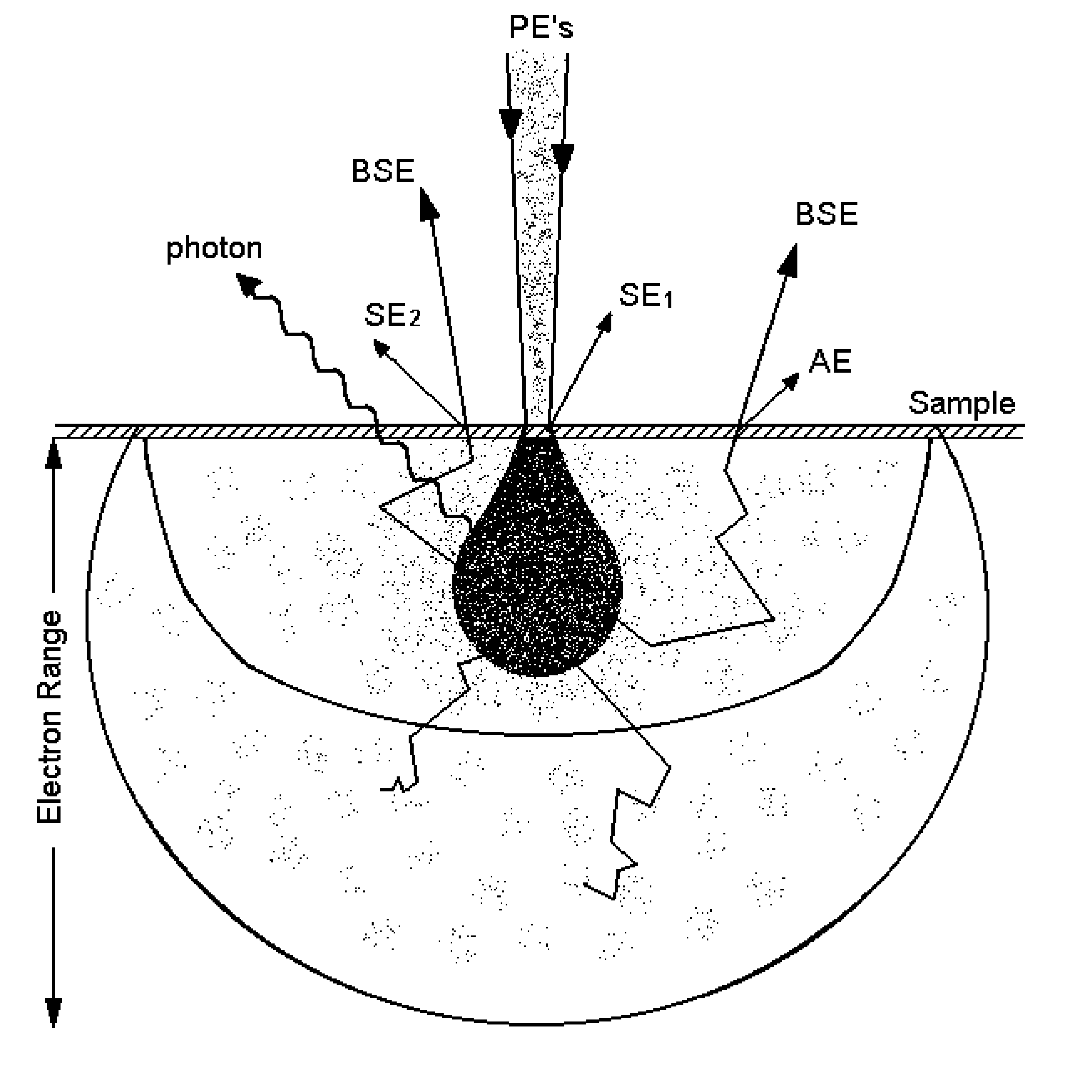


Theoretical Background

- The total electron yield consist of **backscattered** electrons (BSE), and **secondary** electrons (SE)

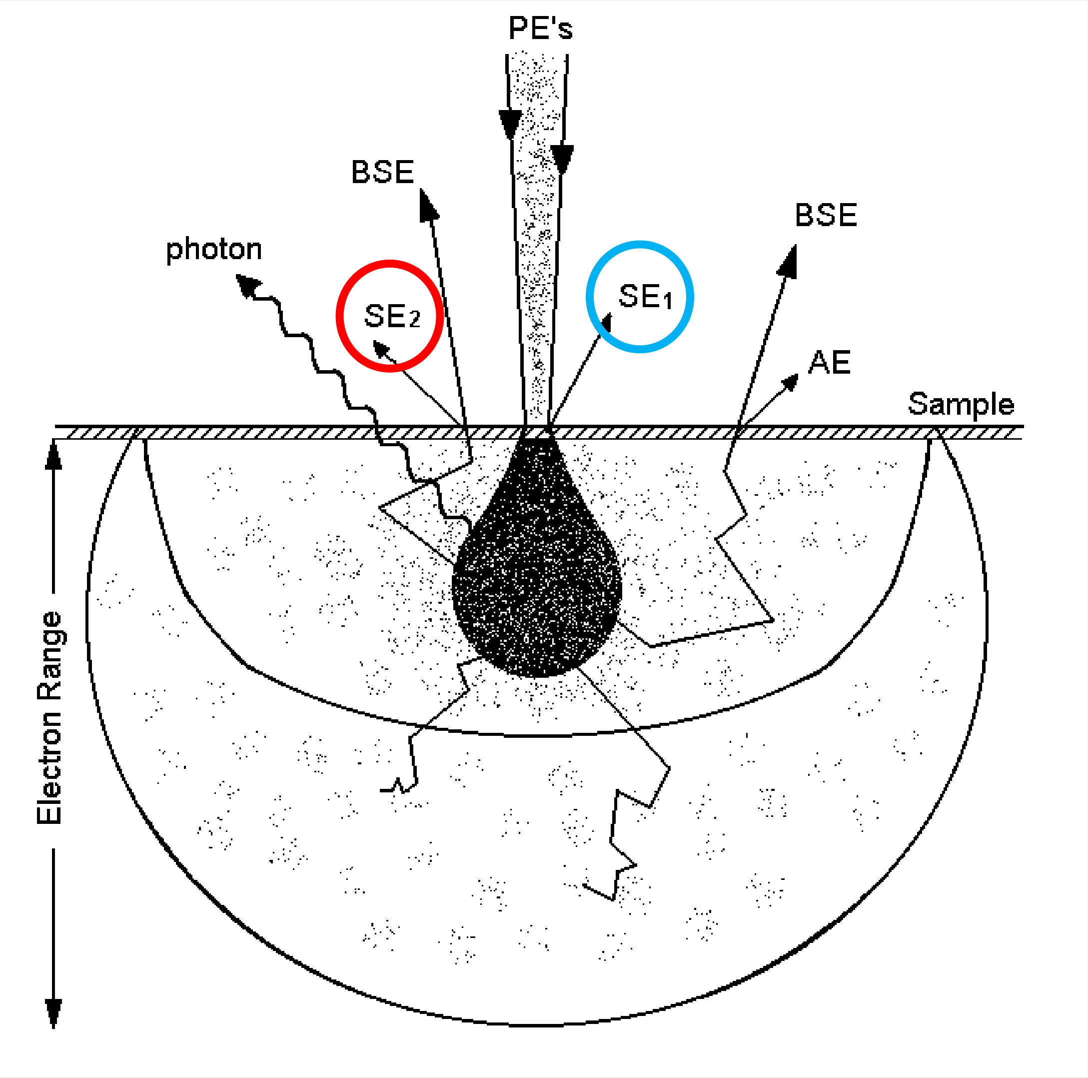
- **Backscattered** electrons are electrons from the incident beam which are redirected toward the surface of the material and emitted.

- **Secondary** electrons are electrons excited within the material which are emitted from the surface.

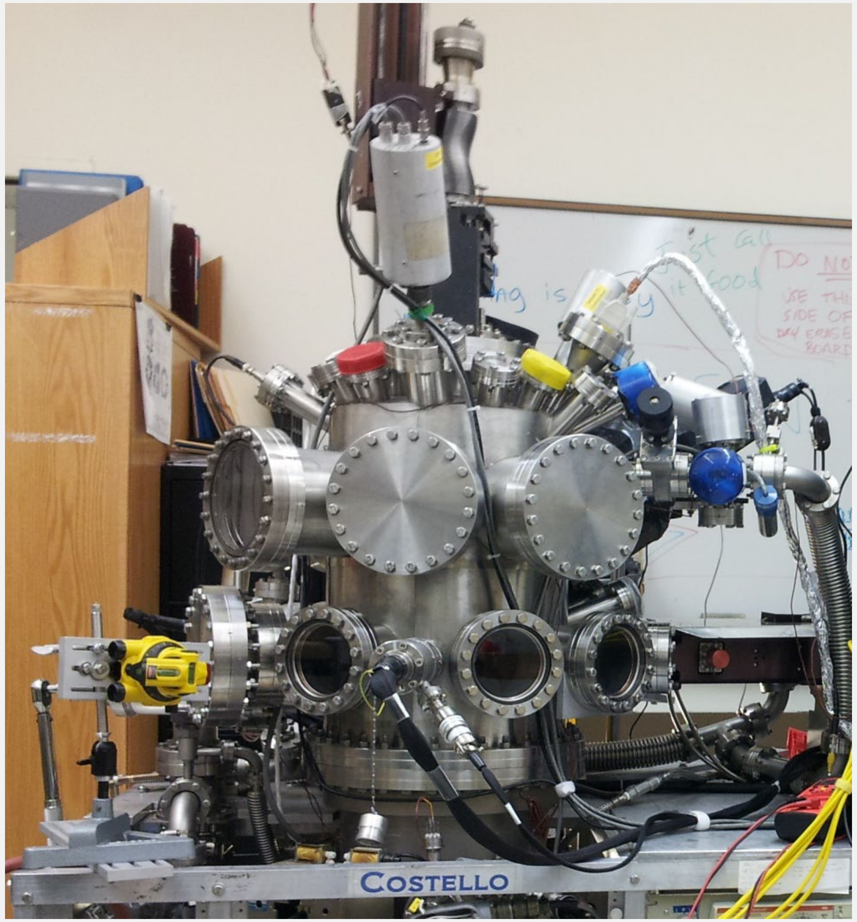


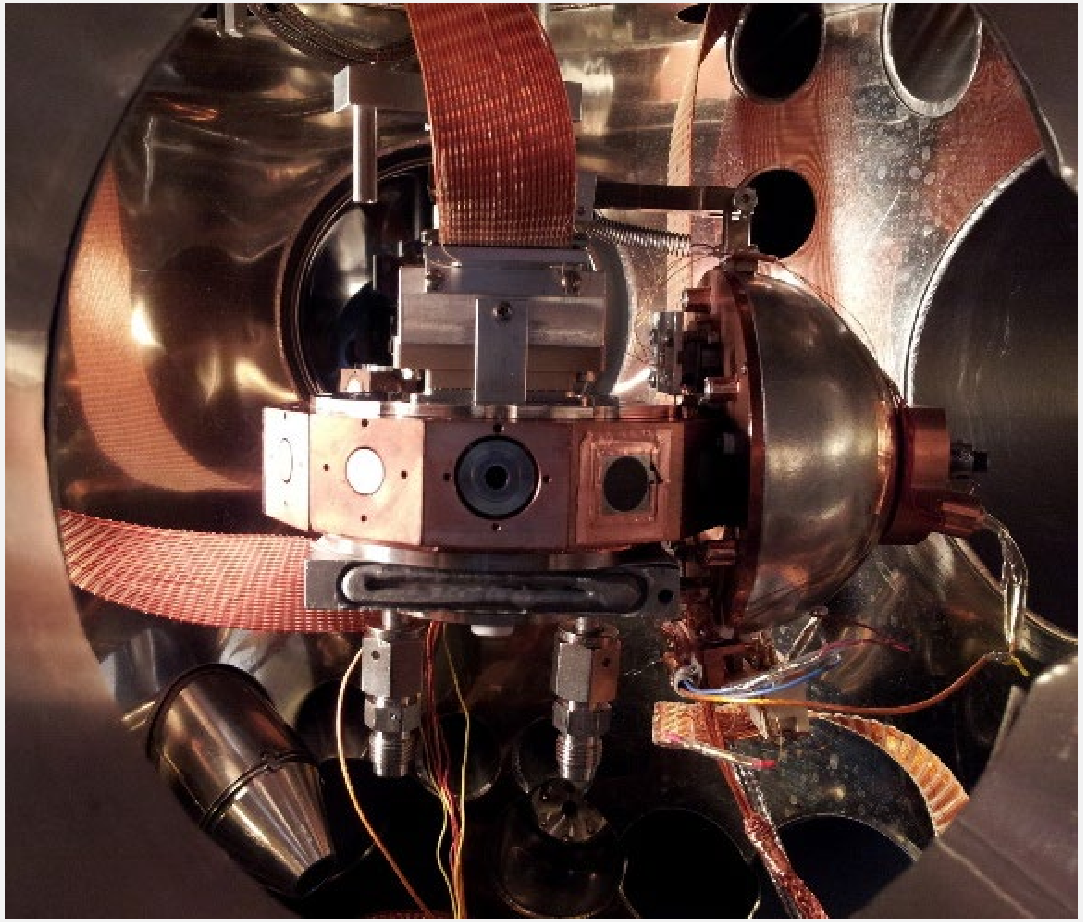
Theoretical Background

- **Secondary** electrons can be excited from either the incident beam, or from backscattered electrons as they undergo collisions near the surface.
- Generally, **secondary** electrons excited from backscattered electrons SE_2 are not distinguished between those excited from incident electrons SE_1
- For **multilayer materials**, this distinction is necessary



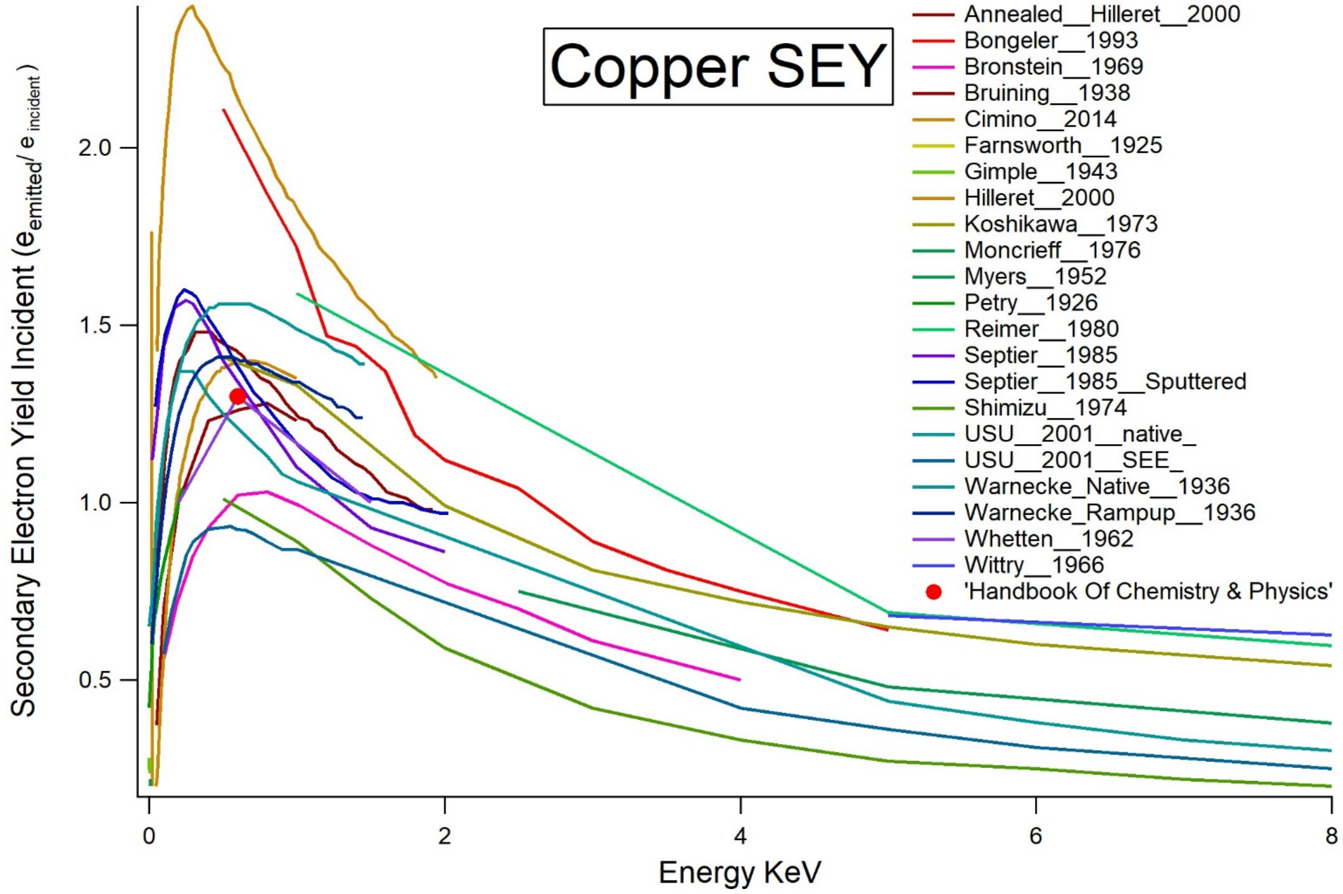
Electron Yield Studies for Spacecraft Charging



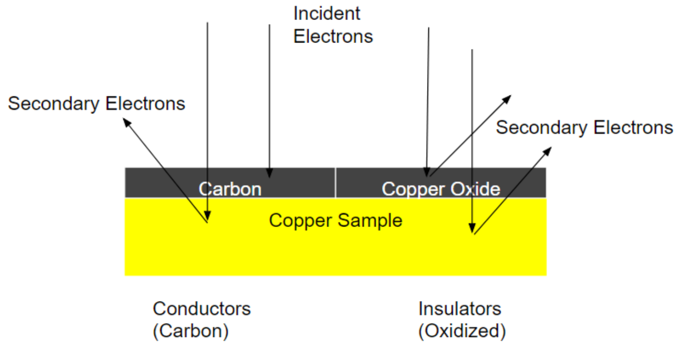


An Analysis of Variations in Published Secondary Electron Yield Measurements of Copper

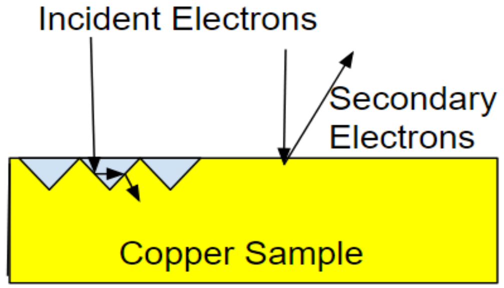
Phillip Lundgreen and JR Dennison



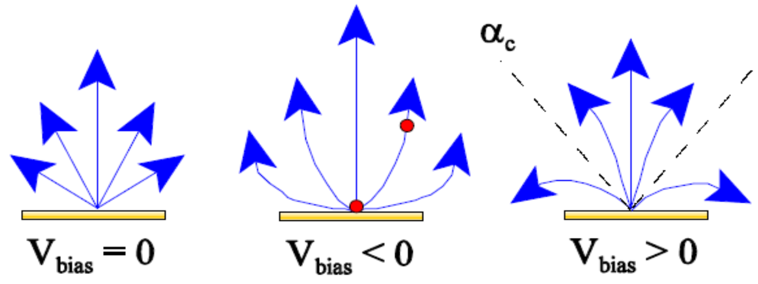
Contamination and Layers



Surface Morphology



Charging

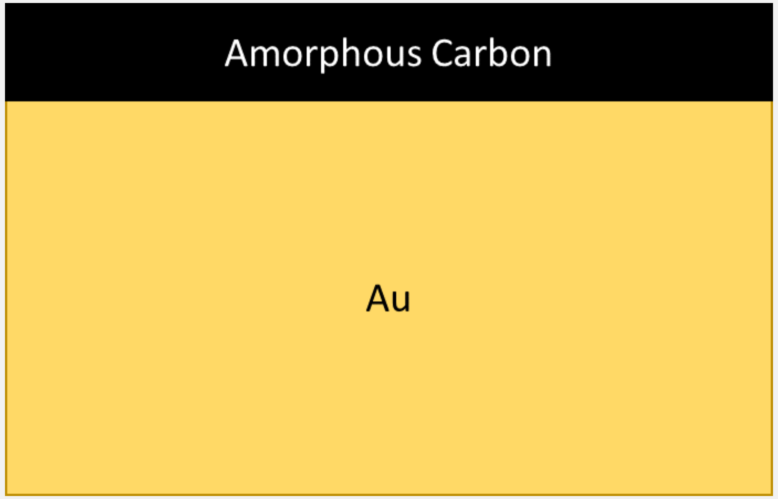


Multilayer Material Samples

- Two smooth, well- characterized, conducting multilayer sample set were prepared
- Sets of layer thicknesses comparable to range of incident electrons, 15 eV to 30 keV

- First sample set consisted of thin layers of graphitic C films adhered to a Au foil substrate
- Second sample set consisted of various thickness of Au deposited on an HOPG graphite substrate

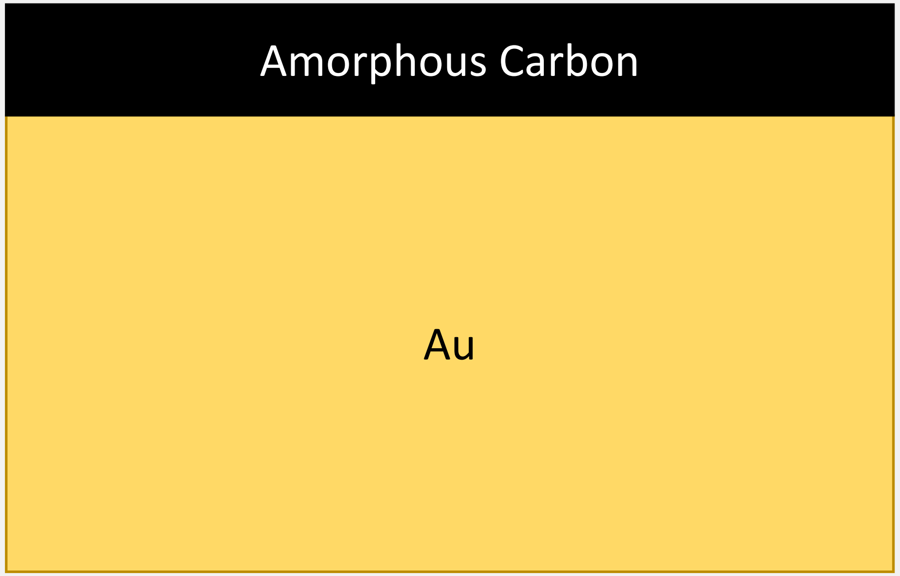
- High contrast with:
  - g-C: Low total yield (low Z), High ratio of SEY/BSEY
  - Au: High total yield (high Z), Low ratio of SEY/BSEY



Amorphous Carbon on Au

- High contrast with:
  - g-C: Low total yield (low Z), High ratio of SEY/BSEY
  - Au: High total yield (high Z), Low ratio of SEY/BSEY

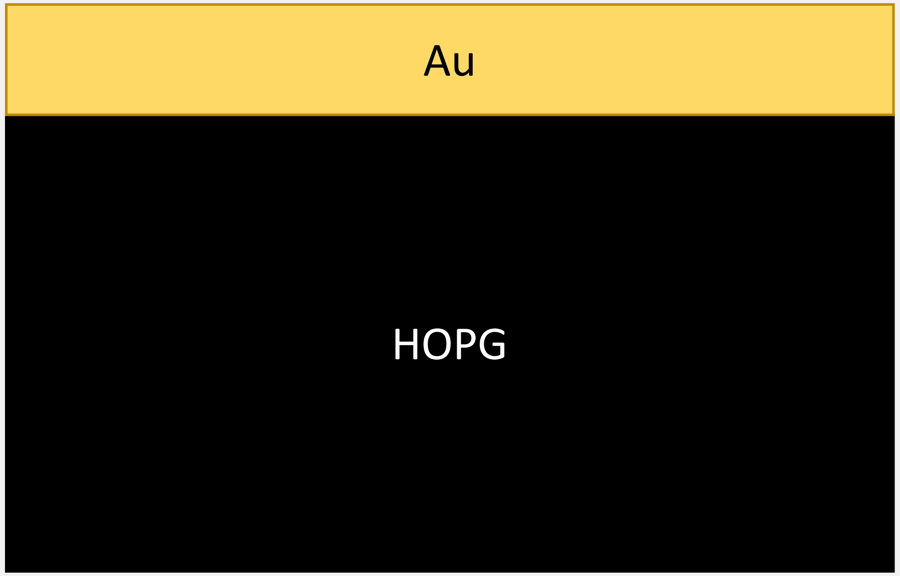
- The thin layer of g-C will have **high secondary yield**.
- High energy electrons that penetrate to the Au will have a **high backscattered yield**
- Those backscattered electrons will **increase the secondary yield** of the carbon surface layer, **increasing** the secondary yield **higher than bulk carbon**



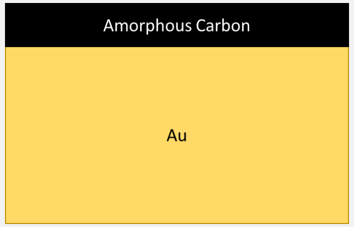
Au on HOPG

- High contrast with:
  - g-C: Low total yield (low Z), High ratio of SEY/BSEY
  - Au: High total yield (high Z), Low ratio of SEY/BSEY

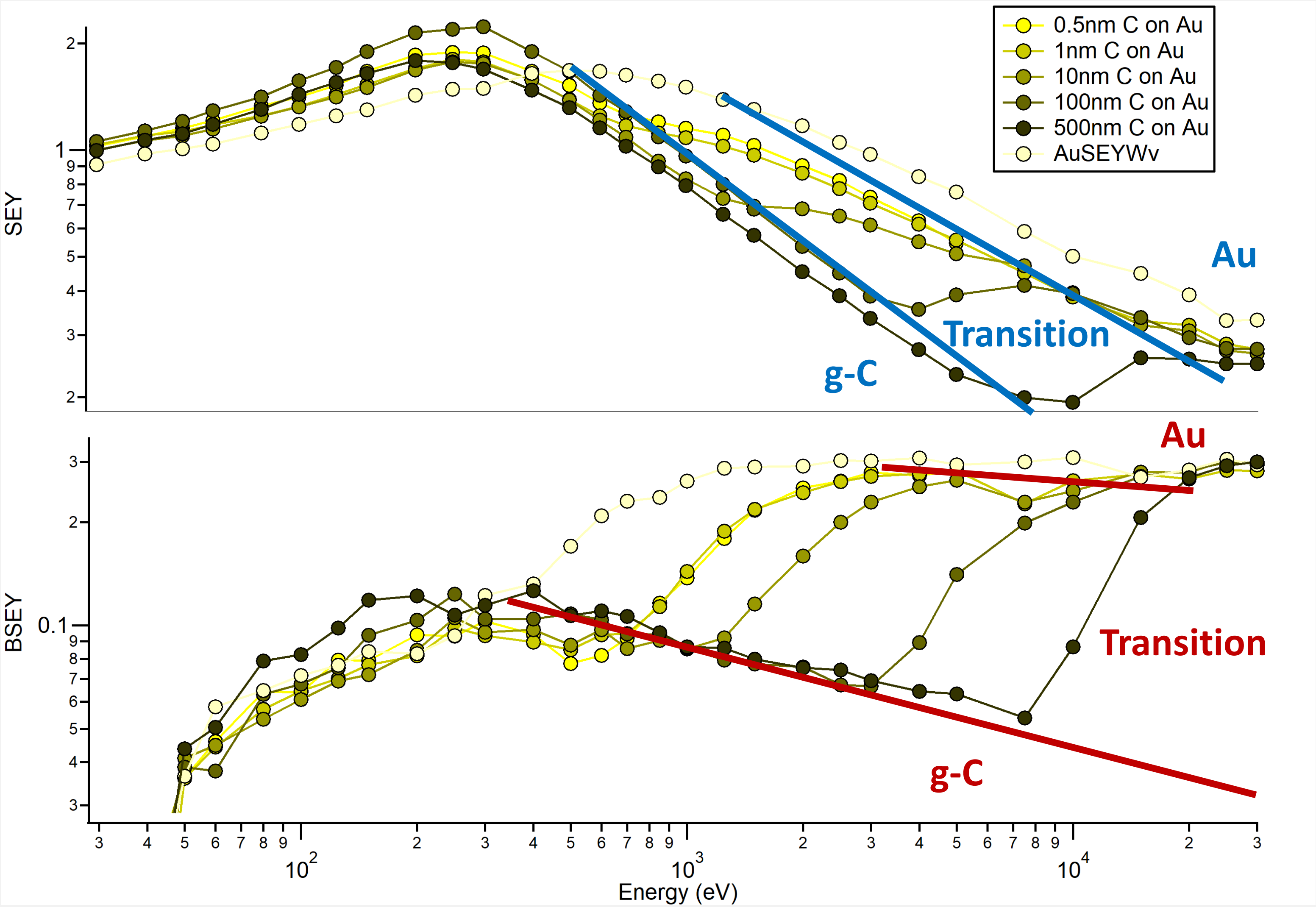
- The thin layer of Au will have **low secondary yield**.
- High energy electrons that penetrate to the carbon will have a **low backscattered yield**
- Those backscattered electrons will **decrease the secondary yield** of the Au surface layer, **decreasing** the secondary yield lower than bulk Au



Amorphous Carbon on Au Substrate

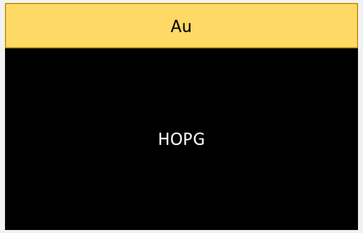


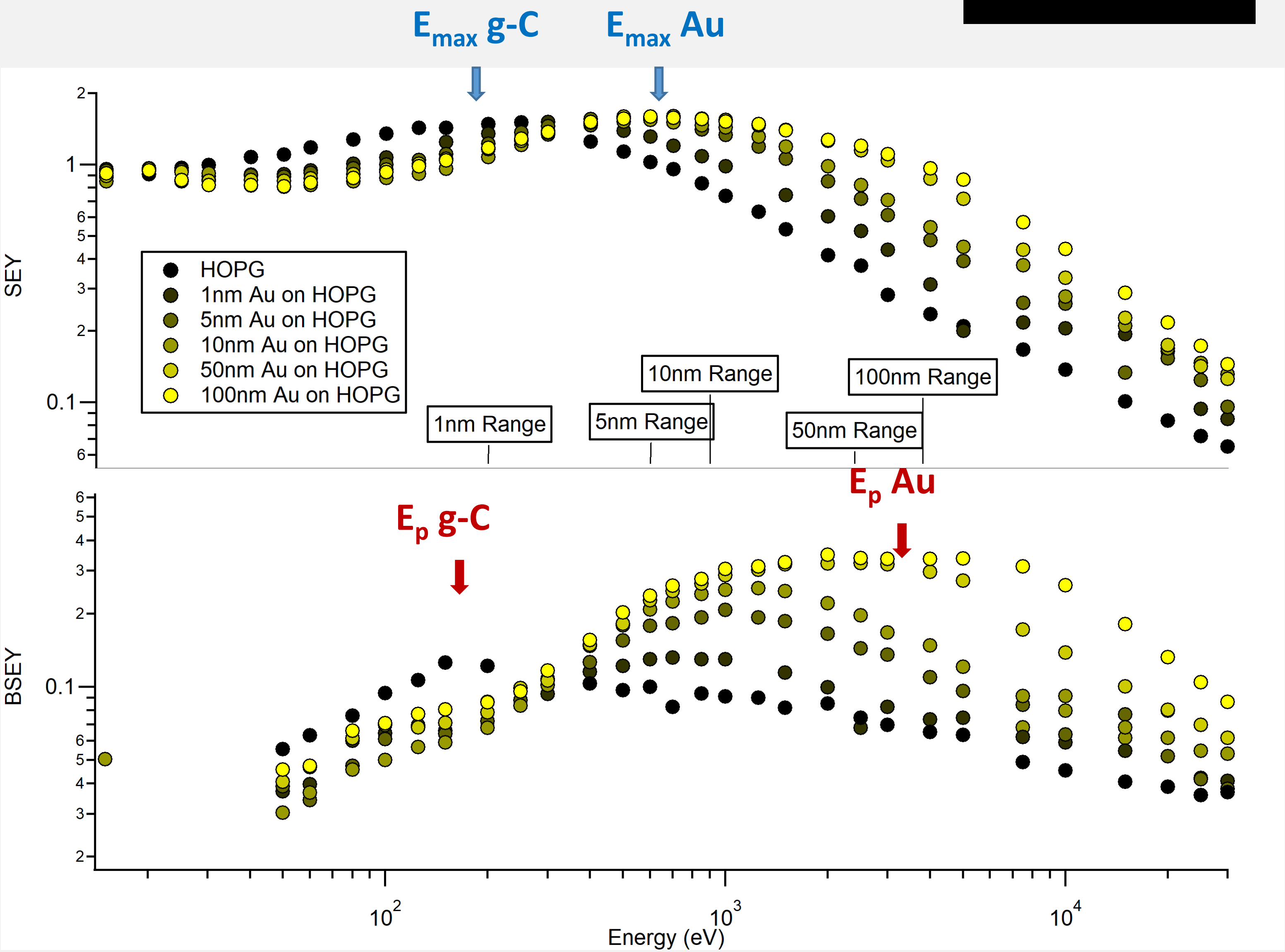
- In general TEY decreases with increasing g-C
- At **high energies**, SEY and BSEY decreases monotonically with increasing g-C
- At **low energies**, SEY and BSEY increase monotonically with increasing g-C
- Transitions energies from g-C behavior to Au depend on thickness
- Thicker surface layers require higher energy electrons to penetrate to the Au.



Au on HOPG Substrate

- **Two clear peaks** seen for C and Au
- Transition region is much sharper in energy
- At **high energies**, SEY and BSEY increases mono-tonically with increasing Au
- g-C overlayer suppresses Au SEY and somewhat BSEY
- At **low energies**, SEY and BSEY decrease mono-tonically with increasing Au
- Au substrate enhances g-C BSEY (and somewhat SEY) through **Au BSE** back through g-C





Conclusions

- Simple combination of layer and substrate energy-dependent yield curves *qualitatively* explains general features
- Magnitudes of yields and details of the transition region require consideration of depth/energy dependent energy deposition and SE/BSE production
- BSE have a measurable effect on SE emission.
- Change in BSEY of substrate can enhance or impede multilayer yields
- Further work to incorporate SEY from BSE is underway to improve multilayer SEY modeling