Secondary Electron Emission (SEE) Calculations

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Harold P. Hjalmarson and Ronald P. Kensek
Sandia National Labs
Albuquerque, NM

Kenneth E. Kambour
Air Force Research Labs
Kirtland AFB, NM

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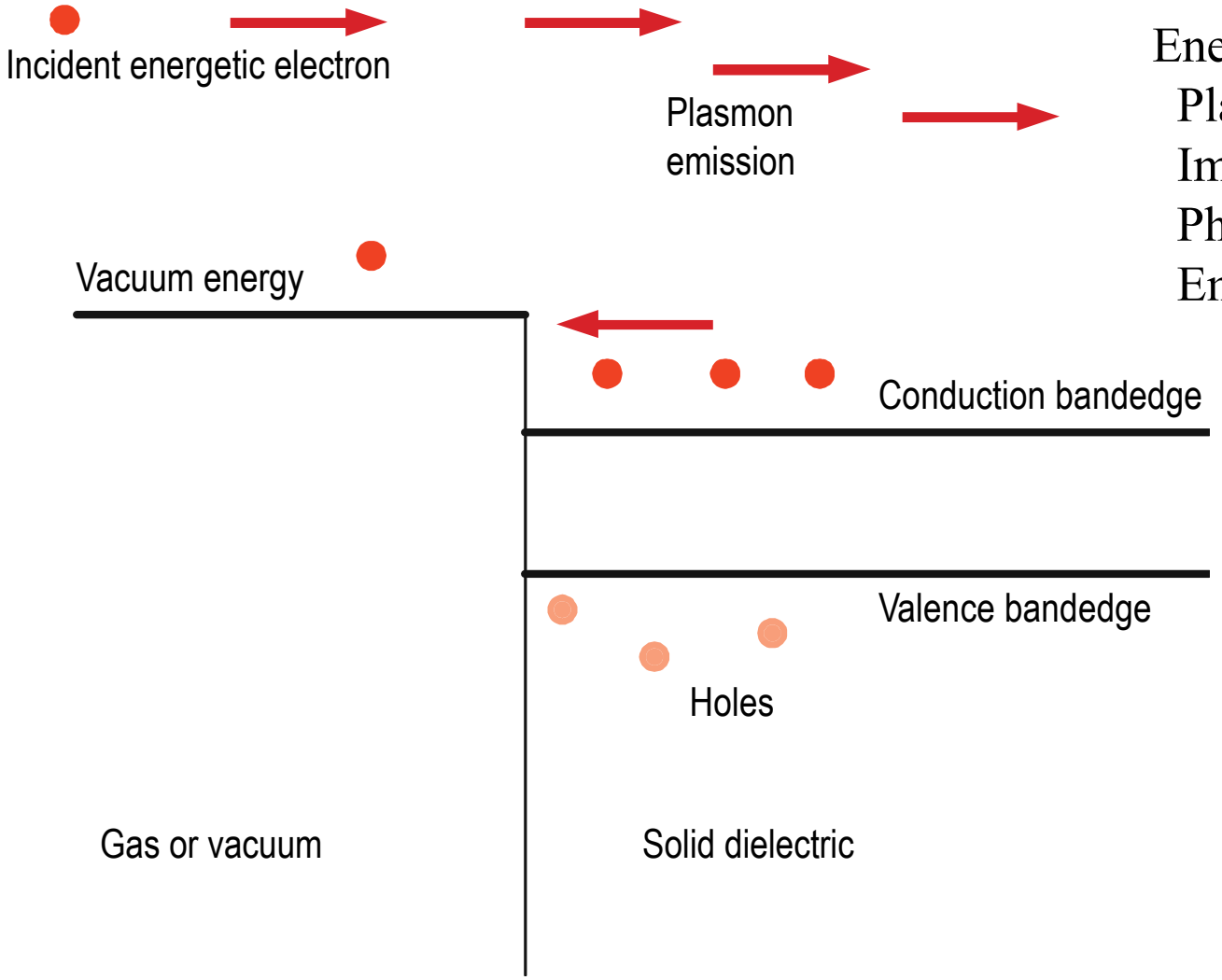
Secondary Electron Emission (SEE): Basic Phenomena



Energy relaxation processes
- Plasmon emission
- Impact ionization
- Phonon emission
- Emission from the solid

Outline

- Basic Phenomena
- Motivation
  - Low energy radiation transport
  - Electrical breakdown at rutile surfaces
- Monte Carlo Calculations
  - Method
  - Results
- Continuum Radiation Effects in Oxides and Semiconductors (REOS) Calculations
  - Method
  - Results
- Why Use Two Methods?
  - More insights are possible
  - A Monte Carlo method to link to radiation transport
  - A continuum method to link to thermal breakdown physics

Experimental Results: Yield Curve

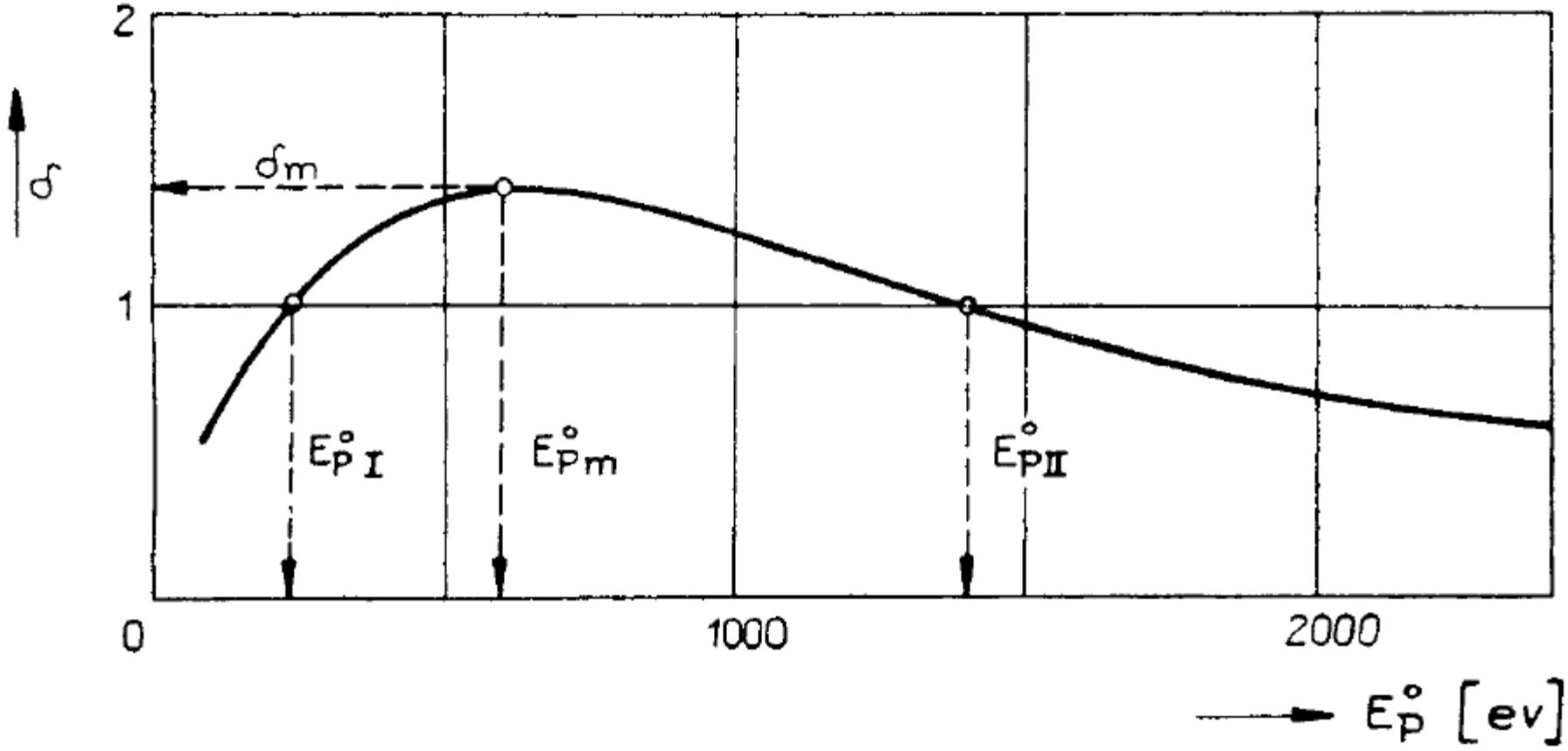


FIG. 11. The general shape of the yield curve δ (E_p°).

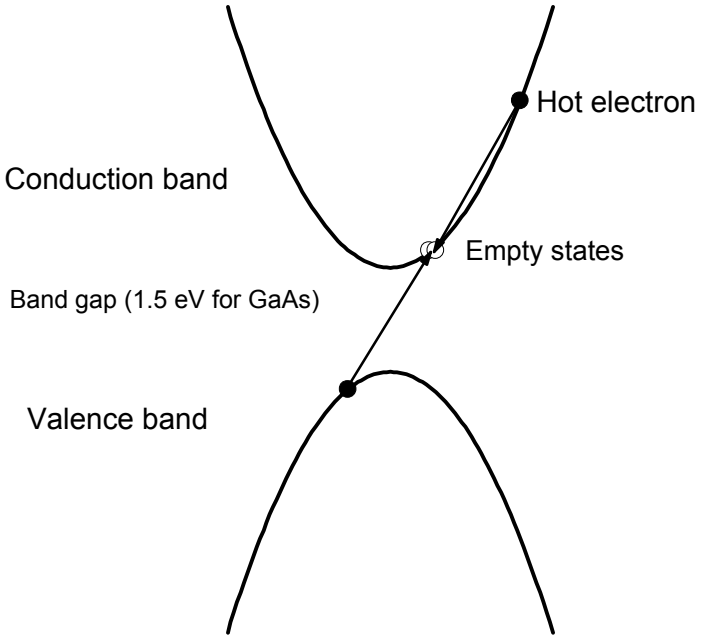
Hachenberg 1959

Monte Carlo Calculations

Procedure

- Follow trajectory of an energetic electron as it enters the solid
- Allow free flights and scattering events
- Scattering events
  - Plasmon emission
  - Impact ionization
  - Phonon scattering
  - Emission from the sample
- Perform these calculations using an ensemble Monte Carlo method
  - Use bandstructure
  - Use empirical scattering information

Evolution in Momentum Space (K-Space)



Energy & momentum restrict the allowed transitions

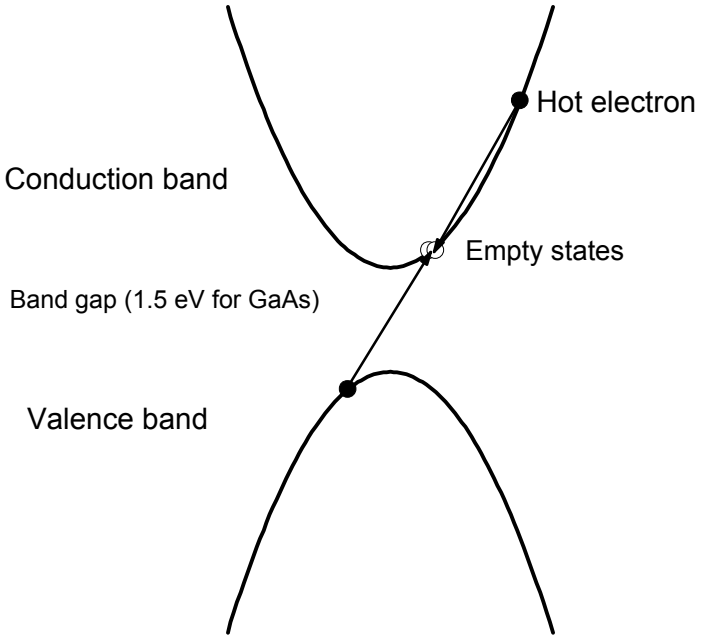
Newton's Laws

$$\frac{dk_z}{dt} = \frac{qF_z}{h}$$

$$\frac{dz}{dt} = \frac{hk_z}{m}$$

F = electric, q = electron charge, m = effective mass

Impact Ionization

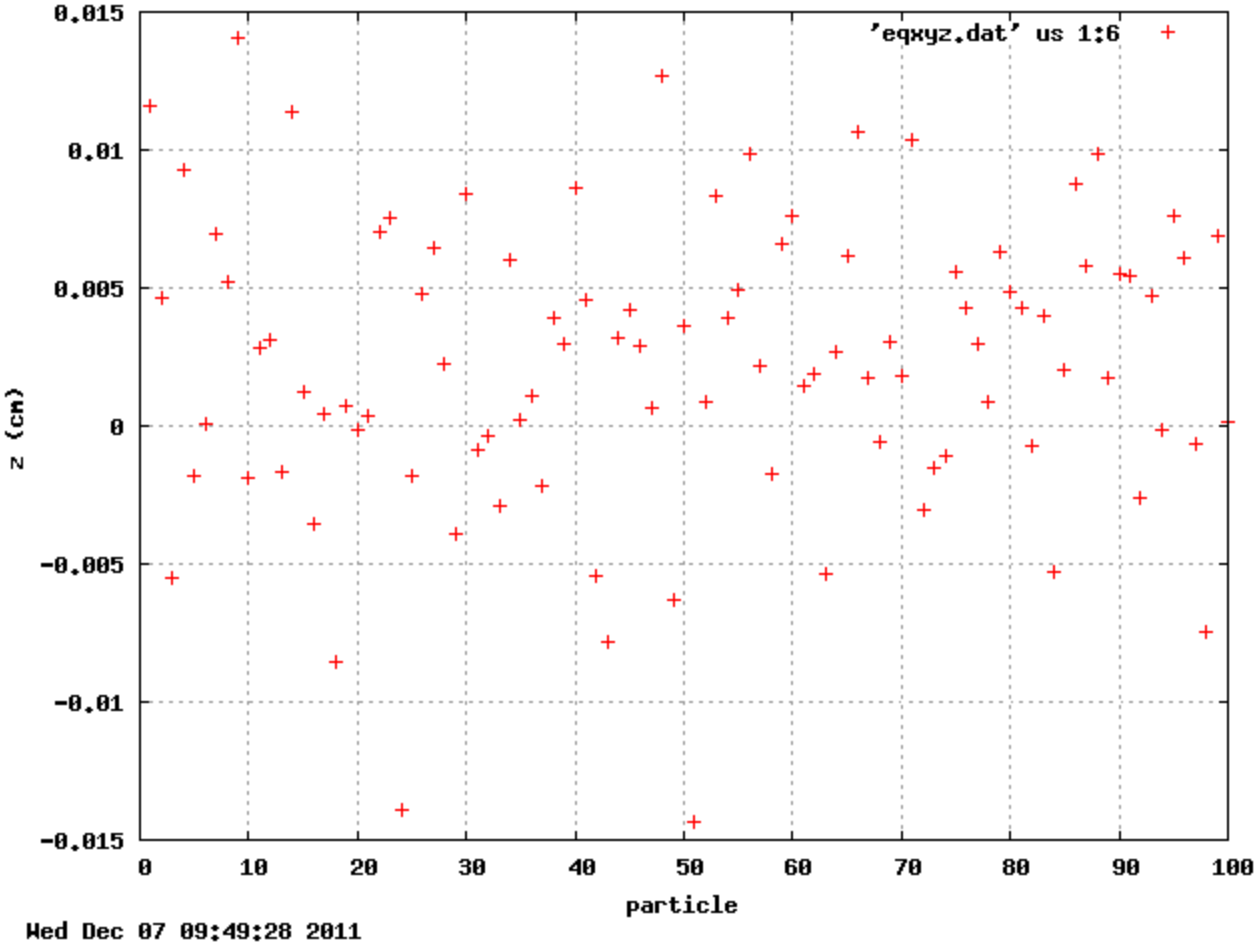


Energy & momentum restrict the allowed transitions

Monte Carlo Methods

- **Simple Description**
  - **“Free flight” of electrons and holes in momentum space (bandstructure)**
  - **Scattering**
    - **Impact ionization**
    - **Phonons**
    - **Emission from the sample (with no return)**

Diffusion



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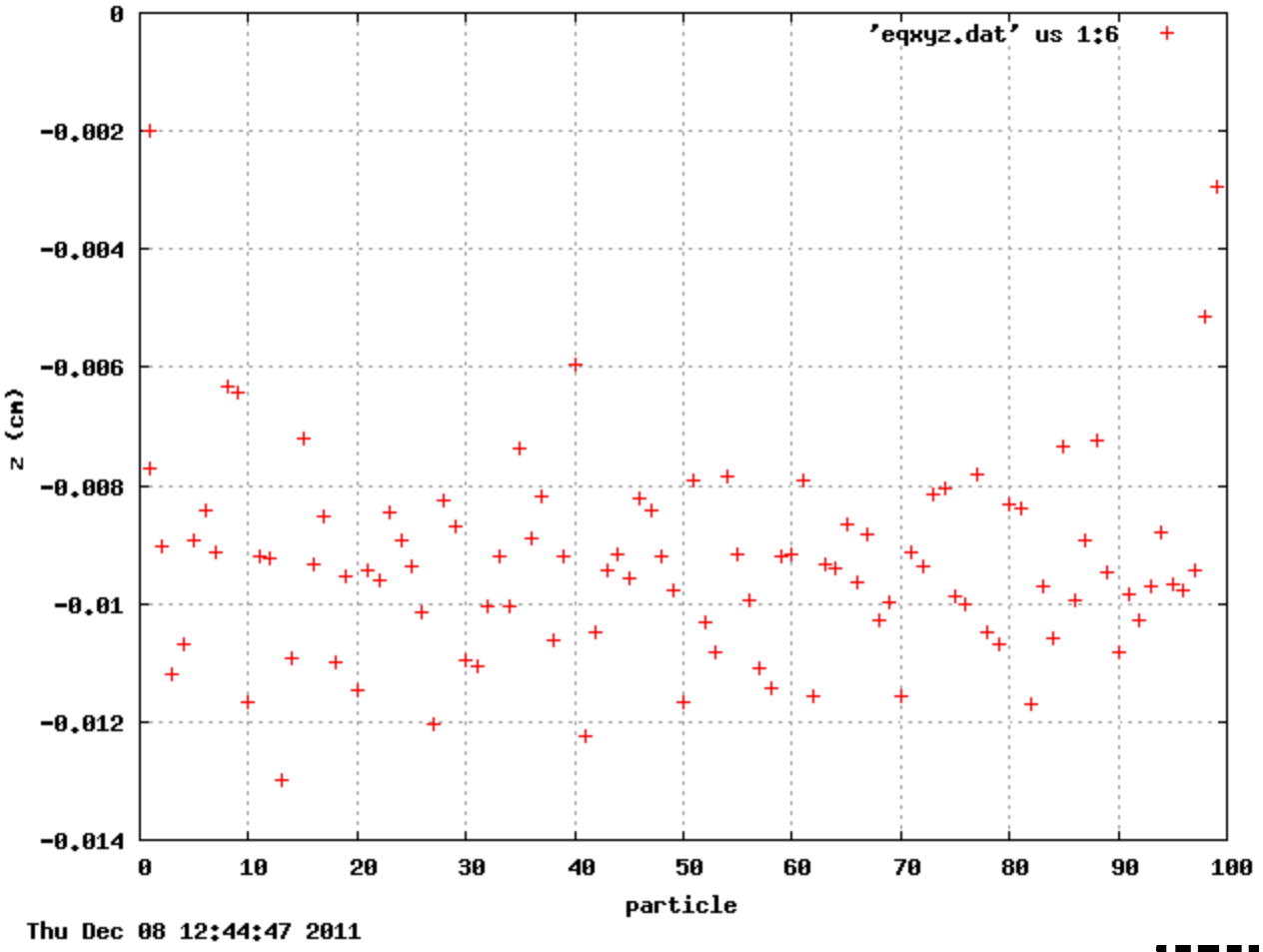
Drift + Diffusion



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Electron Emission: Monte Carlo Results

- **Undecided physics issue: the vacuum-solid interface**
  - **One approach: an electric field over a small region**
    - **qFd = energy shift**
  - **Another approach: A hop to an energy-shifted bandstructure**

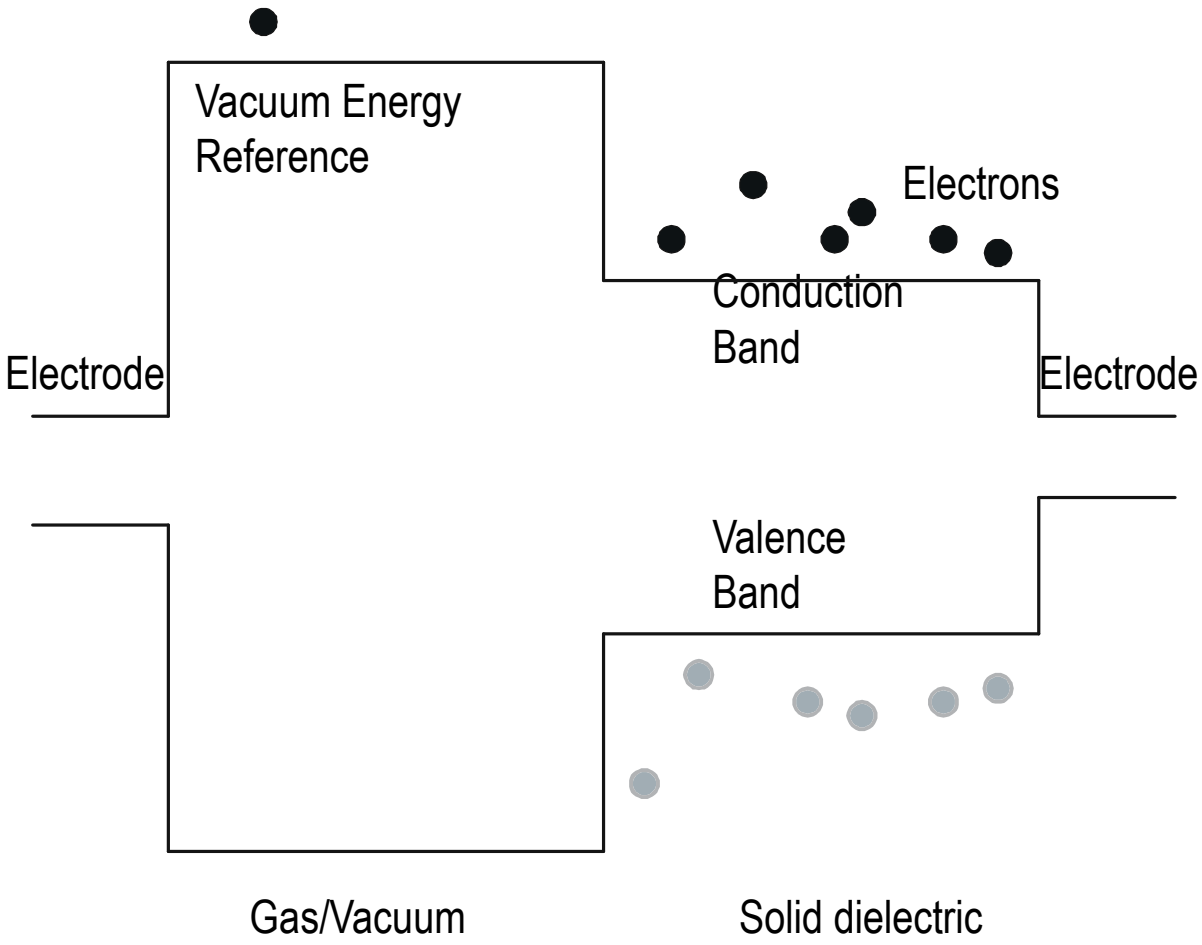
Continuum Calculations

Radiation Effects in Oxides and Semiconductors (REOS) Calculations

- **Features**
  - Transport
  - Energy relaxation
  - Chemical reactions
  - Heteromaterial interfaces
- **Emphasis**
  - Physics
  - Simple geometry
- **Method**
  - Inject electrons and holes in the RHS insulating region
  - Include energy relaxation processes that control the temperature
  - Follow evolution in space and temperature

SEE Calculations: Structure

Metal-insulator-insulator-metal



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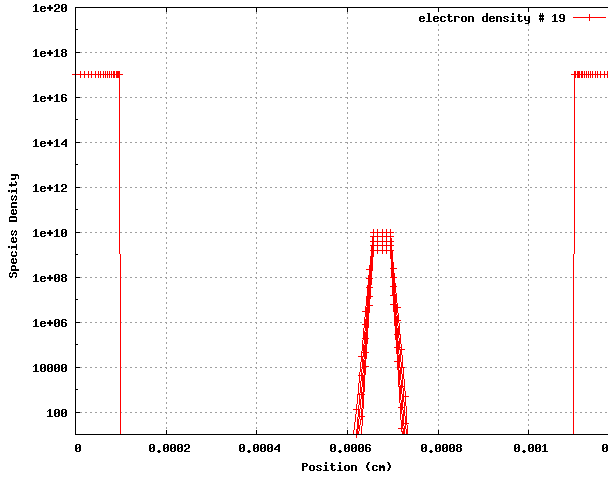
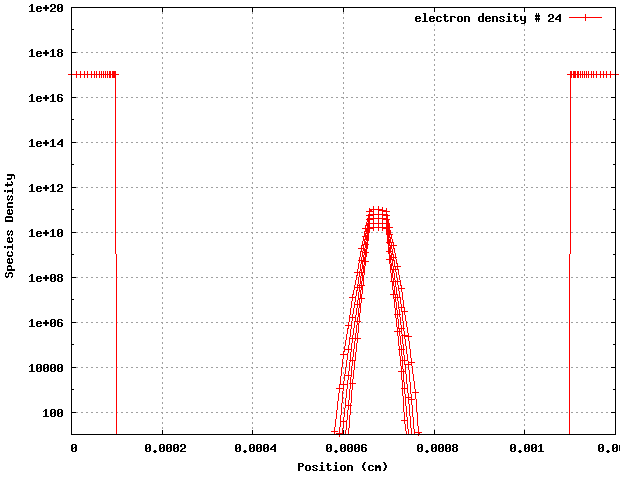
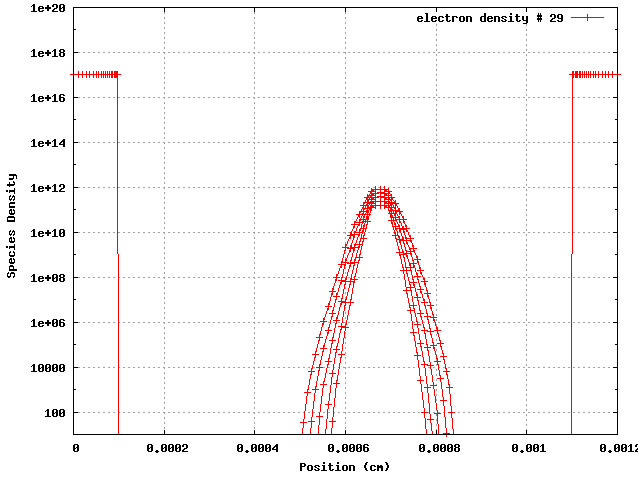
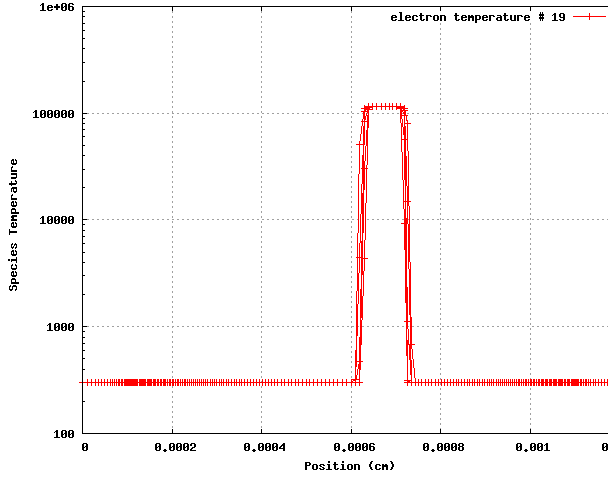
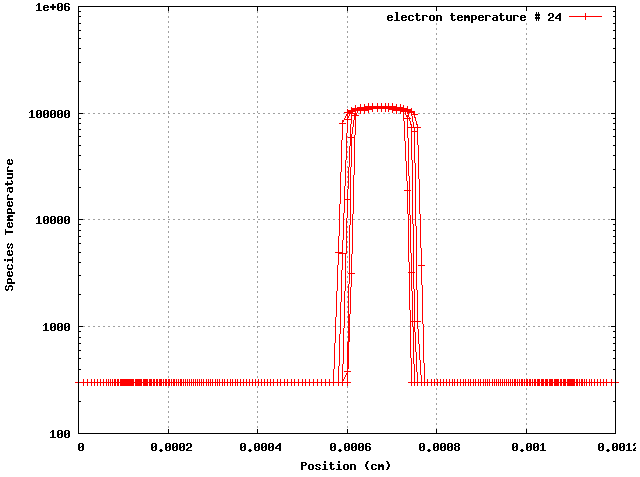
Electron Density and Temperature: 0.1 ps, 1 ps and 10 ps

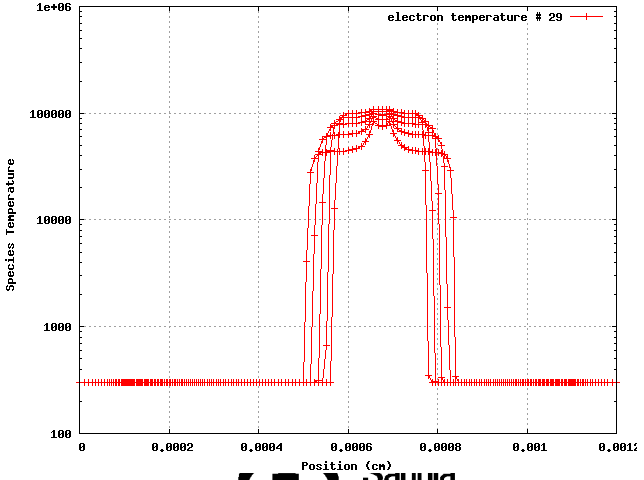




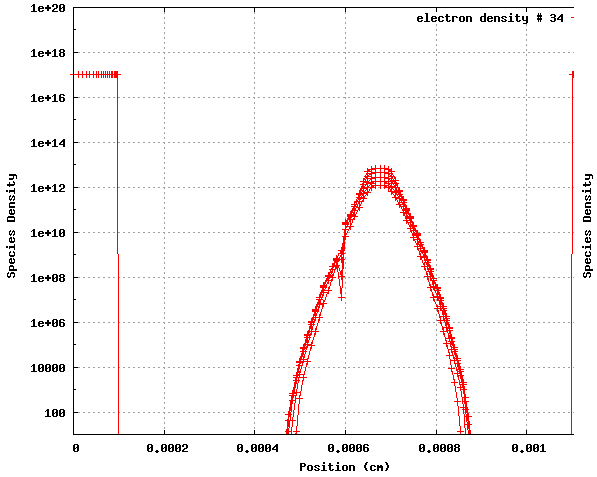


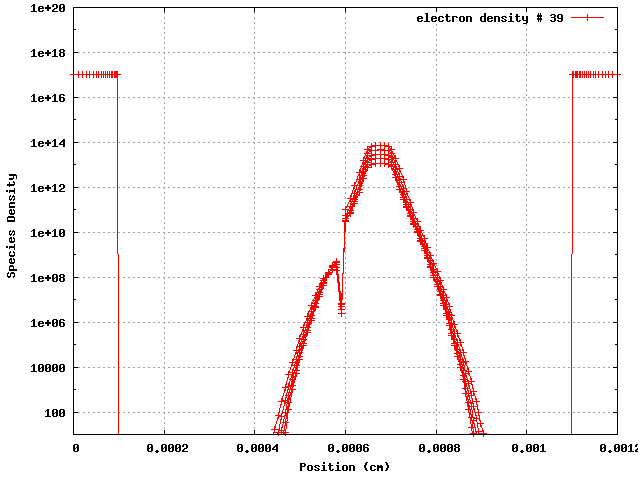


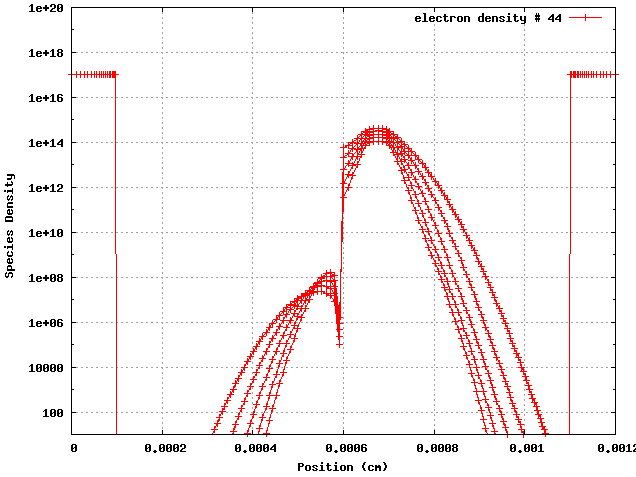


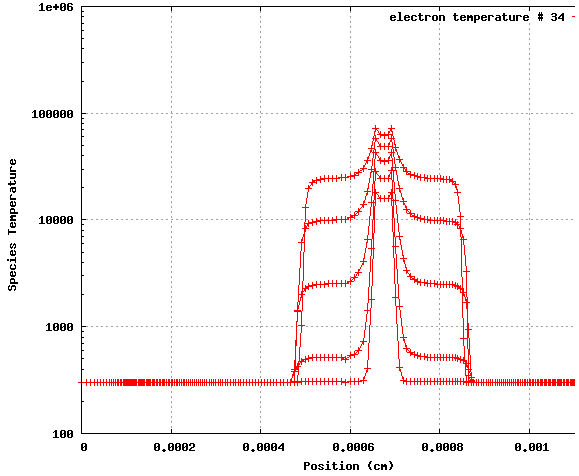


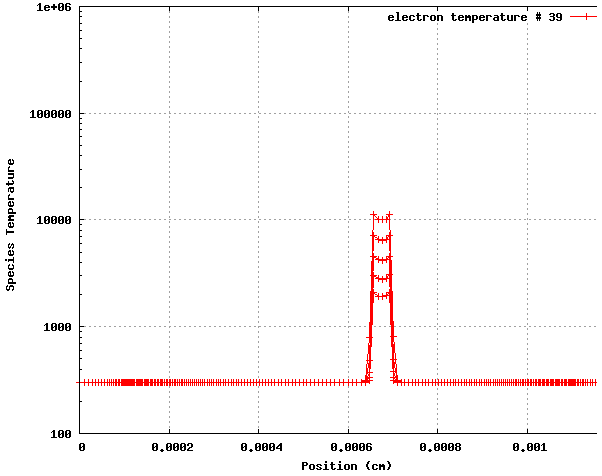
Electron Density and Temperature: 100 ps, 1 ns and 10 ns

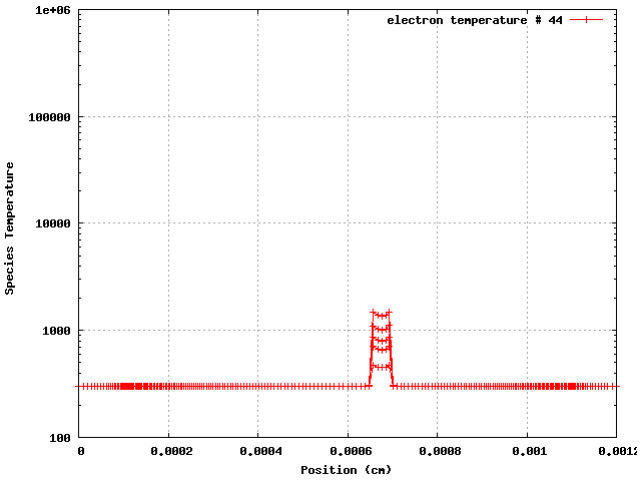












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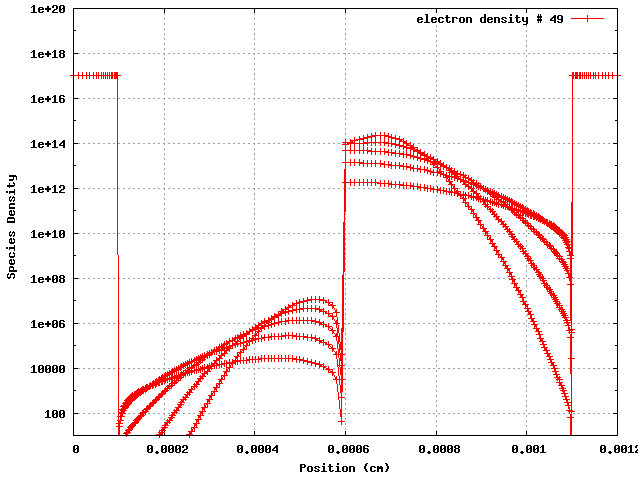
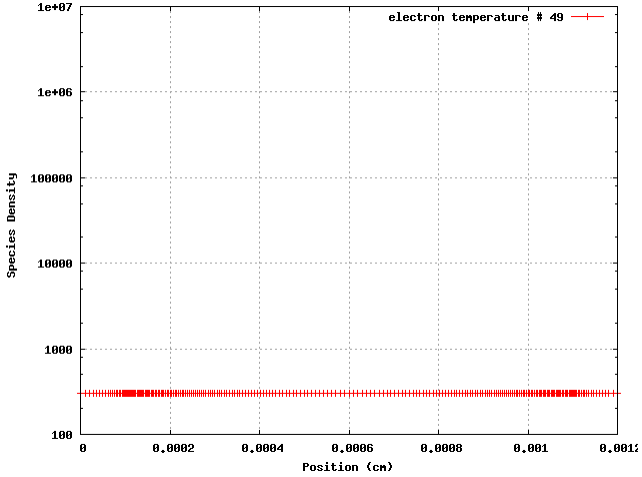
Electron Density and Temperature: 100 ns





Summary: Physics Insights

- Energy deposition rate depends on charged particle velocity
- Cooling versus emission depends on bandgap versus affinity

Low-Energy Radiation Transport LDRD

- **Secondary Electron Emission (SEE) is a good test problem**
  - **Monte Carlo calculations**
  - **REOS calculations**
- **Good results obtained**
  - **SEE information needed for the LAC project**
  - **Will be presented at the APS meeting next week**

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Extra Slides