Radiation Damage: Atom Displacement

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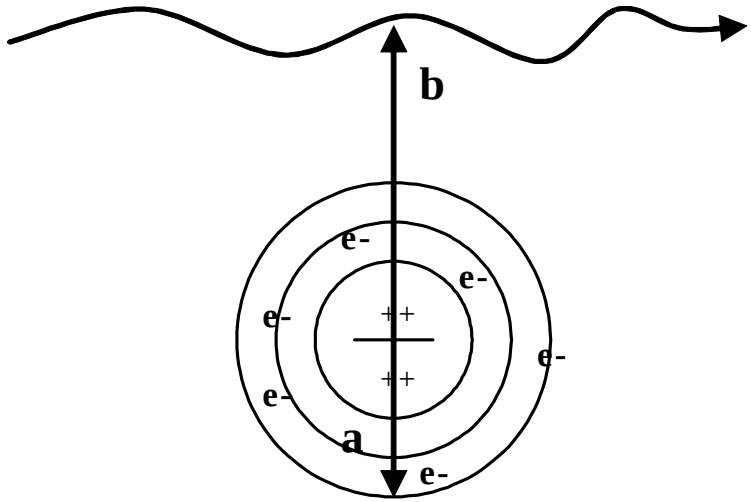
Introduction

- Paper: G.H. Kinchin, R.S. Pease, “The Displacement of Atoms in Solids by Radiation,” Rep Prog. Phys., 18, I. (1955)
- Focus on causes of radiation defects and mechanisms involved

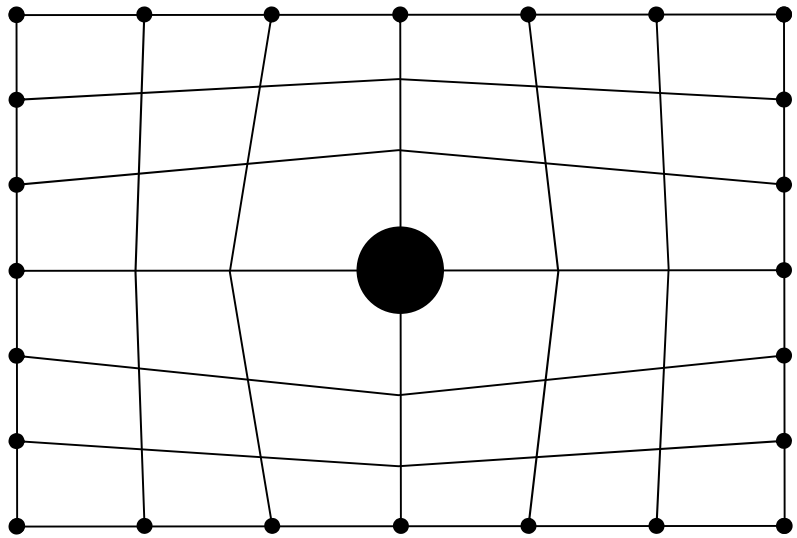
Types of Interaction

- “Hard Sphere” Collision (primary knock-on): Direct collision (b~a)
- “Soft Collision” (Rutherford): Charged particle’s Coulomb field influences atom via exciting electron shells (b>>a)
- Coulomb field interacts with nuclear field (b<<a)



Displacement Energy

- Main movement of single defect is via interstitial-vacancy pair diffusion (Frenkel pair)
  - Comparatively low energy requirements
  - Point defect inserted into solid causing outward dilation in surrounding lattice
- Minimum displacement energy, Ed
  - Lattice atoms have several chemical bonds that must be broke to move
  - Potential barrier between lattice site and stable intersitial where defect moves
  - Experimental/analytical value **~25ev** most materials



Body-Centered Interstitial

Number of Displaced Atoms

- Hard sphere
  - Energy transfer $0 \leq \Delta E \leq E_{max}$
  - Total number atoms displaced

$$N_d \approx E_k / 2E_d$$

- Rutherford
  - Cross section 1/E dependence (number of primary knock-ons vary inversely as square of their energy)

$$N_d = \frac{1}{2}\left\{1 + \ln\left(\frac{E_{\max}}{2E_d}\right)\right\}$$

Conclusion

- Several types of collisions highly dependent on particle energy
- Classical vs. Wave
  - Classical, hard sphere, good for low energy, large particles
  - Wave (w/ Born Approximation) needed for high energy small particles
    - de Broglie wavelength ($\lambda=h/p$) range of strong force (~1fm)
- Big Picture
  - Manifestation of defects affect material properties (E, σy, embrittlement, etc)