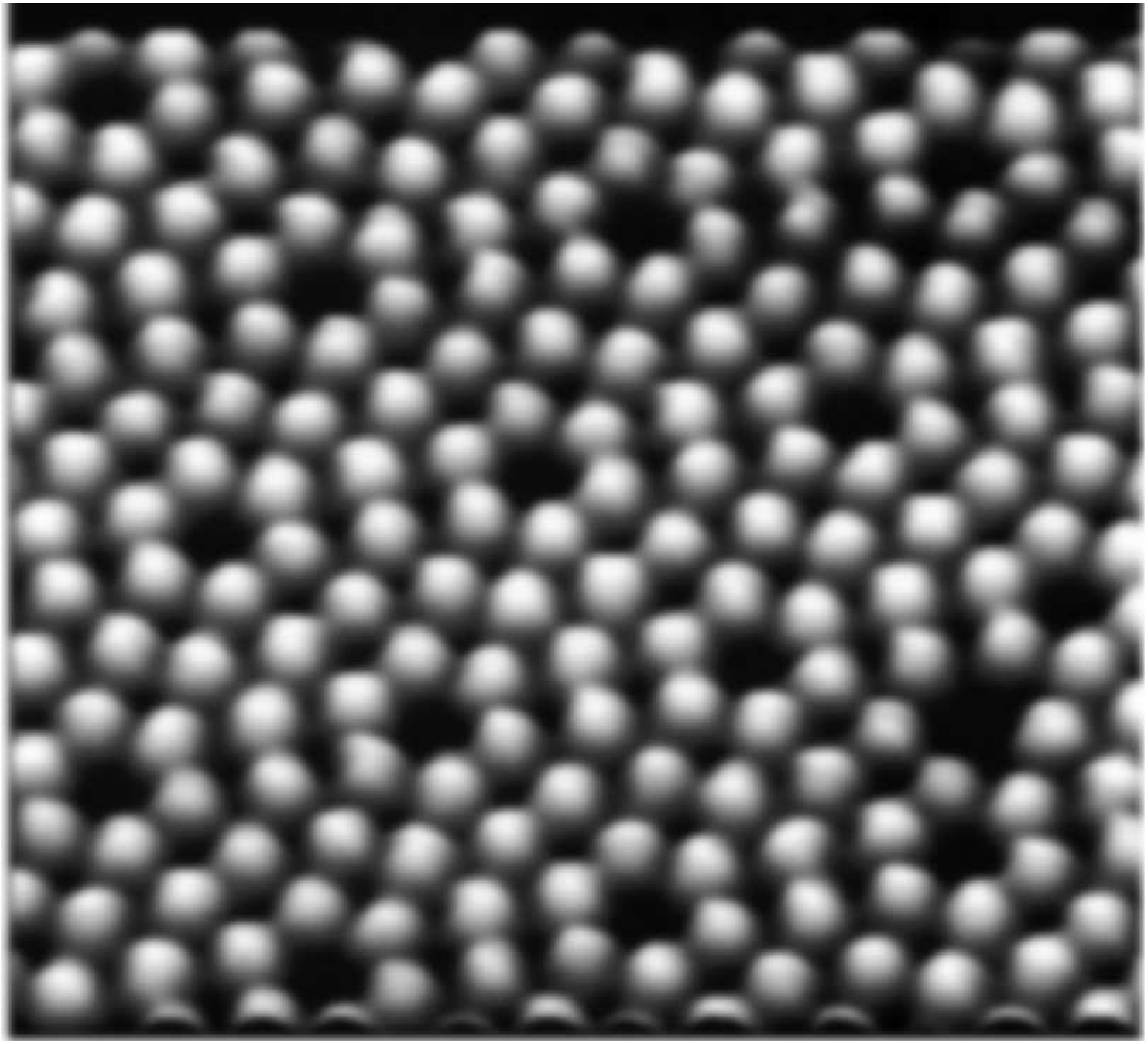
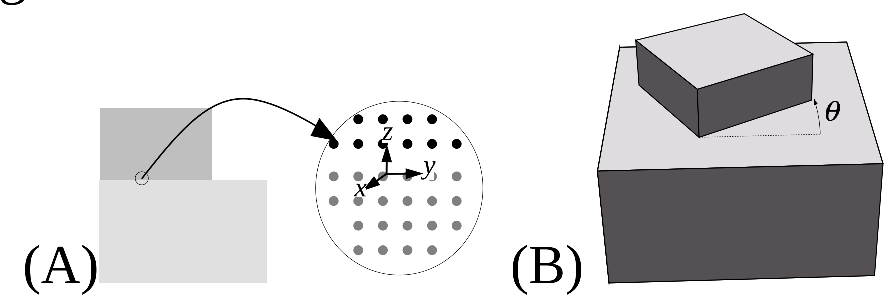
Surfaces and Interfaces

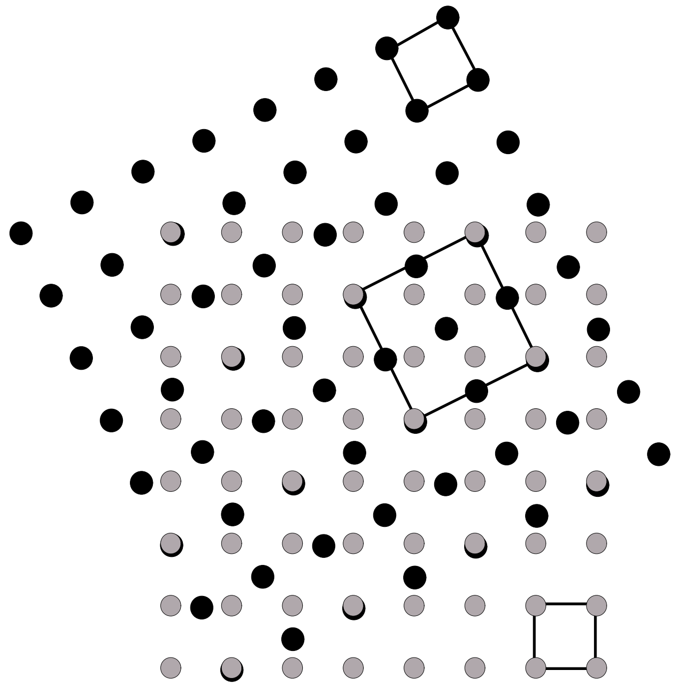


Counting up ways to align two surfaces



Commensuarate and Incommensurate Interfaces

$$n_1\vec{a}_1 + n_2\vec{a}_2 = \begin{pmatrix} \cos\theta & \sin\theta \\ -\sin\theta & \cos\theta \end{pmatrix} (m_1\vec{b}_1 + m_2\vec{b}_2). \tag{L1}$$

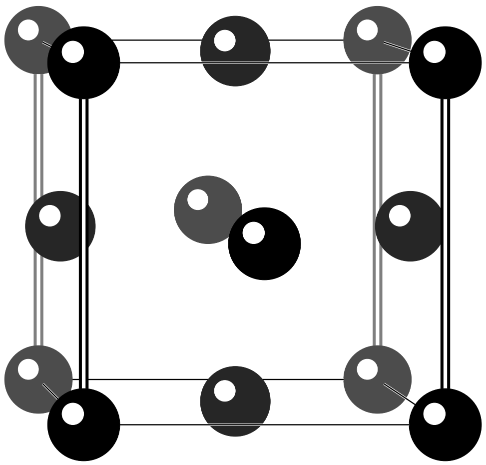


Lattice constants differ by $\sqrt{5}/2$: commensurate but incoherent.

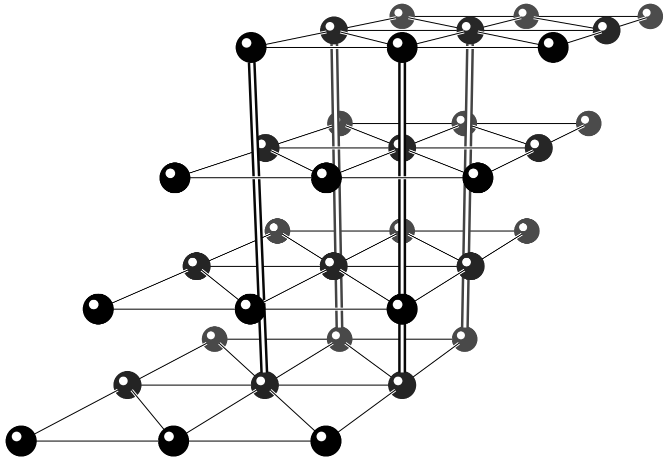
Stacking Period and Interplanar Spacing

$$P = \delta(i^2 + j^2 + k^2), \text{where } \delta \text{ equals 1 or 2.} \quad \text{(L2)}$$

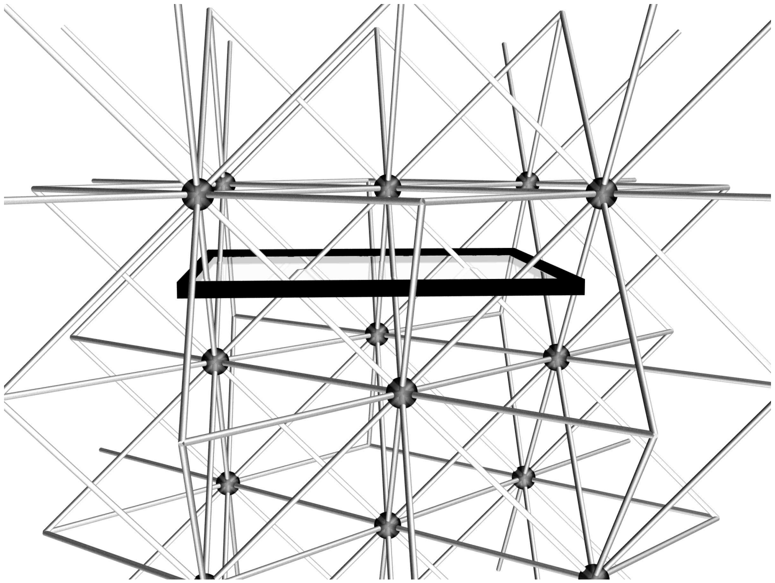
$$d = \epsilon a / \sqrt{i^2 + j^2 + k^2}, \quad \text{(L3)}$$



fcc (100) surface, $P = 2$



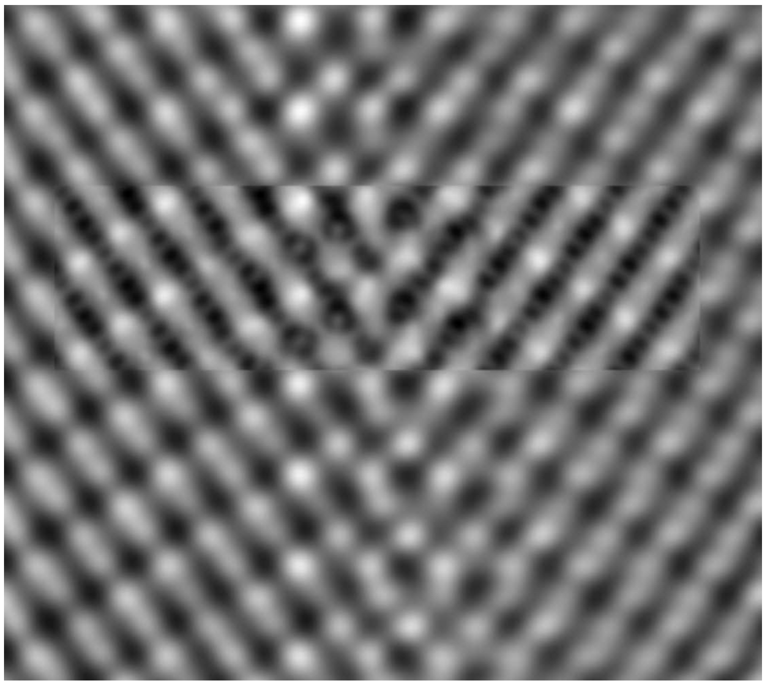
fcc (111) surface, $P = 3$

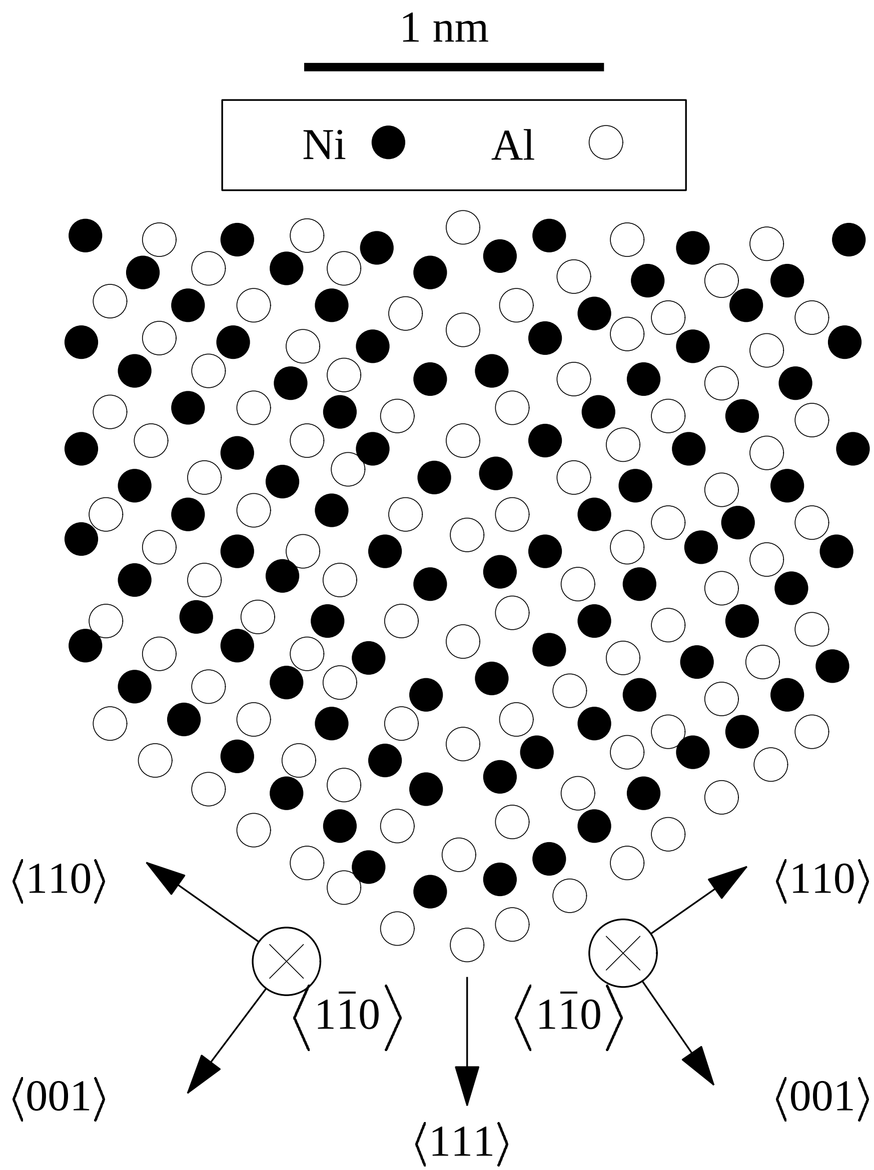


Nomenclature

- Twin boundary
- Twist boundary
- Tilt boundary
- Stacking fault
- And here come the acronyms
- LEED—Low energy electron diffraction
- RHEED—Reflection high energy electron diffraction
- MBE—Molecular beam epitaxy
- FIM—Field ion microscopy
- STM—Scanning tunneling microscopy
- AFM—Atomic force microscopy
- HREM—High resolution electron microscopy

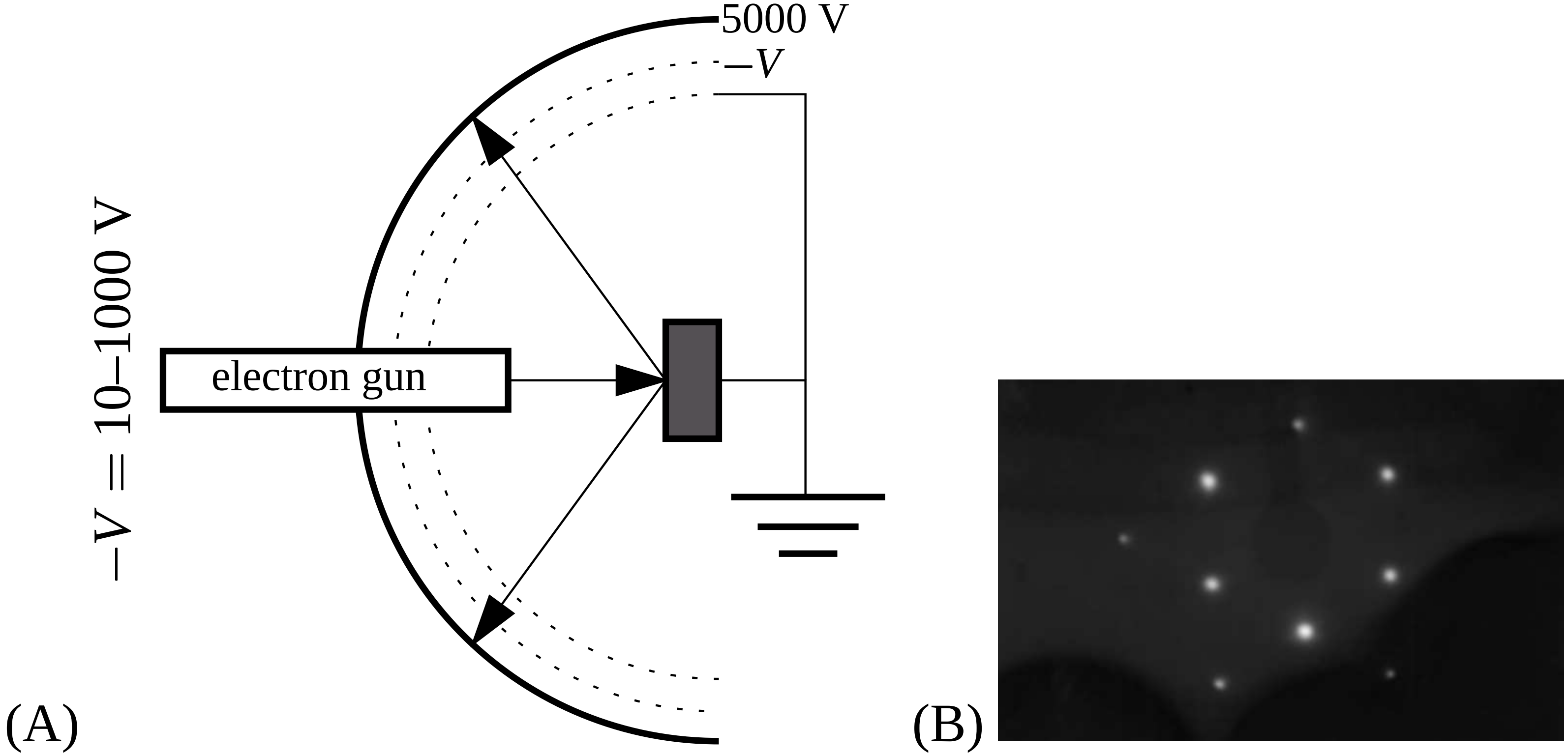
Twin Boundary



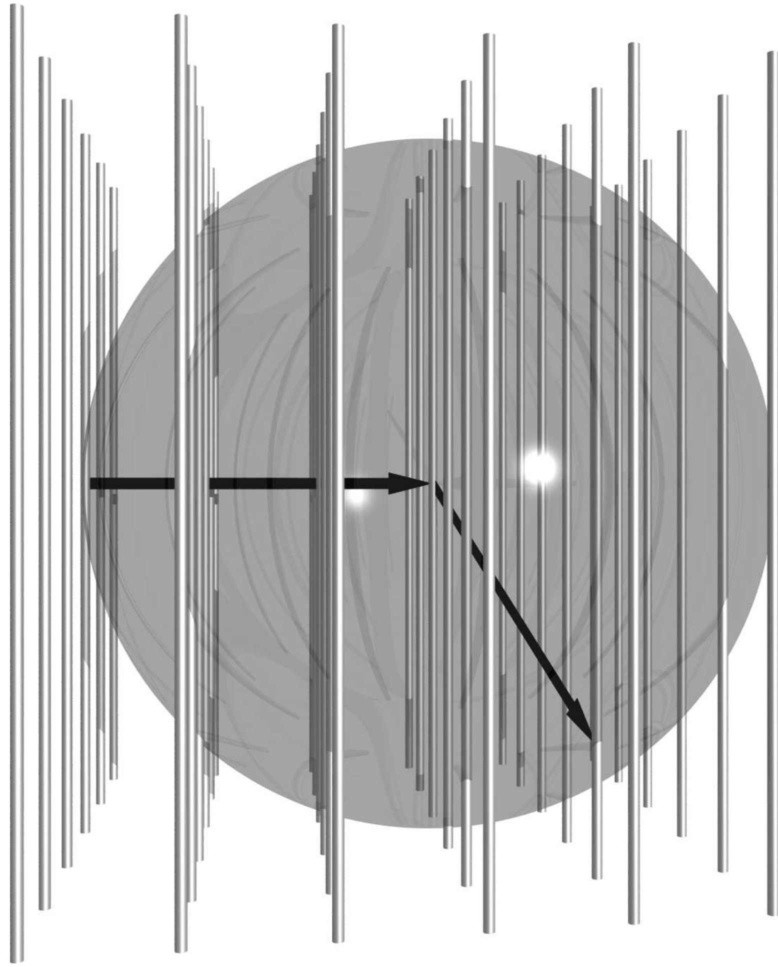


Low-Energy Electron Diffraction (LEED)

Technique used by Davisson and Germer to find wave nature of electron.



Low-Energy Electron Diffraction (LEED)

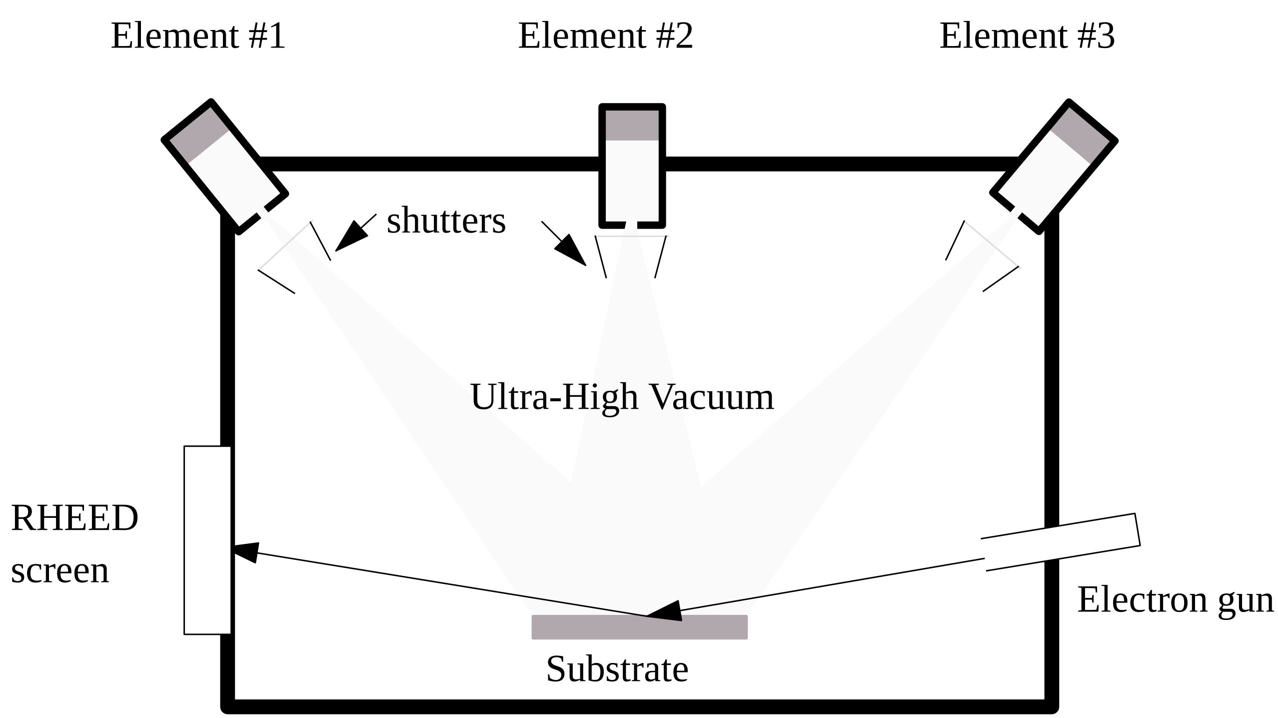


$$\lambda = 12.2\ [\text{energy}/\text{eV}]^{-1/2}\ \text{Å} \tag{L4}$$

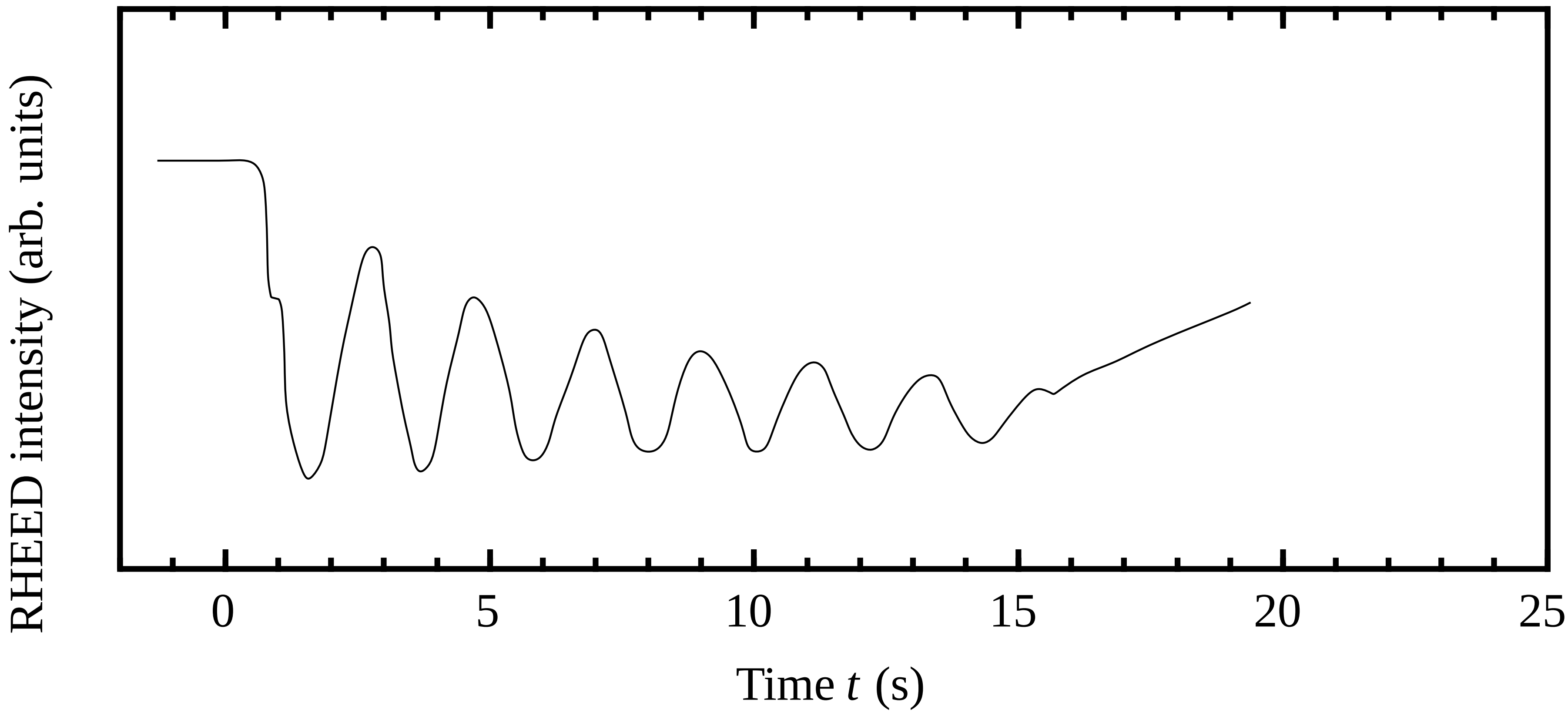
$$\vec{q}\cdot\vec{R} = 2\pi l \quad \vec{q} = (K_x, K_y, q_z). \tag{L5}$$

Molecular Beam Epitaxy (MBE) and Reflection High-Energy Electron Diffraction (RHEED)

Electrons of energy on the order of 100 keV reflected off a surface at a grazing angle. The wave vectors associated with such energies are on the order of 200 $Å^{-1}$, much larger than the spacing between reciprocal lattice vectors.



Molecular Beam Epitaxy (MBE) and Reflection High-Energy Electron Diffraction (RHEED)



Oscillations in RHEED intensity, (001) GaAs surface monitoring the $[\bar{2}10]$ reflection as electrons reflect off the surface at an angle of 0.91°. Braun et al. (1998)

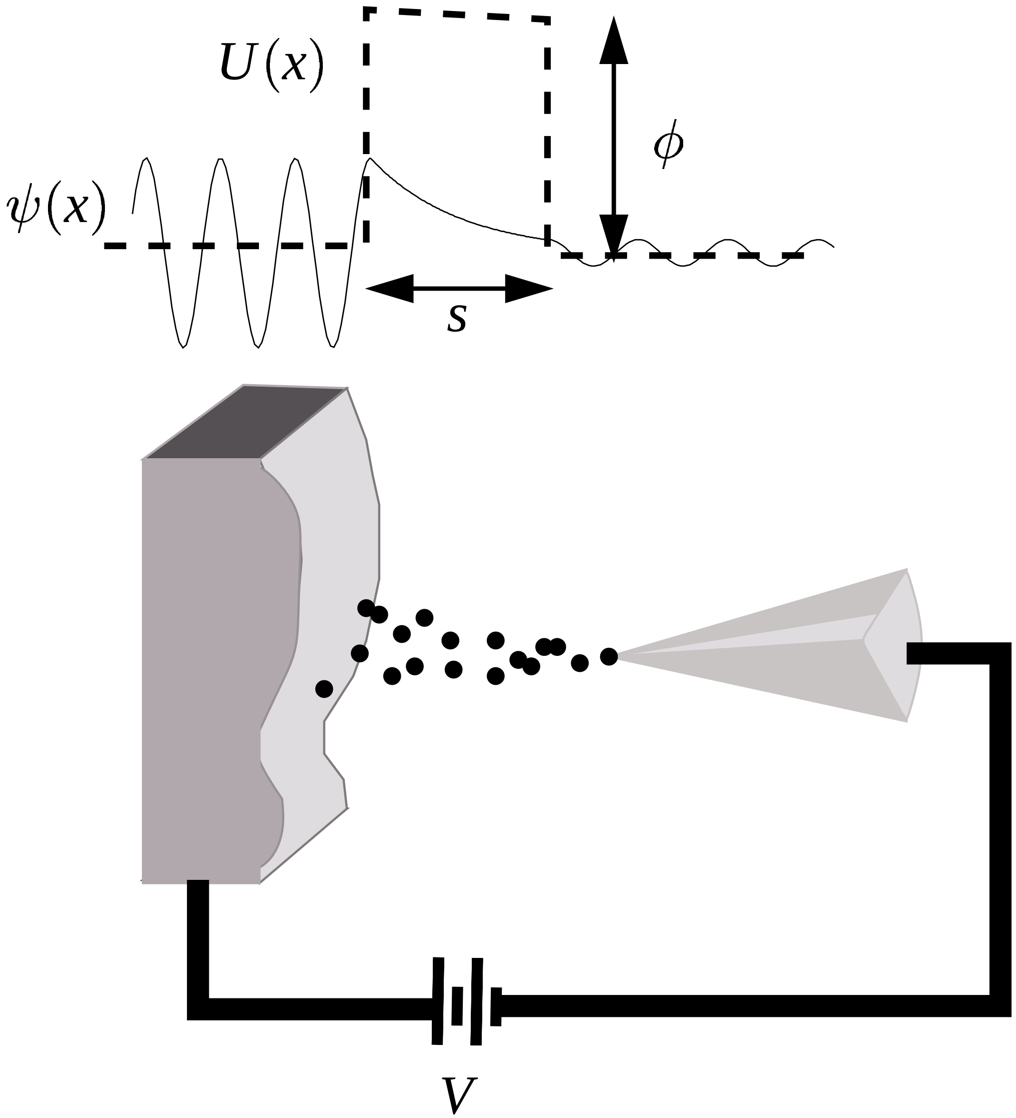
Oppenheimer and tunneling

$$i \sim \exp \frac{-C}{E} \tag{L6}$$

$$\psi \sim \exp[-x\sqrt{2mU/\hbar^2}]. \tag{L7}$$

$$\phi = \frac{1}{2}(\mu_1 + \mu_2). \tag{L8}$$

Scanning Tunneling Microscopy (STM)



Scanning Tunneling Microscopy (STM)

$$\psi(x) \sim \exp\left[(i/\hbar)\int^{x} dx' \sqrt{2m(\mathcal{E} - U(x'))}\right]. \tag{L9}$$

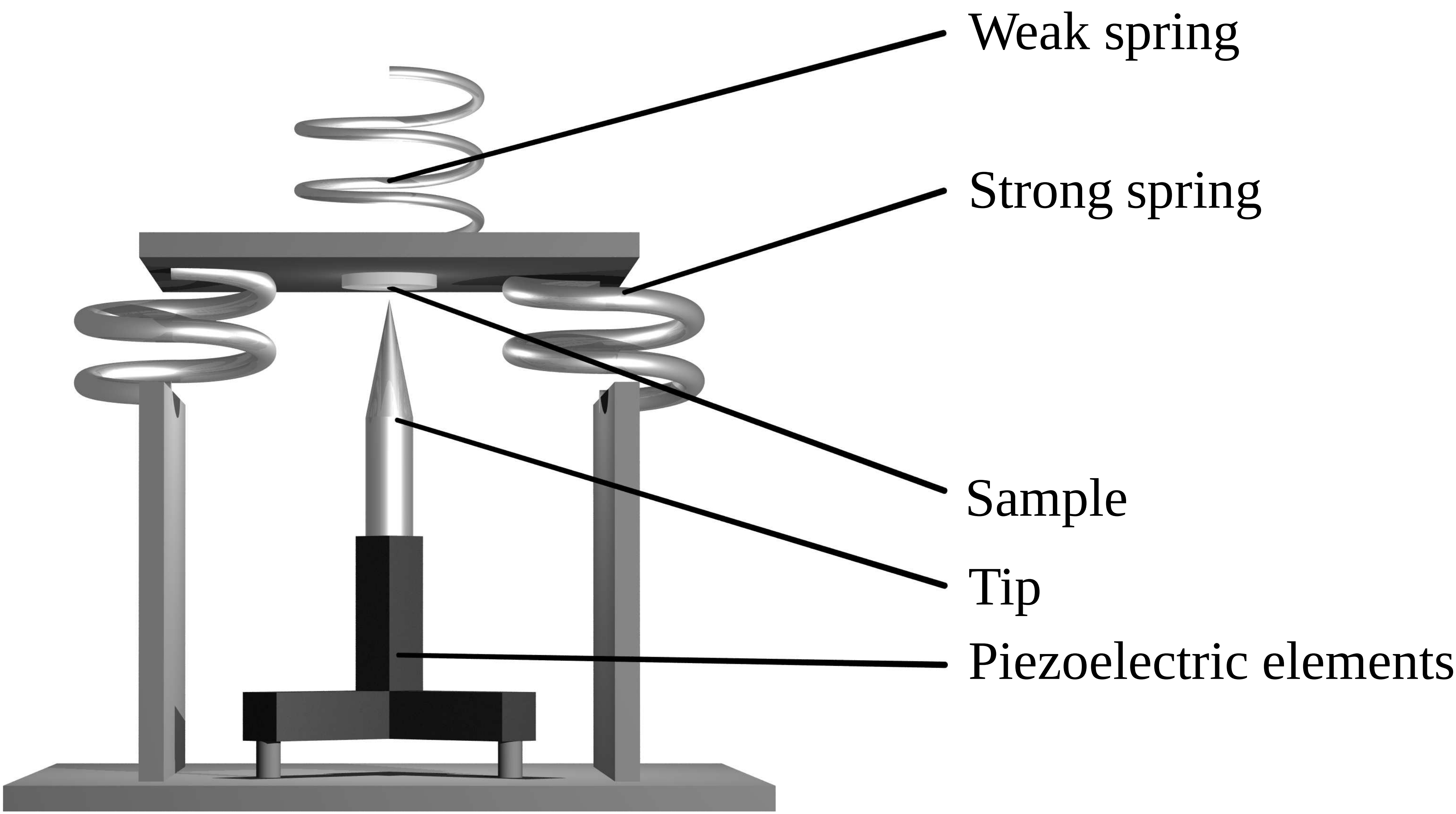
Amplitude drops by

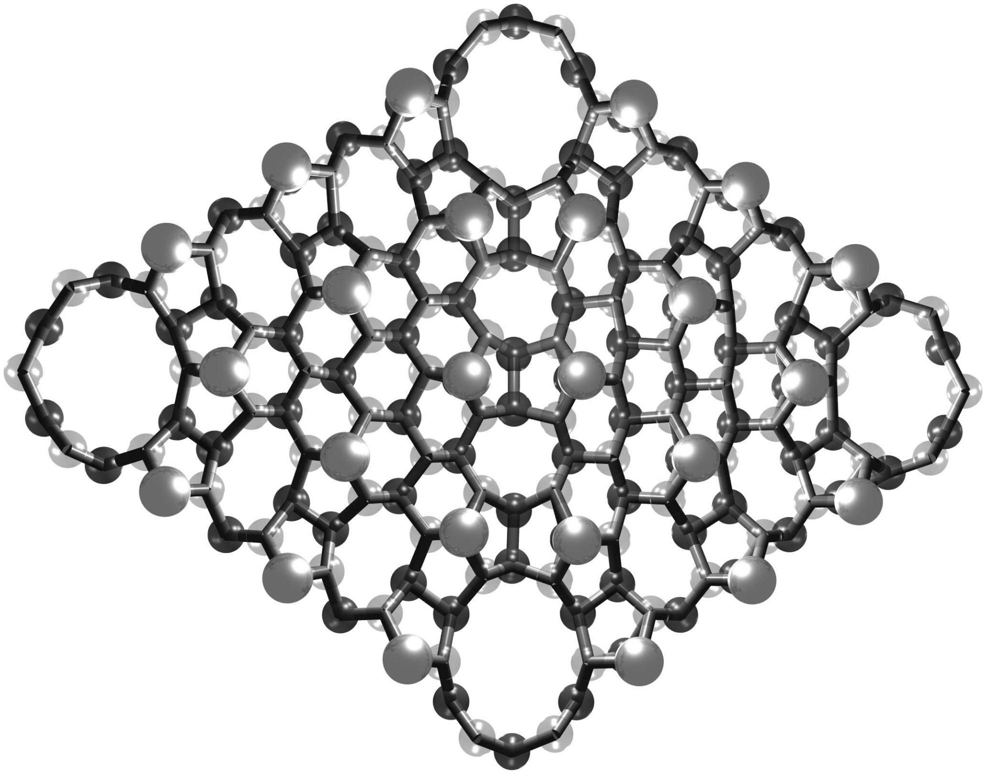
$$\exp\left[-s\sqrt{2m\phi/\hbar^2}\right] \tag{L10}$$

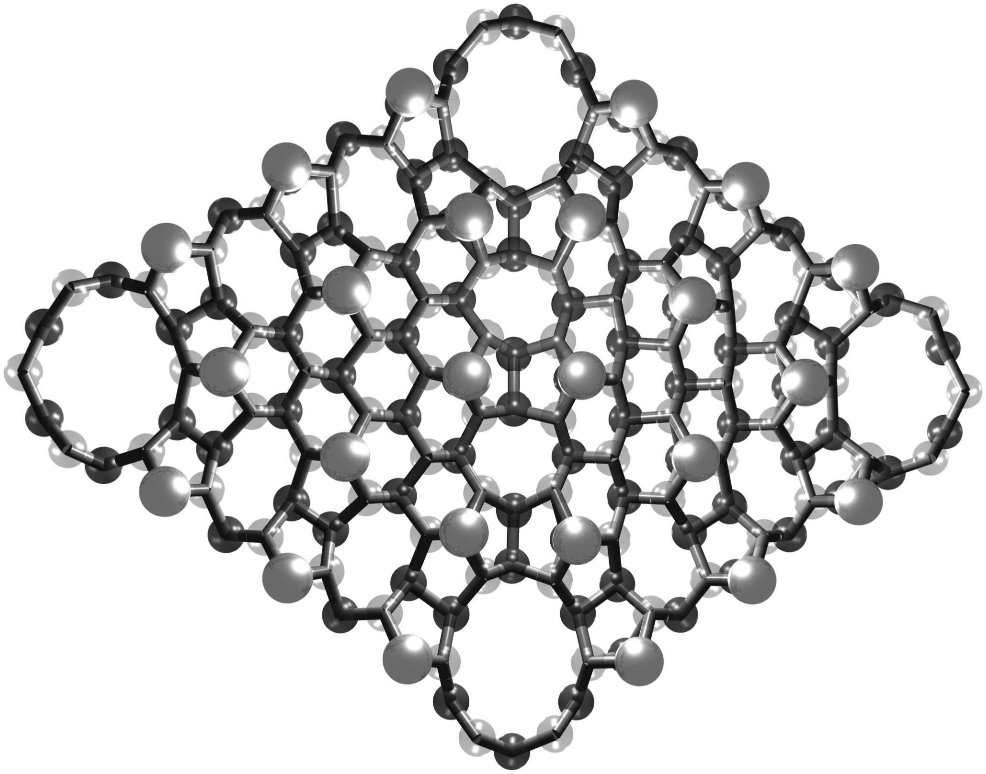
$$J \propto n_\mathrm{i} n_\mathrm{f} V \exp[-2s\sqrt{2m\phi/\hbar^2}] \tag{L11}$$

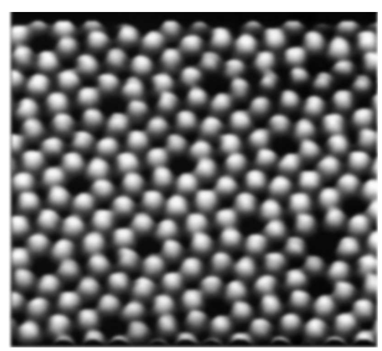
$$\propto \exp\left[-1.02[s/\text{Å}]\sqrt{[\phi/\mathrm{eV}]}\right]. \tag{L12}$$

Scanning Tunneling Microscopy (STM)



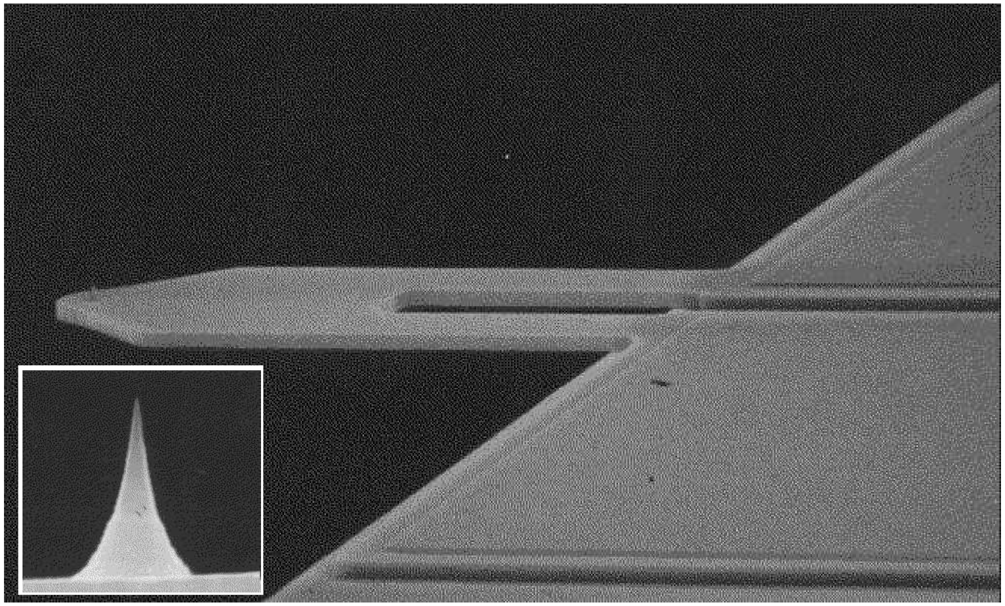


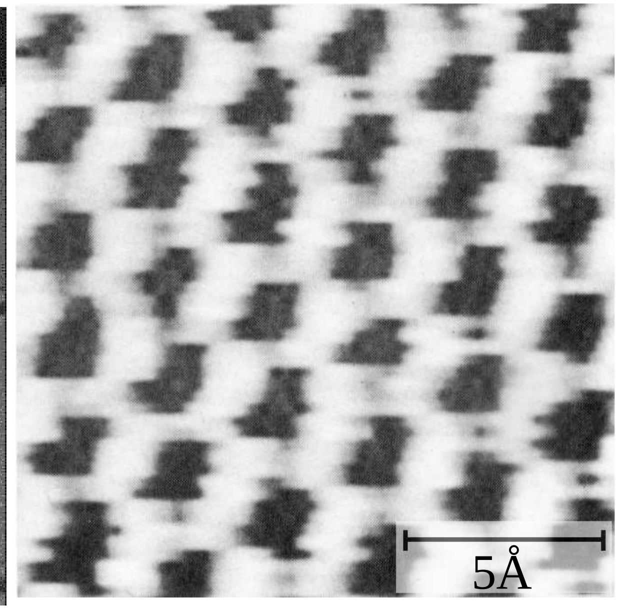




Wolkow and Avouris (1988)

Atomic Force Microscopy (AFM)





M. Tortonese

See Atomic Probe Microscope galleries at

IBM STM Image Gallery

Digital Instruments/Veeco

DLA—Diffusion Limited Aggregation

Witten and Sander

Java simulator of DLA