Atomic Force Microscopy (AFM): General Components and Their Functions

- **laser diode**: spring which deflects as probe tip scans sample surface
- **mirror**:
- **cantilever**: measures deflection of cantilever
- **position sensitive photodetector**: senses surface properties and causes cantilever to deflect
- **probe tip**: actual signal - set point
- **sample**: controls z-sample position
- **sensor output, δc, Fc**: performs data acquisition, display, and analysis
- **piezoelectric scanner**: positions sample (x, y, z) with Å accuracy
- **computer**: controls system
AFM: Force – distance curve, modes of operation

- Tip is in hard contact with the surface; repulsive regime.
- Tip is far from the surface; no deflection.
- Tip is pulled toward the surface - attractive regime.

Flexible cantilever

Contact

Flexible vibrating cantilever

Interaction force

Surface

Horizontal sample motion

Non-contact
AFM: Q-Plus sensor

Si(111)  -7x7
Can you really „see“ atoms?

René Magritte, 1923

Ceci ne sont pas des atomes

Carsten Busse, 1999 (Al(111))
\[ E_{\text{kin}} = \hbar \omega - \phi - E_b \]
Nobel price in physics 1981 for Siegbahn (shared with Bloembergen and Schawlow) “for his contribution to the development of high-resolution electron spectroscopy".
\( \vec{A} \): vector potential of incident light

\( \psi \): incident angle

\( \vartheta \): polar angle of emission

\( \varphi \): azimuthal angle of emission

\( E_{\text{kin}} \): kinetic energy of emitted electron

\( \vec{p} = \hbar \vec{k} = \hbar \frac{2\pi}{\lambda} \vec{e}_k \): momentum of emitted electron

\( \vec{\sigma} \): spin of emitted electron
hemispherical energy analyzer
Three-step model
Chemical shift in XPS

Example:
C 1s XPS signal in ethylfluoroace

![Graph showing chemical shift in XPS with binding energy (eV) on the x-axis and intensity (arb. units) on the y-axis.](image)

- NaCuO₂: Cu³⁺
- CuO: Cu²⁺
- Cu₂O: Cu¹⁺
- Cu metal: Cu⁰⁺
UPS

Cu (110) / θ = 0° (Normal emission)
\( \hbar \omega = 21.2 \text{ eV} \)

Intensity [a.u.]

Binding Energy [meV]

E_{\text{kin}} = \hbar \omega - \Phi

E_{\text{kin}} = 0 (eV)

secondaries
ARPES on graphene
The Universal Curve for the Electron Mean Free Path
New analyzer generation with parallel multi-angle and energy recording

- Improved **energy resolution**
- Improved **momentum resolution**
- Improved **data-acquisition efficiency**

<table>
<thead>
<tr>
<th></th>
<th>$\Delta E$ (meV)</th>
<th>$\Delta \theta$</th>
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</thead>
<tbody>
<tr>
<td>past</td>
<td>20-40</td>
<td>2°</td>
</tr>
<tr>
<td>now</td>
<td>2-10</td>
<td>0.2°</td>
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