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Origin of Elasticity

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Linear elastic behaviour

- Ball and spring model of elasticity:
- Material in tension – bonds stretched and atoms move apart
- Material in compression – bonds compressed and atoms move closer together

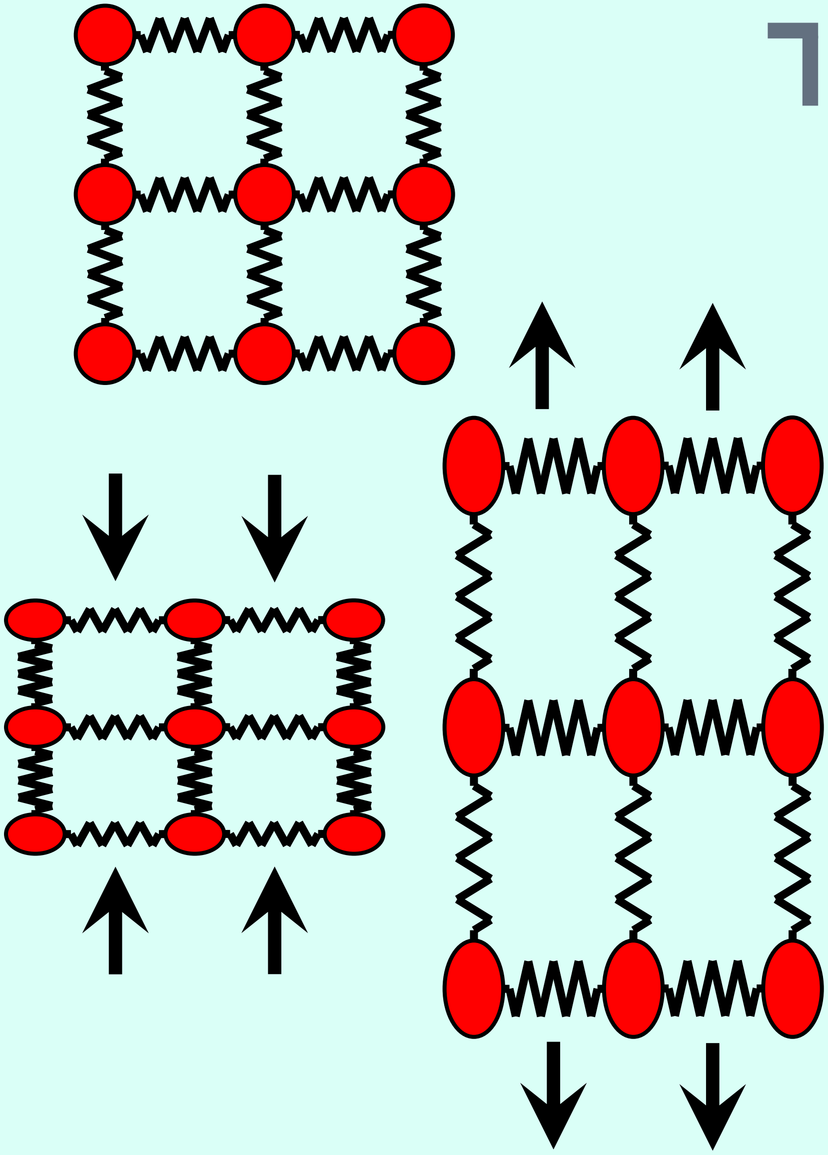

Illustration adapted from: Gordon, J.E., (1978), Structures or Why Thing's Don't Fall Down

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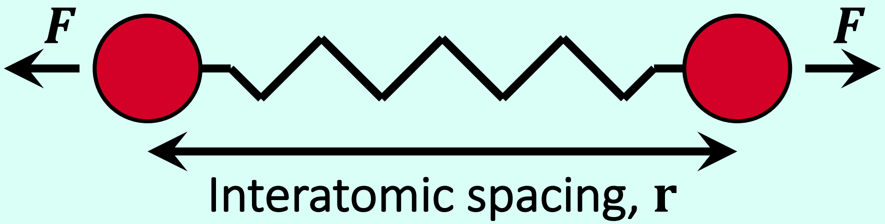
Bonding energies

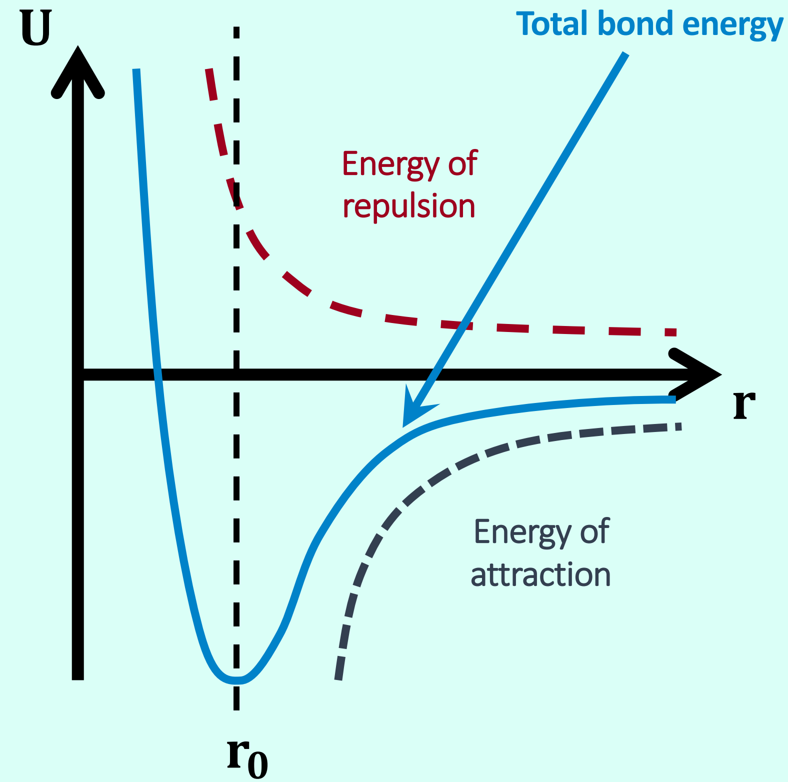


Ball and spring model:

Atoms subjected to competing repulsive and attractive forces

At rest, atoms will be in their lowest energy state

r_0 = equilibrium interatomic spacing
U = potential energy of bond
r = interatomic spacing



Described by: Lennard-Jones, Potential Energy Curve

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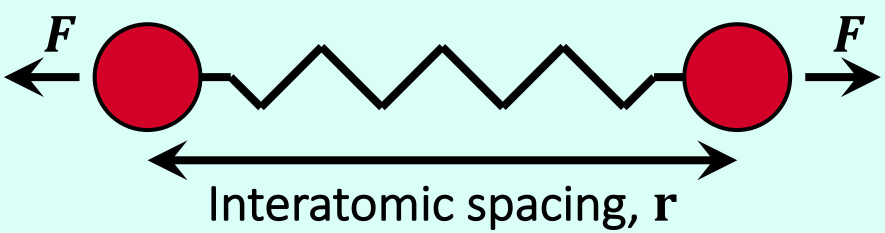
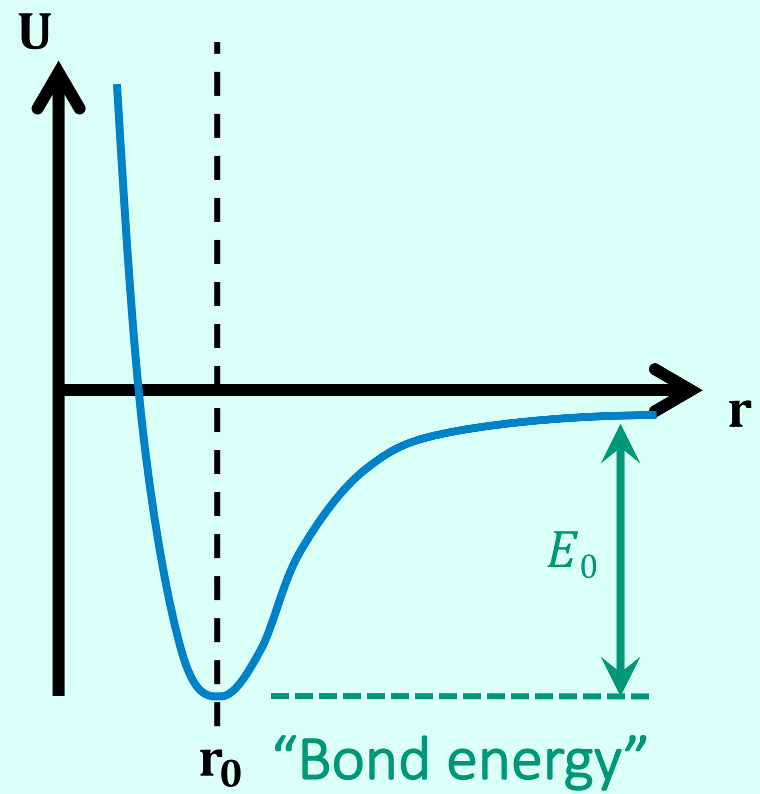
Bonding energies

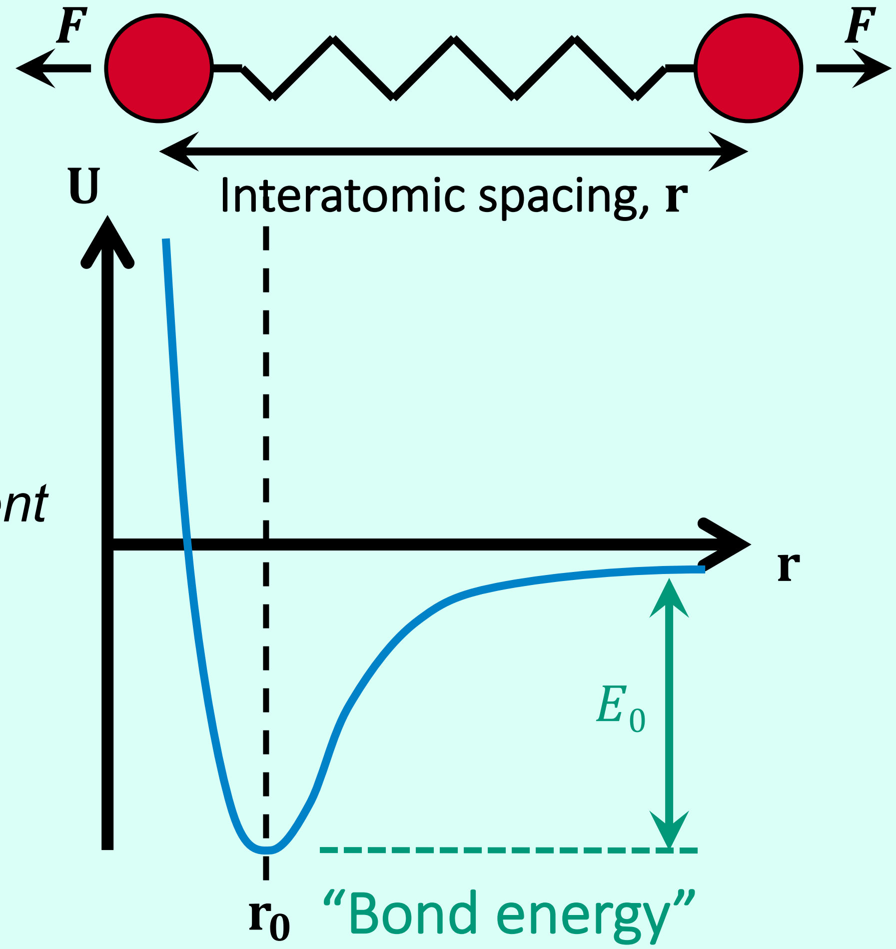


- **Bond energy (E_0)** is the minimum of potential vs spacing curve
- Bond energy describes energy required to break the bond between (dissociate) atoms
- Depth of the 'well' in the total energy curve gives bond strength:
  - Deep well = strong
  - Shallow well = weak



What do bonding energies mean in terms of materials properties?

- Greater bond energy:
  - Greater stiffness (*E*)
  - Greater strength (σ)
  - Higher melting point (T_m)
    Lower thermal expansion coefficient (α)



*Note that there are A LOT of exceptions to these generalisations!

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Deformation

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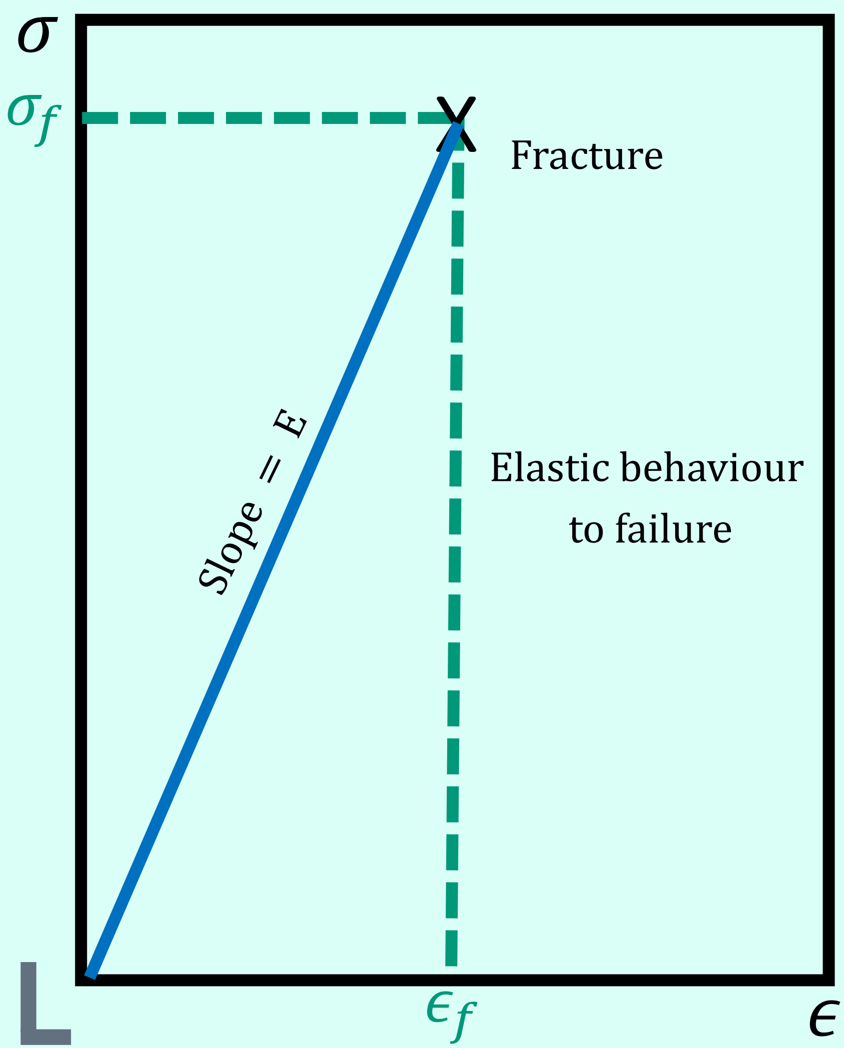
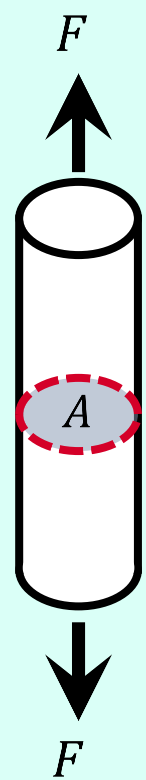
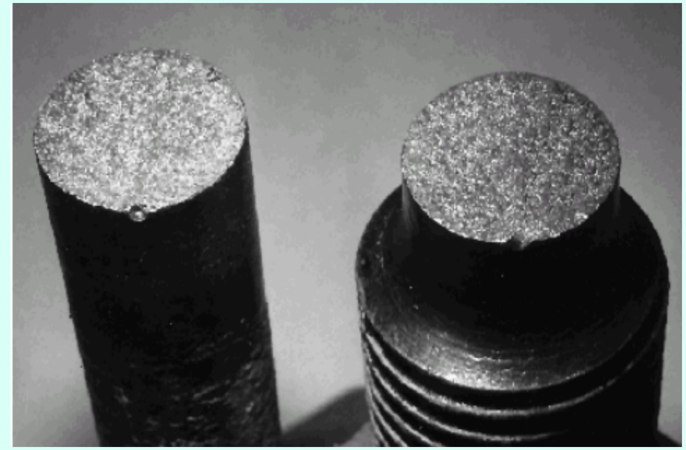
Deformation – Brittle Fracture







Brittle fracture in mild steel

Indirect tensile test of a concrete beam
https://expeditionworkshed.org/workshed/tensile-failure-of-ordinary-concrete-brazilian-test/

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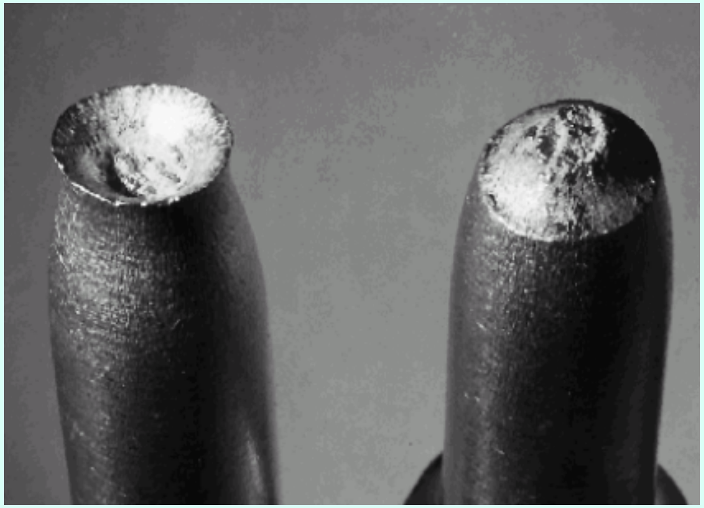
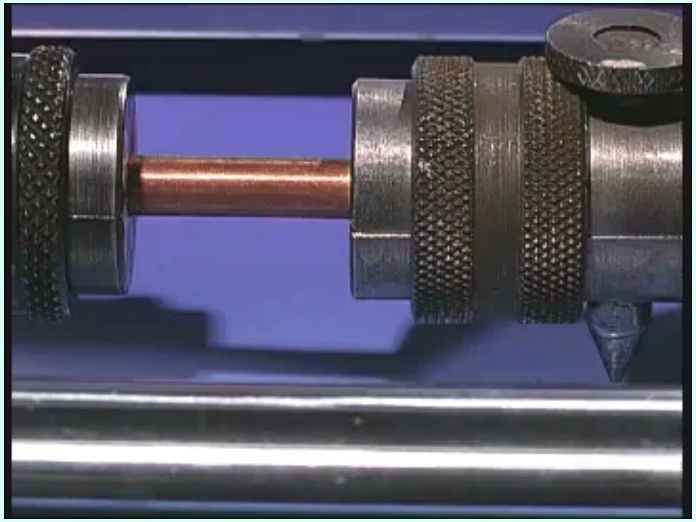
Brittle materials

- In **brittle materials**, **defects or flaws control the strength**. Hence the material is **weak in tension** but **strong in compression**.
- Little/no dislocation movement
- Glass, ceramics, some metals
- Brittle materials lack toughness

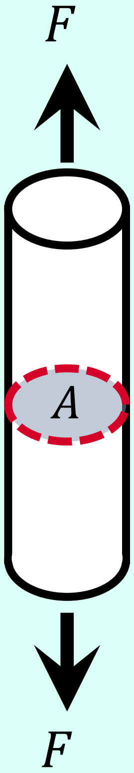
Deformation – Ductile Fracture



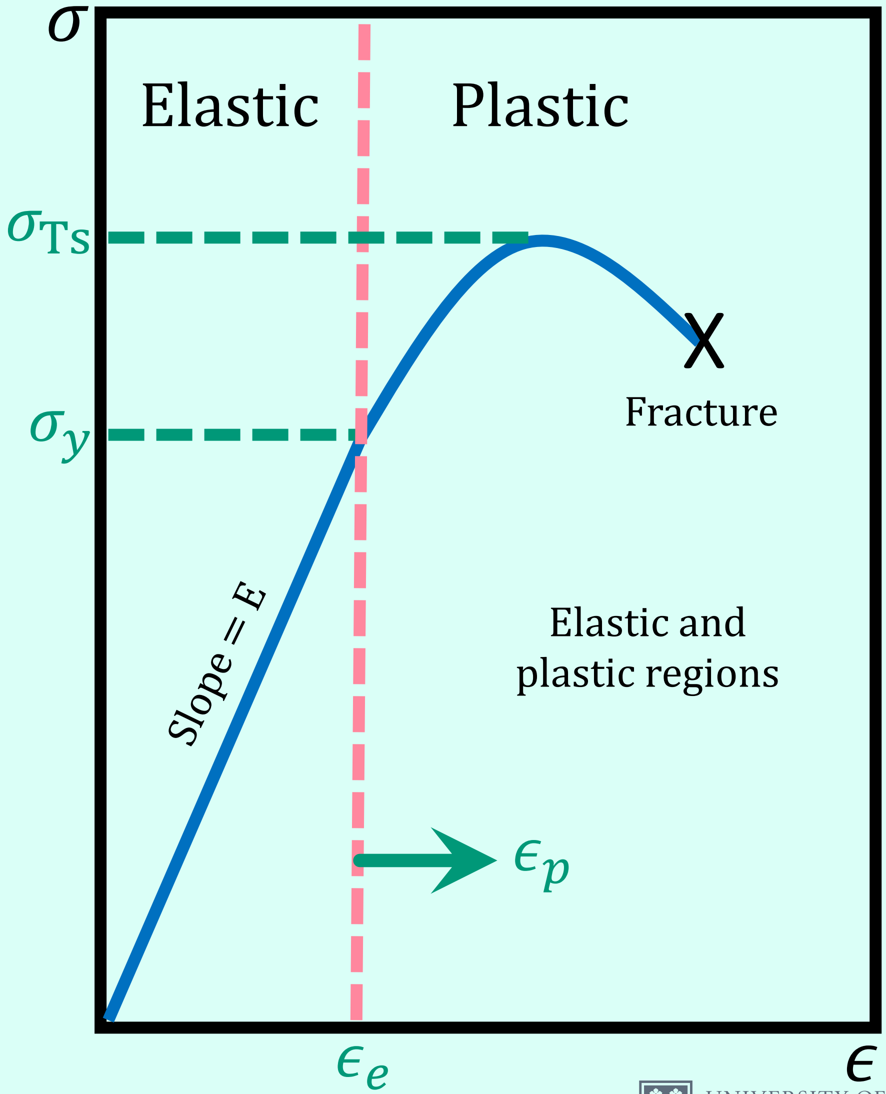
Cup-and-cone fracture in Al



Ductile fracture of annealed copper, Courtesy of DoITPoMS, The University of Cambridge



Total strain, $\epsilon = \epsilon_e + \epsilon_p = \frac{\sigma_y}{E} + \epsilon_p$



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Plastic Deformation

- Shear stresses or direct stresses, depending on the way you look
- Dislocations are a misalignment of atoms in a material.
- In some materials, dislocations can move easily.
  - This is called slip and is the mechanism responsible for plastic deformation.
- In a **ductile** material dislocations can move easily allowing plastic strain to develop above the yield stress of the material.