4.1 Structure and bonding

Name: _____ Class: _____ Date: _____ **Total: 14 marks**

KEY WORDS crystal structure • atomic packing factor • grain refinement

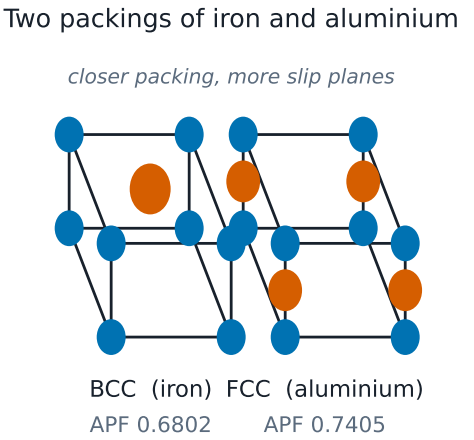
Objective

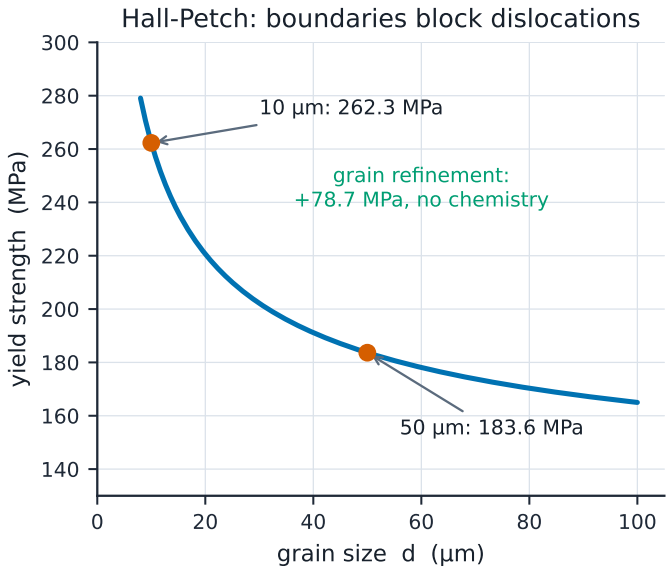
Connect crystal packing and grain structure to yield strength: packing factors, Hall-Petch arithmetic, and the grain size a specification demands.

1 Key knowledge and worked examples

■ Packing and blocking

APF: BCC $\pi\sqrt{3}/8 = 0.6802$, FCC $\pi/(3\sqrt{2}) = 0.7405$. Hall-Petch: $\sigma_y = \sigma_0 + k/\sqrt{d}$.





*Denser packing, finer grains

■ Worked example. The bracket steel

$\sigma_0 = 120$ MPa, $k = 0.45$: at 50 µm, $\sigma_y = 183.6$ MPa; at 10 µm, 262.3 MPa ✓ - a 78.7 MPa gain from processing alone.

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2 Practice

A steel has $\sigma_0 = 100$ MPa and $k = 0.60$ MPa $\cdot \sqrt{\text{m}}$.

2.1 The yield strength at grain sizes 25 µm and 16 µm (one decimal each). [4]

2.2 The largest grain size that meets a 300 MPa specification (micrometres, one decimal). [3]

2.3 The atomic packing factors of BCC and FCC (four decimals each), computed from the hard-sphere geometry. [4]

2.4 One sentence each: why does FCC deform more easily than BCC at room temperature, and why do grain boundaries strengthen a metal? [3]

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Solutions

2.1

- $\sigma_y(25) = 100 + 0.60/\sqrt{25 \times 10^{-6}} = 100 + 120.0 = 220.0$ MPa.
- $\sigma_y(16) = 100 + 0.60/0.004 = 250.0$ MPa.

2.2

- $100 + 0.60/\sqrt{d} \geq 300$ gives $\sqrt{d} \leq 0.003$ m$^{1/2}$.
- $d \leq 9.0$ µm.

2.3

- BCC: $2 \times \frac{4}{3}\pi(\sqrt{3}a/4)^3/a^3 = \pi\sqrt{3}/8 = 0.6802$.
- FCC: $4 \times \frac{4}{3}\pi(\sqrt{2}a/4)^3/a^3 = \pi/(3\sqrt{2}) = 0.7405$.

2.4

- FCC's closer packing (0.7405 vs 0.6802) carries more close-packed slip systems, so dislocations glide more easily.
- Grain boundaries block dislocation motion; more boundaries (smaller grains) mean more blocking and higher yield.

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