## 2.2.2 Alloys

Pure metals are rarely used - in the real world you use **alloys**.

In principle, the specific resistivity ρ of an alloy can be obtained from the phase diagram and the ρ - values of the phases involved. Lets look at the extremes:

1. Complete *immiscibility*, e.g. in the case of **Au/Si**, or **Cu/W**. We may treat the resulting mix of metal particles as a *network of resistors* being linked in series and parallel. The volume fractions of the phases would constitute the weights - the treatment is not unlike the elastic modulus of compounds.
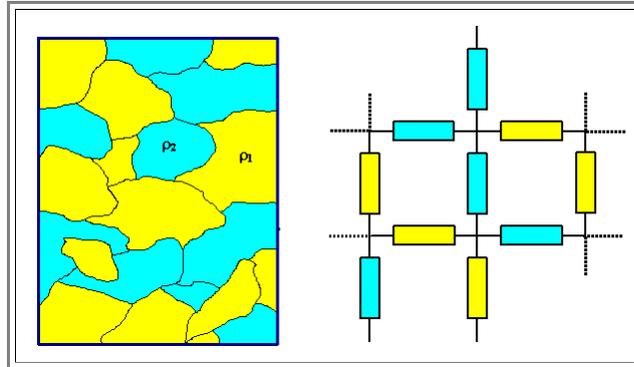
But no matter what kind of volume fraction you use and how you treat the resistor network - the resulting resistivity will *never* be smaller than that of the ingredient with the smallest resistivity.

2. Complete *miscibility* (e.g. **Au/Ag**, **Cu/Ni**). Experimentally we find for small amounts (some **%**) of **B** in **A** (with **[B]** = concentration of **B**)

$$\rho \approx \rho_A + \text{const.} \cdot [B]$$

This formula is a special case of **Nordheims rule** which states .

$$\rho \approx X_A \cdot \rho_A + X_B \cdot \rho_B + \text{const.} \cdot X_A \cdot X_B$$

This is pretty much an empirical law, it does not pay to justify it theoretically. Again, it is not possible to produce an alloy with a *resistivity smaller than one of its components*.

If you have *intermetallic compounds* in your phase diagram, use Nordheim's rule with the intermetallic phases as X_A and X_B.

This leaves open the possibility that some intermetallic phase, i.e. a defined compound with its own crystal lattice, might have a lower resistivity than its constituents. While this is unlikely (if not outright impossible?) on theoretical grounds, no such intermetallics have been found so far.

The sad fact then is that unleashing the full power of metallurgy and chemistry on mixing conductors (i.e. metals), will not give you a conductor with a specific conductivity better than **Ag**.
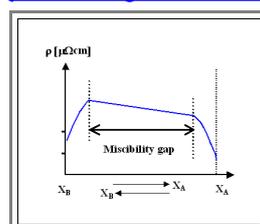
You will have to turn to **superconductors** (forgetting about cost considerations), if you can't live with **Ag**.
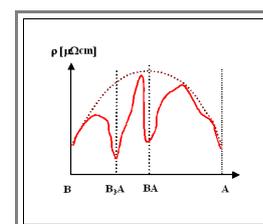
Lets look at some examples:

Complete miscibility
(e.g. **Au/Ag**)
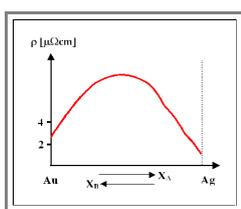
Miscibility gap
(e.g. **Ag/Cu**);
phase diagram in the link.

Intermetallic phases
(e.g. **Cu/Au**)

What do we learn? Something simple:

- Again: The resistivity *always* goes up in alloys or mixed materials as compared to the pure materials.
- Things are generally complicated, but *full of potential* for custom tailored properties!

Questionaire
Multiple Choice questions to 2.1.2