

## 2.2.4 Summary to: Conductors - Definitions and General Properties

What counts are the *specific* quantities:

- Conductivity  $\sigma$  (or the specific resistivity  $\rho = 1/\sigma$ ).
- current density  $j$ .
- (Electrical) field strength  $\cdot E$ .

The basic equation for  $\sigma$  is:  
 $n$  = concentration of carriers,  
 $\mu$  = mobility of carriers.

Ohm's law states:  
 It is valid for metals, but not for all materials.

$$[\rho] = \Omega\text{m}$$

$$[\sigma] = (\Omega\text{m})^{-1} = \text{S/m}; \text{S} = \text{"Siemens"}$$

$$\sigma = |q| \cdot n \cdot \mu$$

$$j = \sigma \cdot E$$

$\sigma$  (of conductors / metals) obeys (more or less) several rules; all understandable by looking at  $n$  and particularly  $\mu$ .

Matthiesen rule:  
 Reason: Scattering of electrons at defects (including phonons) decreases  $\mu$ .

" $\rho(T)$  rule":  
 about **0,04 %** increase in resistivity per **K**  
 Reason: Scattering of electrons at phonons decreases  $\mu$ .

Nordheim's rule:  
 Reason: Scattering of electrons at **B** atoms decreases  $\mu$ .

$$\rho = \rho_{\text{Lattice}}(T) + \rho_{\text{defect}}(M)$$

$$\Delta\rho = \alpha_{\rho} \cdot \rho \cdot \Delta T \approx \frac{0,4\%}{^{\circ}\text{C}}$$

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

Major consequence: You can't beat the conductivity of pure **Ag** by "tricks" like alloying or by using other materials  
 (Not considering superconductors).

Non-metallic conductors are *extremely* important.

Transparent conductors (TCO's)  
 ("ITO", typically oxides).

Ionic conductors (liquid and solid).

Conductors for high temperature applications; corrosive environments, ..  
 (Graphite, Silicides, Nitrides, ...).

Organic conductors (and semiconductors).

No flat panels displays = no notebooks etc. without **ITO**!

Batteries, fuel cells, sensors, ...

Example: **MoSi<sub>2</sub>** for heating elements in corrosive environments (dishwasher!).

The future High-Tech key materials?

Numbers to know (order of magnitude accuracy sufficient)

$\rho$ (decent metals) about **2  $\mu\Omega\text{cm}$** .  
 $\rho$ (technical semiconductors) around **1  $\Omega\text{cm}$** .  
 $\rho$ (insulators) > **1  $\text{G}\Omega\text{cm}$** .

### Questionnaire

All Multiple Choice questions to 2.1