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Electrical resistivity testing.

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Electrical resistivity testing

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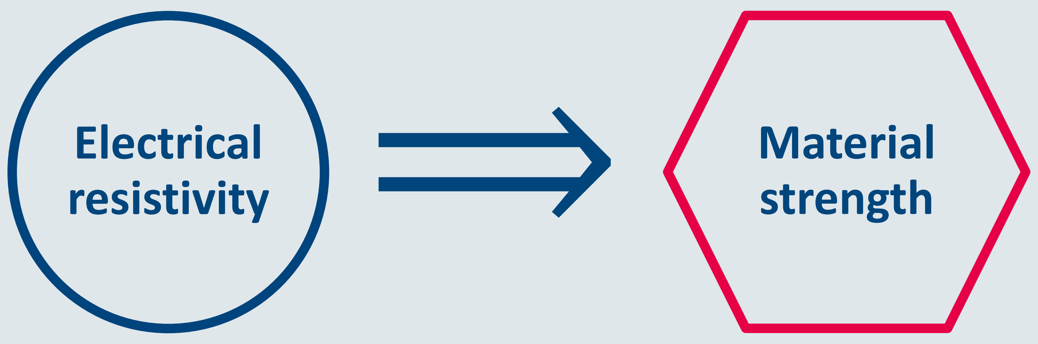
Objectives

- Quantification of the material strength of material states of the Mg-Ag system
- Development of a combined model for attribution and evaluation of the resistivity
- Design and establish a robust quality testing methods for tailorable material properties

Goal: Attribution of the electrical resistivity to the microstructure and properties

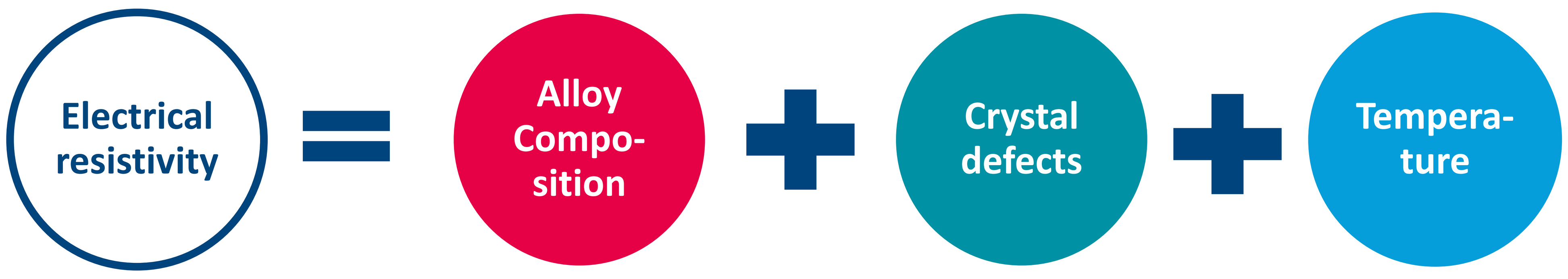


Four point probe resistivity measurement is used as a non-destructive, fast and simple method suitable for large scale quality control.

Material strength is a multiscale property composed of multiple microstructural aspects. By combining **solid solution hardening** and **dislocation hardening** the electric properties can depict the mechanical strength.

First principle approach

Matthiesen rule describes the resistivity as the sum of all intrinsic and temperature dependent properties:



Alloy composition

Alloying elements perturb the electron flow in the magnesium lattice and cause scattering. For dilute concentrations the resistivity increases linearly.

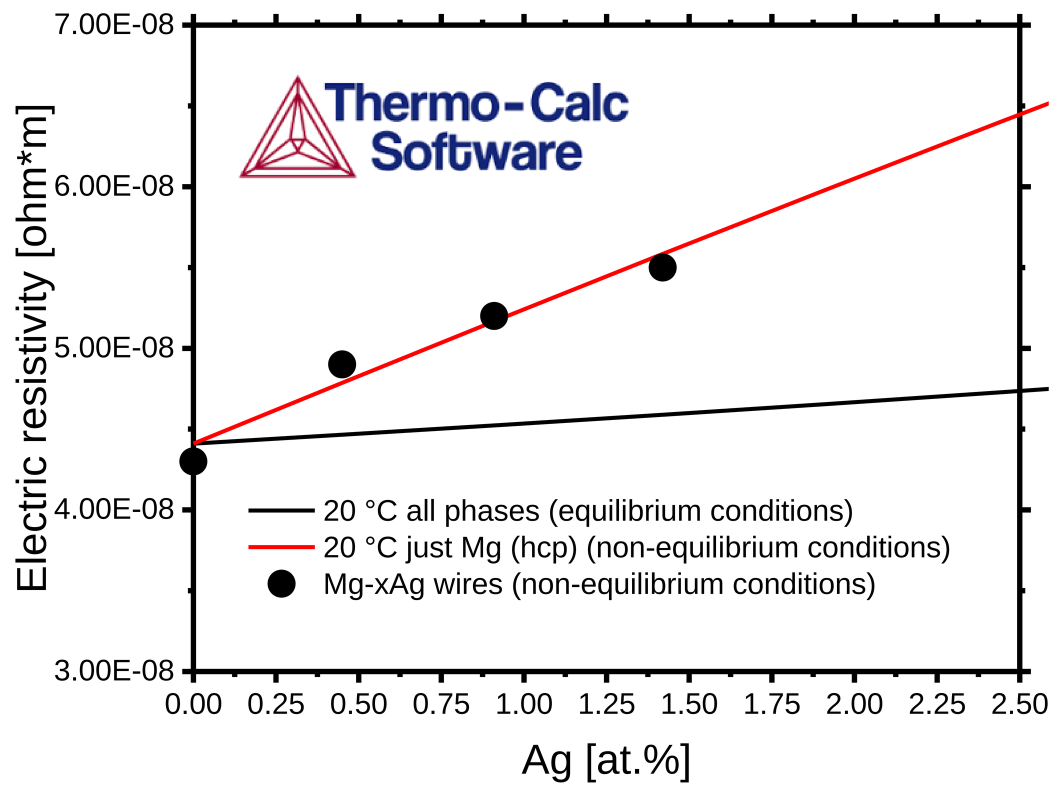
- **Elements**

  specific Nordheim constant C

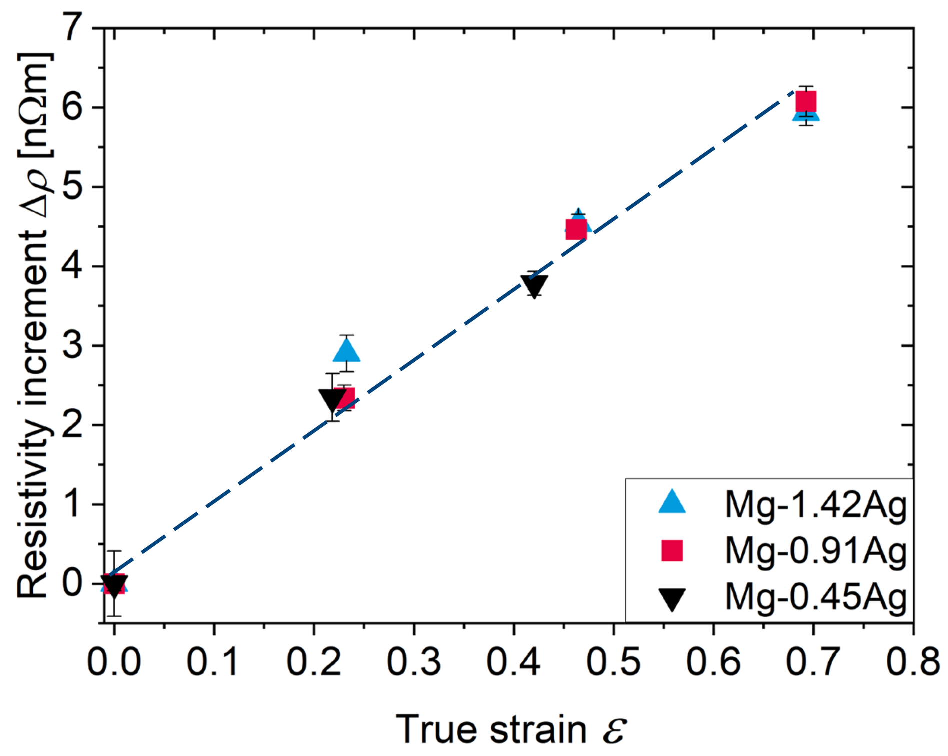
- **Concentration**

  $\rho(x) = C \cdot x[\text{at.\%}]$

Mg alloying element	C [nΩm/at.%]
Ag	6.8
Zn	7.8
Al	17.0
Gd	86.0



Crystal characterization



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With increasing plastic strain, the concentration of crystal defects such as dislocations increases.

- **True strain**

  $\rho(\varepsilon) = k \cdot \varepsilon$

Element	k [nΩm]
Mg	8.9

Work hardening

The material strength is increased by dislocation pile ups, which impede their movement and further plastic deformation

strain	R_{tm}
0	226
0.23	290
0.46	375

- Work hardening

  324 MPa/true strain

- Resistivity sensitivity

  36 MPa/nΩm

Solid solution hardening

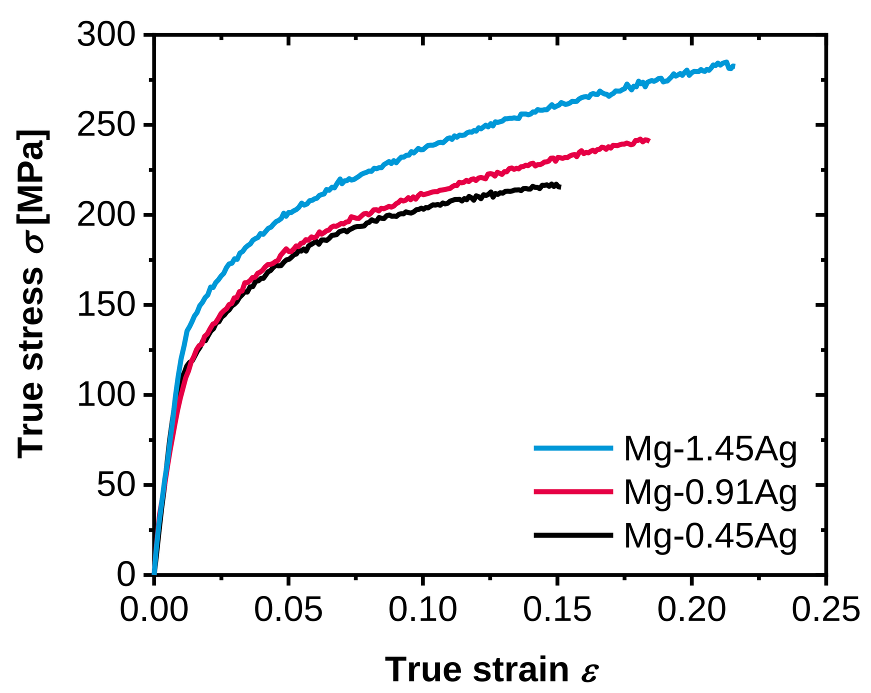
Dissolved foreign atoms also act as an obstacle to dislocation movements during plastic deformation. The strength increases with concentration approx. linearly.

- Solid solution hardening

  69 MPa/at.% Ag

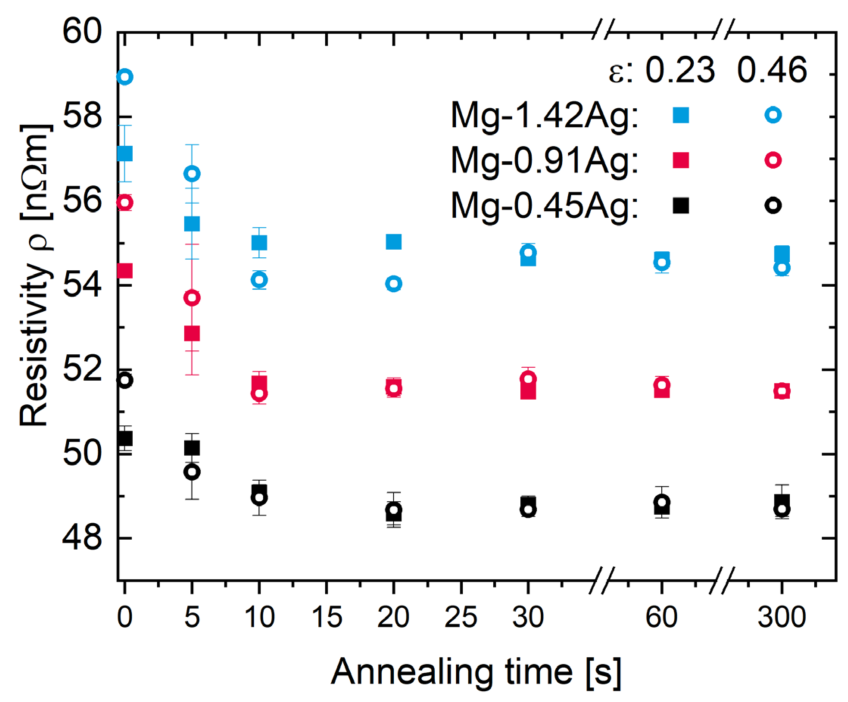
- Resistivity sensitivity

  10 MPa/nΩm



Attribution and Application

- In quality control, the alloy concentration can be checked in a known system, especially accurate with elements of high Nordheim constants.
- Quantitatively, work hardening (36 MPa/nΩm) has greater impact on resistivity, in the Mg-Ag system than solid solution hardening (10 MPa/nΩm).
- The resistivity evolution can be used to determine suitable heat treatments. An example is shown in the right diagram. The strength and the recrystallization state can be calculated and adjusted.



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