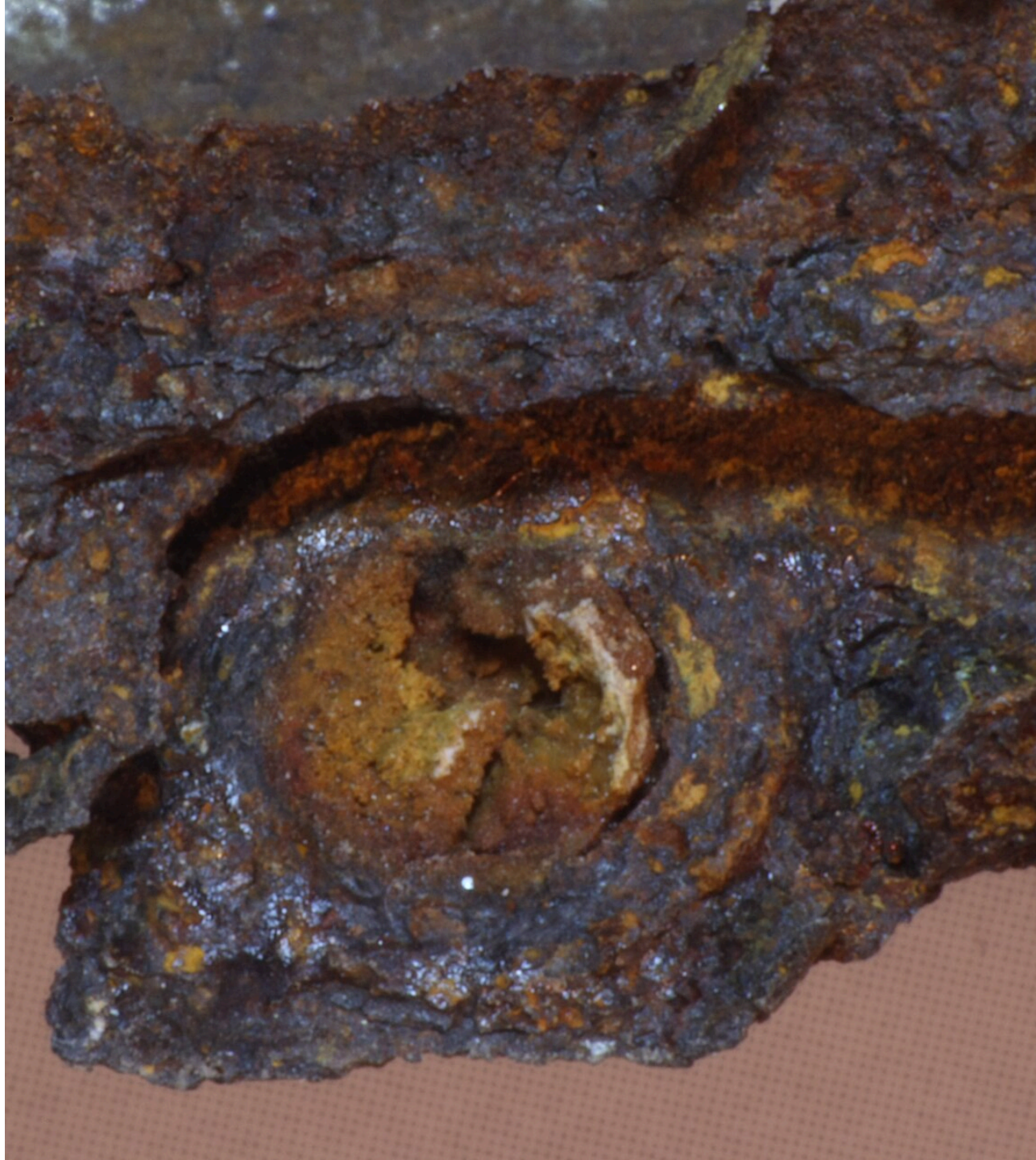
Corrosion

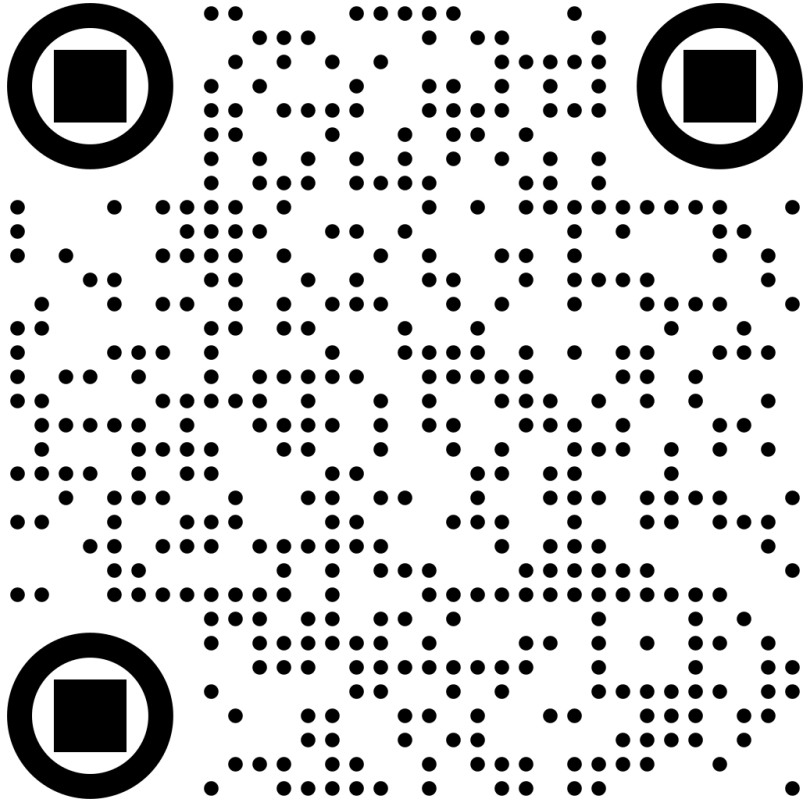
Prof. Dr.-Ing. Christian Willberg
University of Applied Sciences
Magdeburg-Stendal

Contact: christian.willberg@h2.de

Parts of the script are taken from
Prof. Dr.-Ing. Jürgen Häberle



Contents



Corrosion

- divided into chemical, electrochemical, or physical reactions of metals with the environment
- affects the material properties
- most corrosion damages are electrochemical

Further Reading

Chemical Corrosion

- immediate reaction of metals with the environment
- involves direct electron exchange
- reaction partner is usually oxygen $\mathrm{O_2}$
  Example:
  $\mathrm{Mg + O_2 \rightarrow MgO_2}$
- mostly occurs at higher temperatures (process: scaling)

Electrochemical Reaction

- most corrosion damages are electrochemical
- two partial reactions, often spatially separated
- both reactions require an exchange of charge carriers
    - metals enable this through their conductivity
    - outside the metal, the circuit is closed by an electrolyte

Electrolyte

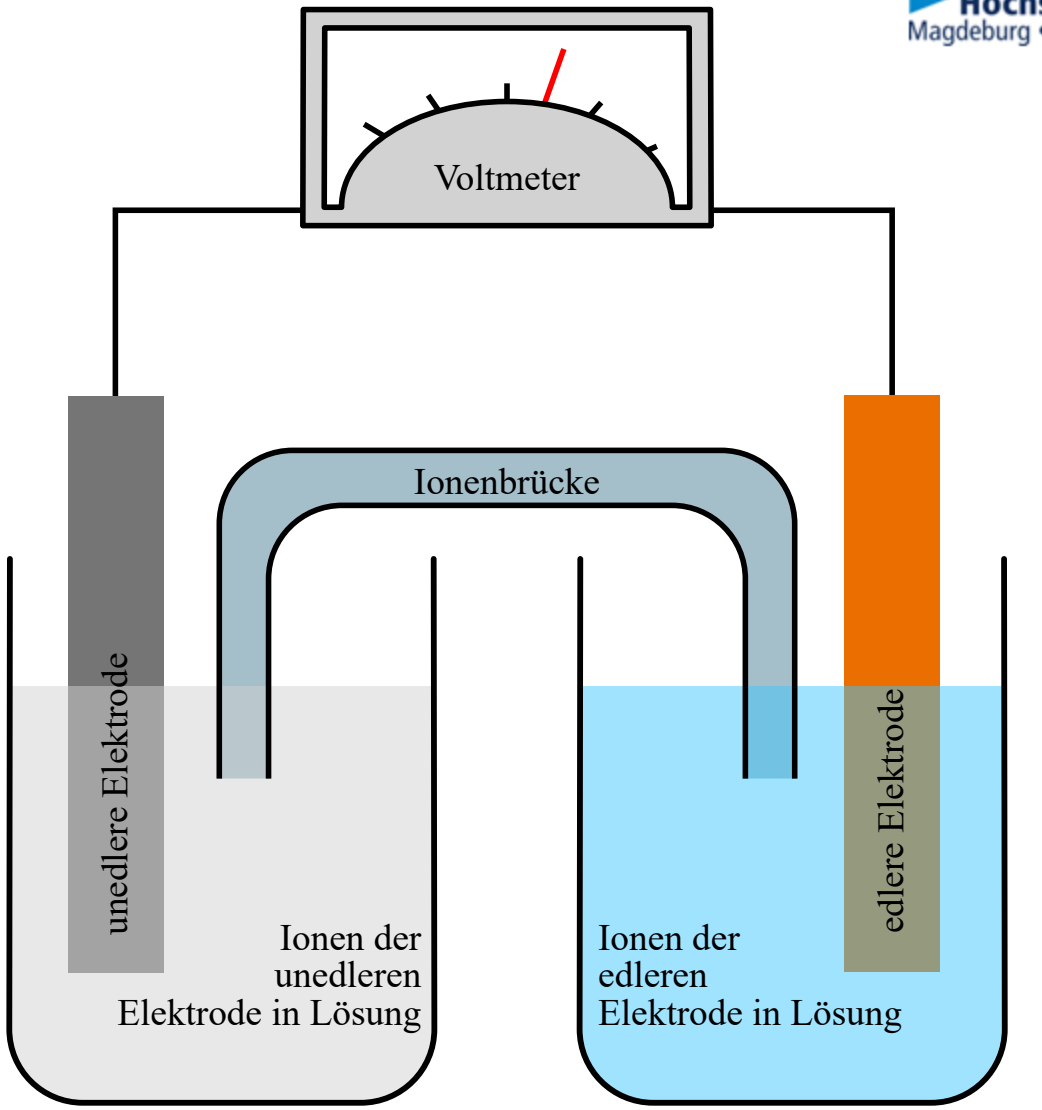
- a medium in which ions can move (*ion conduction*)
- mostly aqueous solutions
- also includes soil, molten salts, or solids (used in fuel cells)

Degree of Dissociation

- determines the aggressiveness of the electrolyte
- the further the ion concentration deviates from the concentration in water, the more aggressive the electrolyte
- can be represented by pH value.
  pH < 7 acidic
  pH = 7 neutral
  pH > 7 basic (alkaline)

Schematic of a Galvanic Cell

- Anions - negative ions
- Cations - positive ions
- under direct current, negatively charged ions migrate to the anode
- Spatial separation (Anode, Cathode)



Galvanization

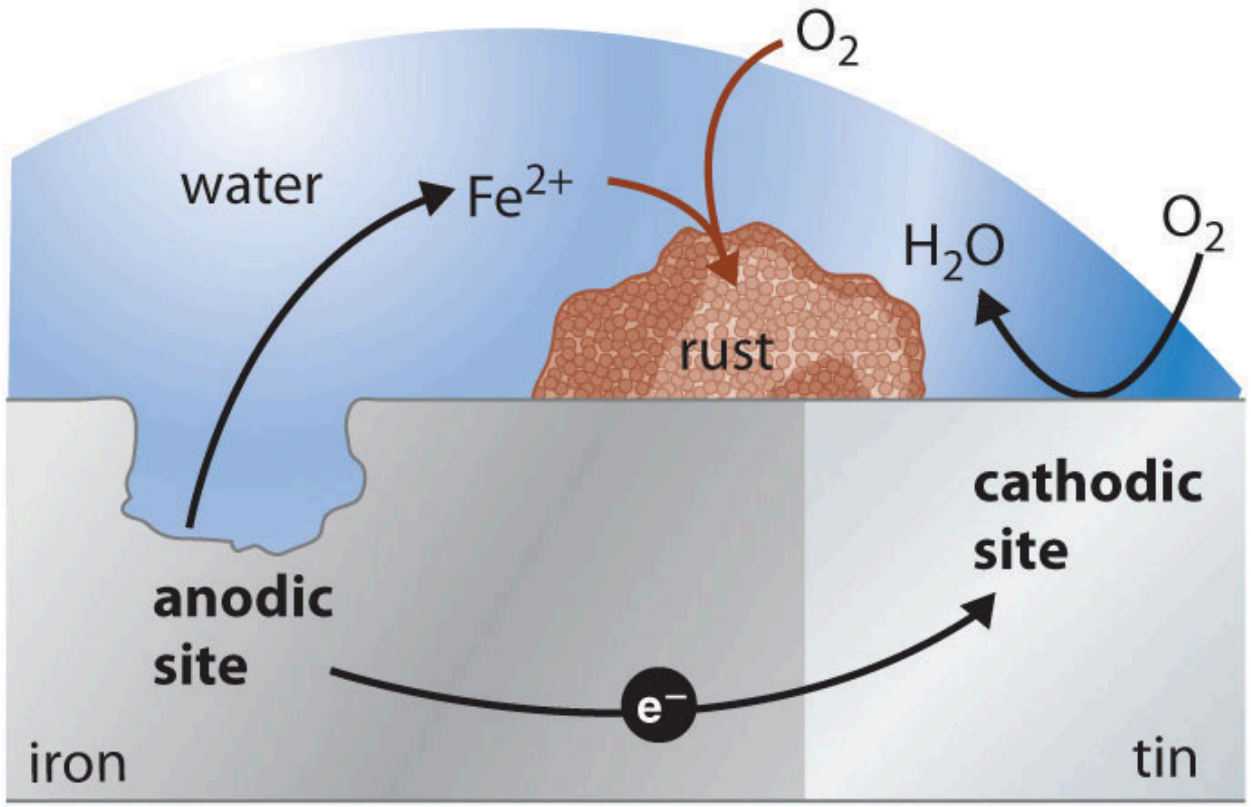
- the cathode reaction is a reduction

$$\text{Metal ion} + \text{Electron} \rightarrow \text{Metal atom}$$

- a deposit forms on the surface
- principle of electroplating
- at the anode, oxidation occurs (release of electrons)

Schematic of Corrosion Element

- two components
- conductively connected areas
  - two metals
  - identical metals with different electrical potentials
- Electrolyte wetting



- the nobler material becomes the cathode
- the less noble electrode becomes the anode
  - as in galvanization, the anode releases electrons
    $\mathrm{Metal} \rightarrow \mathrm{Metal}^{++} + 2\mathrm{e}^{-}$
  - it dissolves and corrodes
- At the cathode, a metal-metal ion reaction cannot occur
  - a redox reaction takes place
  - hydrogen corrosion or oxygen corrosion

Metal	Potential	Corrosion behavior
Gold	+1.50 V	noble
Platinum	+1.18 V	
Silver	+0.80 V	
Copper	+0.34 V	
Hydrogen	+0.00 V	neutral
Tin	-0.14 V	
Iron	-0.41 V	
Zinc	-0.76 V	
Titanium	-1.75 V	

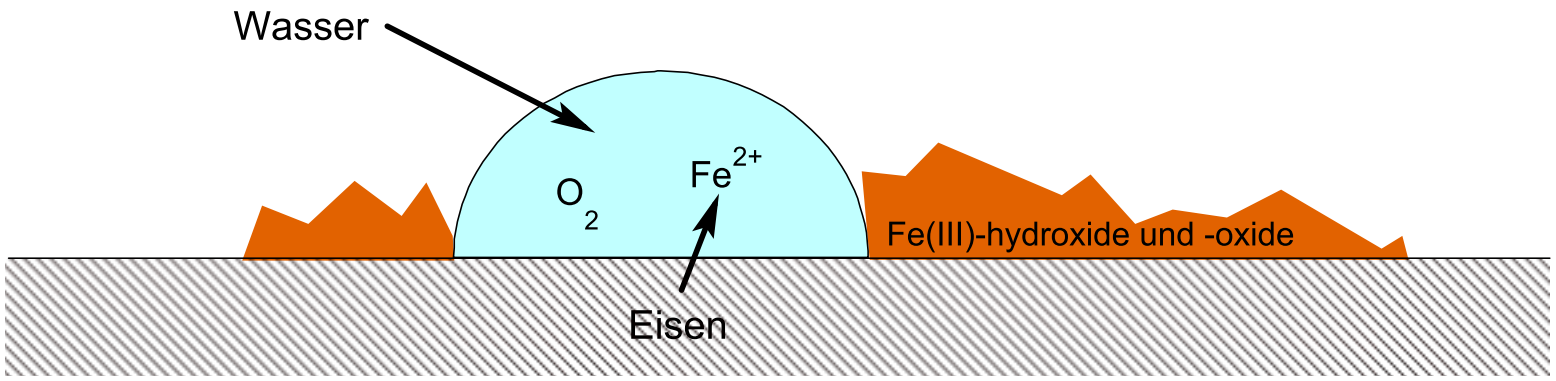
Hydrogen Corrosion

- only possible in very acidic electrolytes
- occurs in the presence of water but in the absence of oxygen

> Acid corrosion

Oxygen Corrosion

- free electrons react with water to form hydroxide ions
  $\mathrm{H_2O} + \frac{1}{2}\mathrm{O_2} + 2\mathrm{e^-} \rightarrow 2\mathrm{OH^-}$
  $2\mathrm{Fe^{2+}} + 4(\mathrm{OH})^- + \mathrm{H_2O} + \frac{1}{2}\mathrm{O_2} \rightarrow 2\mathrm{Fe(OH)_3}$
- can decompose further



Physical Corrosion

- Microcracks or dislocations form due to stress, where corrosion can begin
- Corrosion occurs in combination with a mechanical load (static or dynamic - oscillating)

Types of Corrosion

- 36 types of corrosion according to DIN EN ISO 8044

Surface Corrosion

- large area corrosion
- easily visible and relatively harmless
- the coating layer provides corrosion protection

Types of Corrosion

Pitting Corrosion

- often goes unnoticed for a long time
- can expand in a trough shape in depth

Types of Corrosion

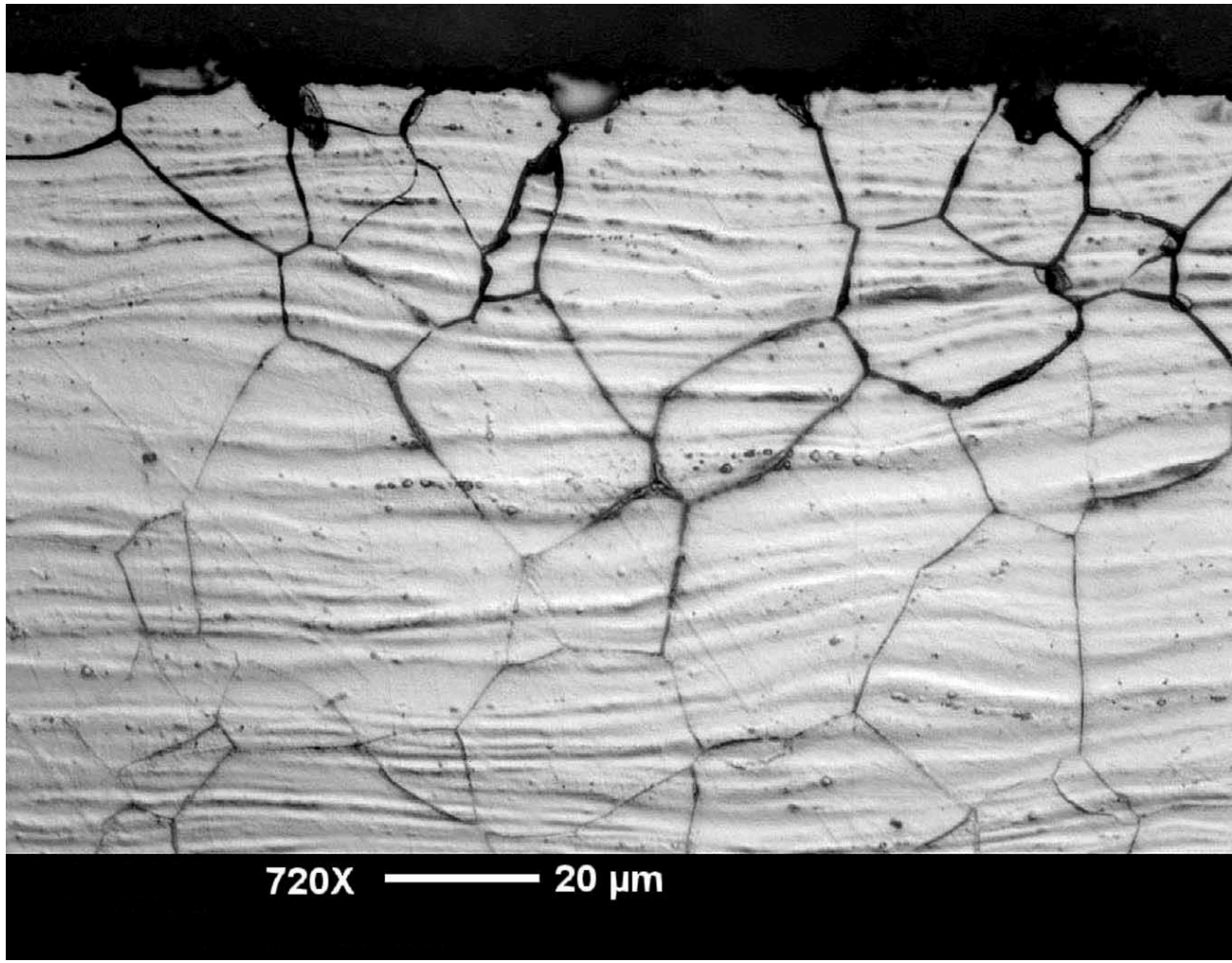
Crevice Corrosion

- occurs on metal parts in narrow, non-closed crevices like overlaps, applied ridges, and in non-continuously welded seams
- difficult to detect
- should be structurally avoided in critical areas

Types of Corrosion

Intergranular Corrosion

- also known as grain boundary corrosion
- occurs at grain boundaries
- Reminder: Influence of the crystal lattice - aggressive media attack preferential planes



Other Types of Corrosion

- Microbial Corrosion
  - Sewage
  - Aviation fuel
  - Fungal infestation
- Undermining Corrosion
- High-Temperature Corrosion
- Stress Corrosion Cracking
  - the protective layer is breached, leading to corrosion
- ...

Corrosion Protection

- Distinguishable between passive and active protection
- Passive: Separation of metal and electrolyte / corrosive medium
- Active: Complete separation is not necessary

Corrosion Protection

- Work in small groups, 10–15 minutes of research
- group work:
- Identify 3 passive methods
- Identify 3 active methods
- Brief presentation of results (use the board if needed)
    - Highlight the main takeaways