Aalto University

# Zinc and its chemistry

*Akseli Rautakorpi, Henrik Stenbrink, Patrick Hyvärinen*
*School of chemical engineering*
*Aalto university*

# OVERVIEW

1. General information
2. Chemistry
3. Compounds
4. Applications

# General information

# 1. General information

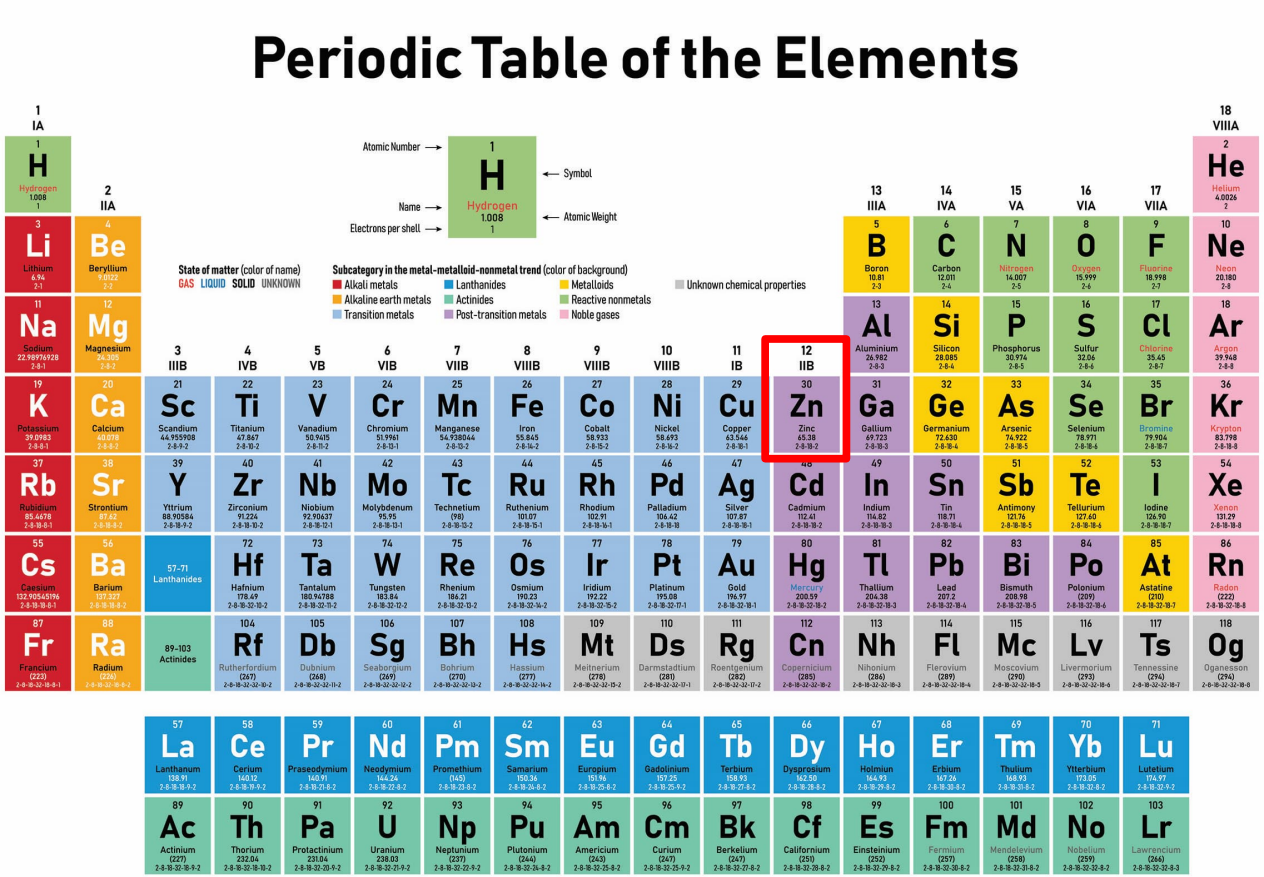
- **Discovered by Andreas Marggraf, 1746, German**
- **Zinke = Prong, Tooth**
- **Properties: Brittleish, silver-gray, relatively low m.p.**
- **Uses: Galvanization (50%), batteries, dietary supplements**
- **24th most abundant in earth's crust**
- **Annual production: ~14 million tonnes (recycling ~30%)** **[1]**



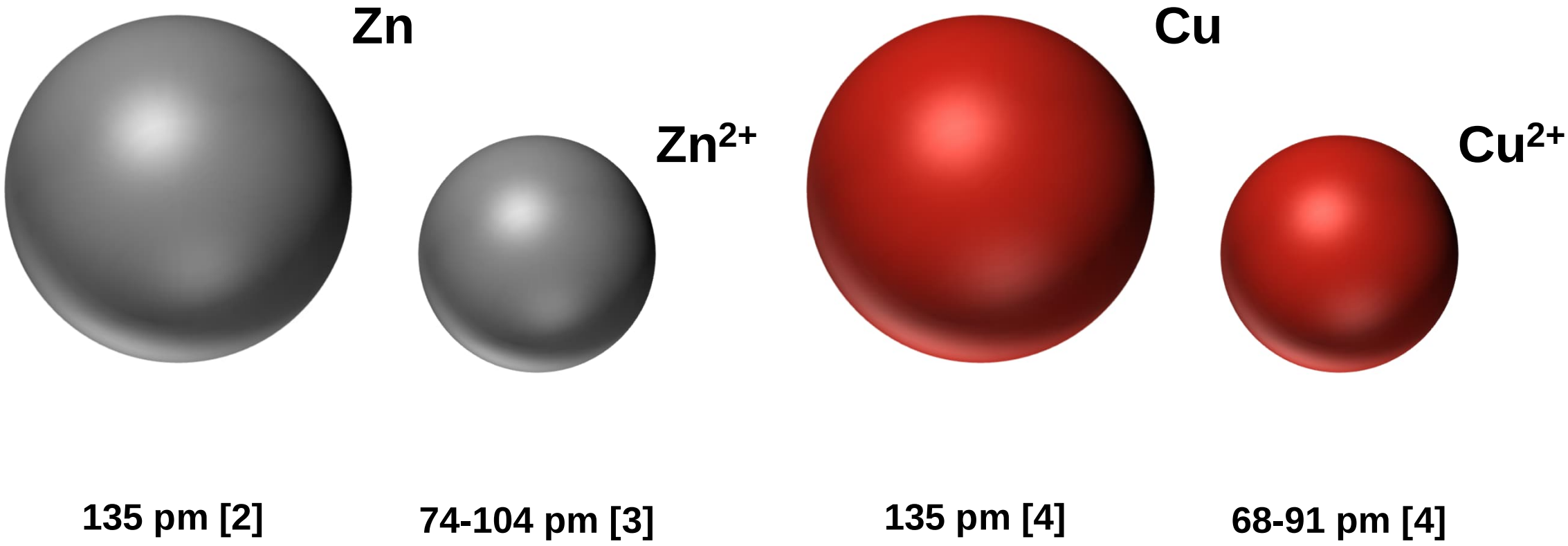
[1] https://en.wikipedia.org/wiki/Zinc

# Chemistry of zinc

# 2. Chemistry of zinc



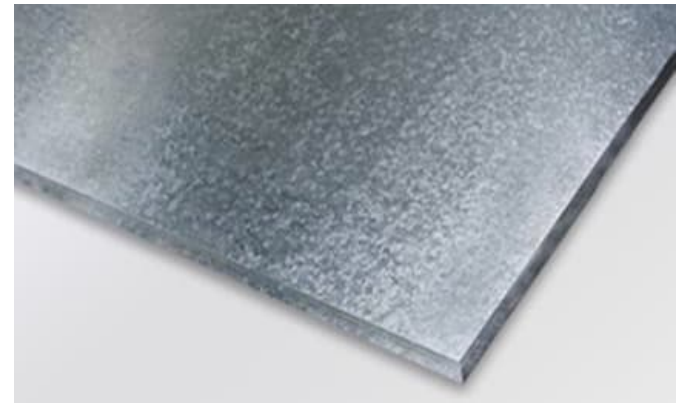

# 2. Chemistry of zinc

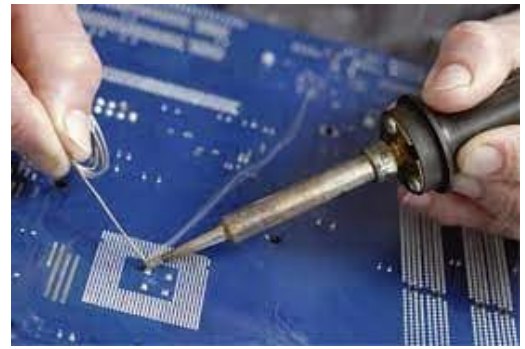



[2] J. C. Slater, ”Atomic radii in crystals”, 1964
[3] http://abulafia.mt.ic.ac.uk/shannon/radius.php?Element=Zn
[4] https://www.webelements.com/copper/atom_sizes.html

# 2. Chemistry of zinc

- **Reaction with air → ZnO**
- **Reaction even with weak acids → $H_2$**
- **Reaction with alkalies → zincates $[Zn(OH^-)4]^{2-}$**
- **Alloying with similarly sized metal atoms**





# Compounds

# 3. Compounds and their properties and common applications

**Zinc Oxide, ZnO**

- High melting point of 1975 C
- One of the most common zinc compunds used in industry. Common uses are use in rubber, photocopy paper and paints.

**Zinc carbonate, $ZnCO_3$**

- Colourles crystal or white crystalline powder. Evoleves carbon dioxide at 300 C
- Used as fireproofing filler for rubber and plastic compositions exposed to high temperatures

**Zinc chloride, $ZnCl_2$**

- Melting point of 275 C and boiling point of 756 C
- High variety of applications ranging from fluxes to use in medicine. **[5]**



[5] Department of Climate Change, Energy, the Environment and Water, *Zinc and compounds*, https://www.dcceew.gov.au/environment/protection/npi/substances/fact-sheets/zinc-and-compounds 16.9.2022

# 3. Compounds and their properties and common applications

**Zinc acetate, $(CH_3COO)_2Zn$**

- Decomposes at 200 C
- Common uses are in wood preserving,

**Zinc fluoride, $ZnF_2$**

- Exists as colourless crystals or white crystalline mass. Melting point 872 C and boiling point 1502 C
- Used in fluorination of organic compaunds and manufacturing of phosphors for fluorescent lights. Also used in medicine. **[5]**



[5] Department of Climate Change, Energy, the Environment and Water, *Zinc and compounds*, https://www.dcceew.gov.au/environment/protection/npi/substances/fact-sheets/zinc-and-compounds 16.9.2022

# 3. Compounds and their properties and common applications

**Other common zink compunds:**

- Zinc chromate, ZnCrO4
- Zinc cyanide, $Zn(CN)_2$
- Zinc phosphide, Zn3P2
- Zinc sulfate, $ZnSO_4$
- Zinc sulfide, ZnS **[5]**



[5] Department of Climate Change, Energy, the Environment and Water, *Zinc and compounds*, https://www.dcceew.gov.au/environment/protection/npi/substances/fact-sheets/zinc-and-compounds 16.9.2022

# Applications

# ZnO in thin film technology

# 4. ZnO in thin film technology

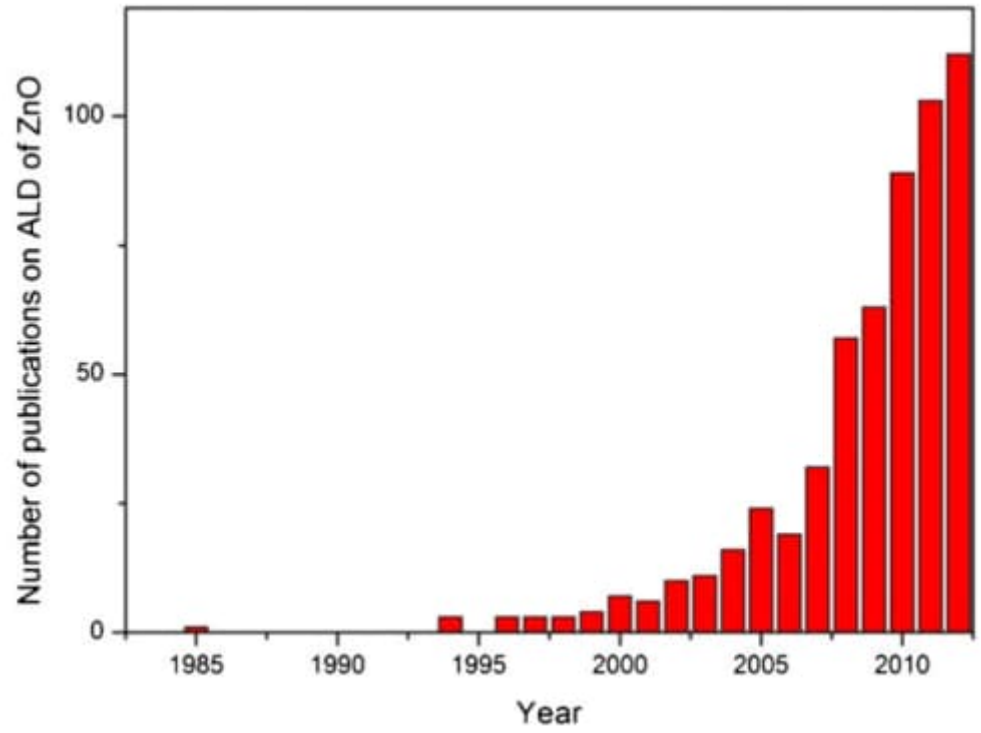
**Usefull properties of ZnO for use in thin films**

- Band gap of 3.37 eV
- High transparency to visible light
- ZnO is easely synthesized in thin film form using different techniques
- Low cost

**Applications for ALD ZnO thin films**

- Solar cells
- Thin-film transistors
- Gas censors

**[6]**






[6] Tommi Tynell and Maarit Karppinen 2014 Semicond. Sci. Technol. 29 043001.

# 4. ZnO in thin film technology

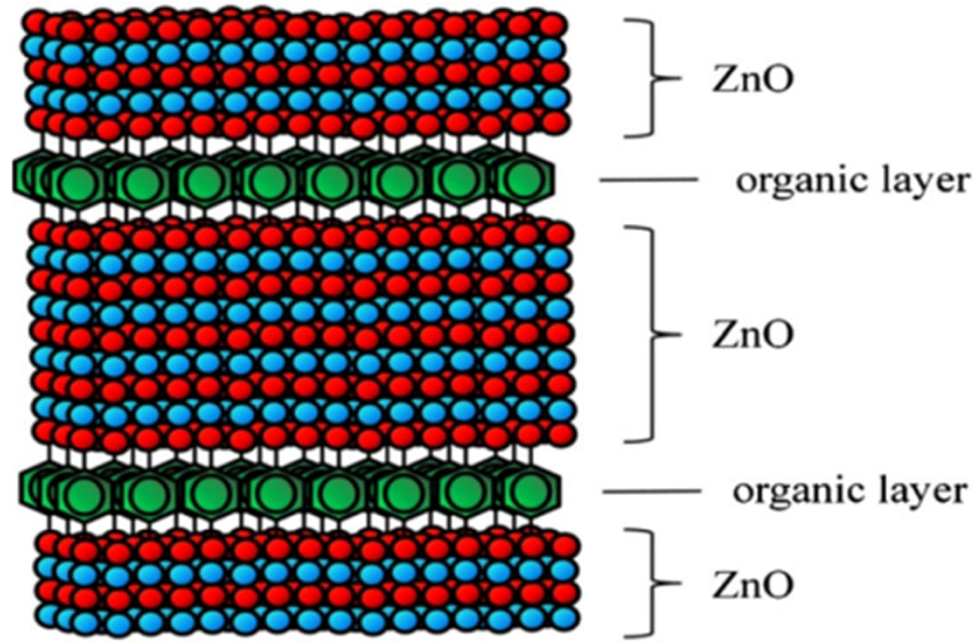
## Inorganic–organic hybrid thin films

- Using organic compunds in inorganic-organic superlattice thin films can be used to modify the properties of thin films
- Properties that can be modified include:
  - *Heat conductivity*
  - *Mechanical properties*

## Potential applications

- Wearable electronics
- Implantable medical devices

**[7]**






[7] Ramin Ghiyasi, Milena Milich, John Tomko, Patrick E. Hopkins, and Maarit Karppinen , "Organic-component dependent thermal conductivity reduction in ALD/MLD grown ZnO:organic superlattice thin films", Appl. Phys. Lett. 118, 211903 (2021) https://doi.org/10.1063/5.0052450

# Rechargable zinc-air batteries

# 4. Rechargable zinc-air batteries - Motivation

- **High theoretical energy density**
  - Zinc-air 1086 Wh/kg [8], Li-ion 100-265 Wh/kg now [9]
- **Low price**
  - Zinc-air <10 $/kWh [8], Li-ion 100-150 $/kWh
- **Material availability**

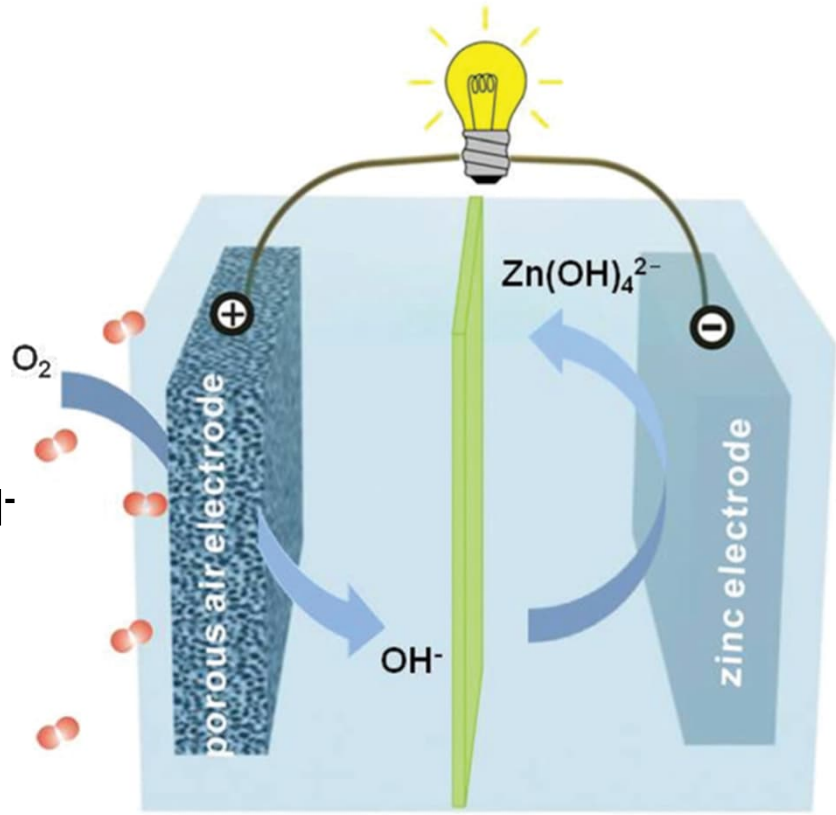


[8] Y. Li and H. Dai, “Recent advances in zinc–air batteries,” Chem Soc Rev, p. 20, 2014.
[9] https://www.cei.washington.edu/education/science-of-solar/battery-technology/ 16.9.2022

# 4. Rechargable zinc-air batteries – Principal of operation

**Porous positive air electrode with metal catalyst**

$O_2 + 4e^- + 2H_2O \rightarrow 4OH^-$




**Negative zinc electrode**

$Zn + 4\ OH^- \rightarrow Zn(OH)_4^{2-} + 2e^-$

$Zn(OH)_4^{2-} \rightarrow ZnO + H_2O + 2\ OH^-$

**Selective separator for passing $OH^-$**

**[8]**

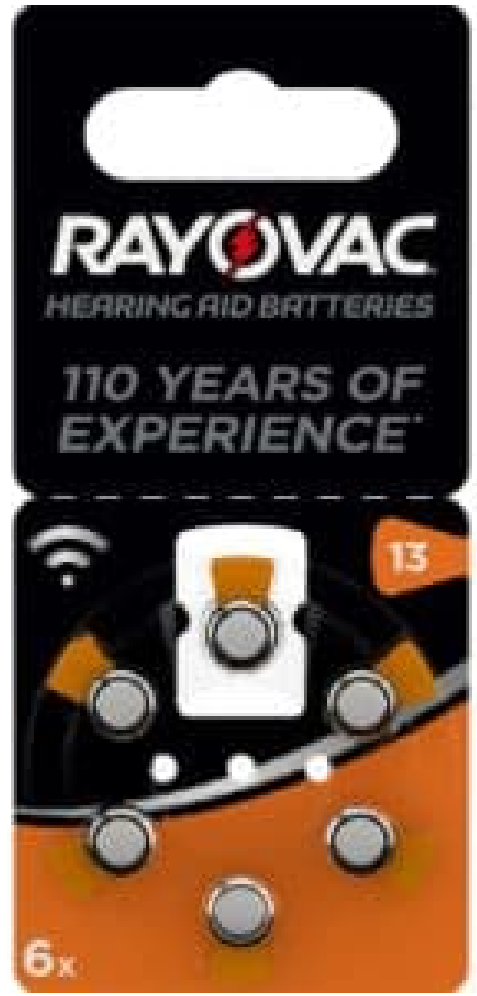


[8] Y. Li and H. Dai, "Recent advances in zinc–air batteries," Chem Soc Rev, p. 20, 2014

# 4. Rechargable zinc-air batteries – Areas of improvement

- **Slow kinetics at air electrode**
- **Bifunctional air electrode**
  - OER and ORR
- **Dendrite growth during cycling**
- **Water loss**

**[8]**






[8] Y. Li and H. Dai, “Recent advances in zinc–air batteries,” Chem Soc Rev, p. 20, 2014.

# Galvanization

# 4. Galvanization - Overview

- **Protection**
- **Easy**
- **Doesn't require much equipment**
- **Cost efficient**

# 4. Galvanization – How is it applied?

- **Hot-dip for thicker coating**
- **Electroplating for thinner**

**[9]**



[9] P. Sahoo et al., 3.3 Surface Finish Coatings, Comprehensive Materials Finishing, Elsevier, 2017, Pages 38-55

# 4. Galvanization – Hot-dip

- **3-step process**
  - Surface treatment – Alkaline/acid, rinse, HCl
  - Galvanization – Metallurgical reaction
  - Post-treatment – Quenching/cooling (Optional) [10,11]



[10] F. Ozturk et al., 3.12 Hot-Dip Galvanizing Process. Comprehensive Materials Finishing, Elsevier, 2017,.Pages 178-190
[11] https://www.galvanizing.org.uk/galvanizing-process/

# 4. Galvanization – Electroplating

- **4-step process**
  - Pre-treatment – Alkaline bath & heat
  - Activation/Pickling - removal of oxides with acids
  - Electroplating – controlled electrolysis
  - Post-treatment – Rinse & Dry [12]



[12] https://sciencestruck.com/zinc-electroplating-process

# 4. Galvanization – How does it work?

- **Physical  - barrier prevents contact**
- **Chemical – Sacrificial role (Iron/Steel)**
- **Weather improves it – creates a passive layer**

**[9,11]**



[9] P. Sahoo et al., 3.3 Surface Finish Coatings, Comprehensive Materials Finishing, Elsevier, 2017, Pages 38-55
[11] https://www.galvanizing.org.uk/galvanisation/, 16.9.2022

# 4. Galvanization – Why Zinc over others?

- **Relatively abundant raw material**
- **Low melting point low, energy costs relatively low**
- **"Appropriately" reactive**
- **Easy to apply**

# CONCLUSION

Aalto University

# Questions?