# Steam Cycle Chemistry in ACCs

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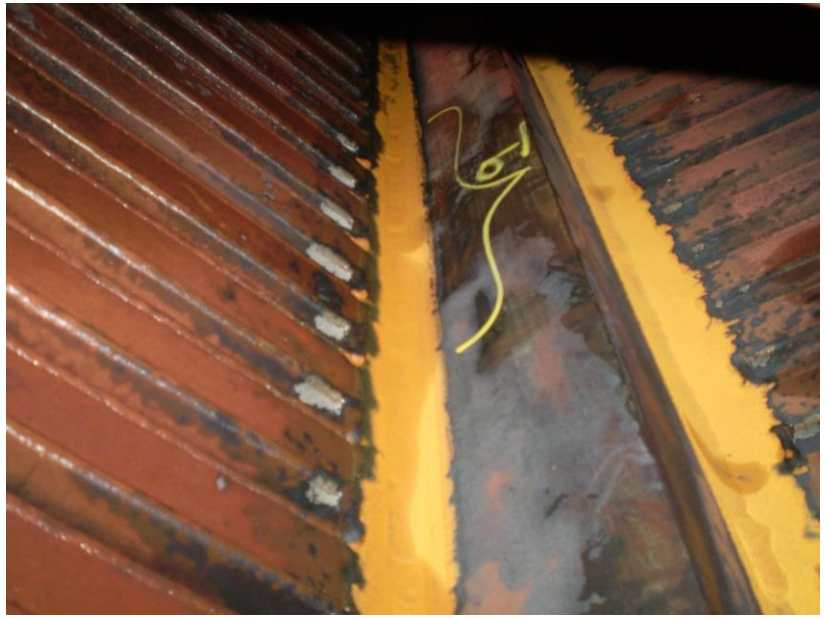
# Idiosyncrasies of ACC Steamside Corrosion

pH 9.40-9.55

*2011*



pH 9.40-9.55

*2014*

pH 9.50-9.60

*2017*



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# Flow-Accelerated Condensate Corrosion
## - *form of 2-phase FAC*



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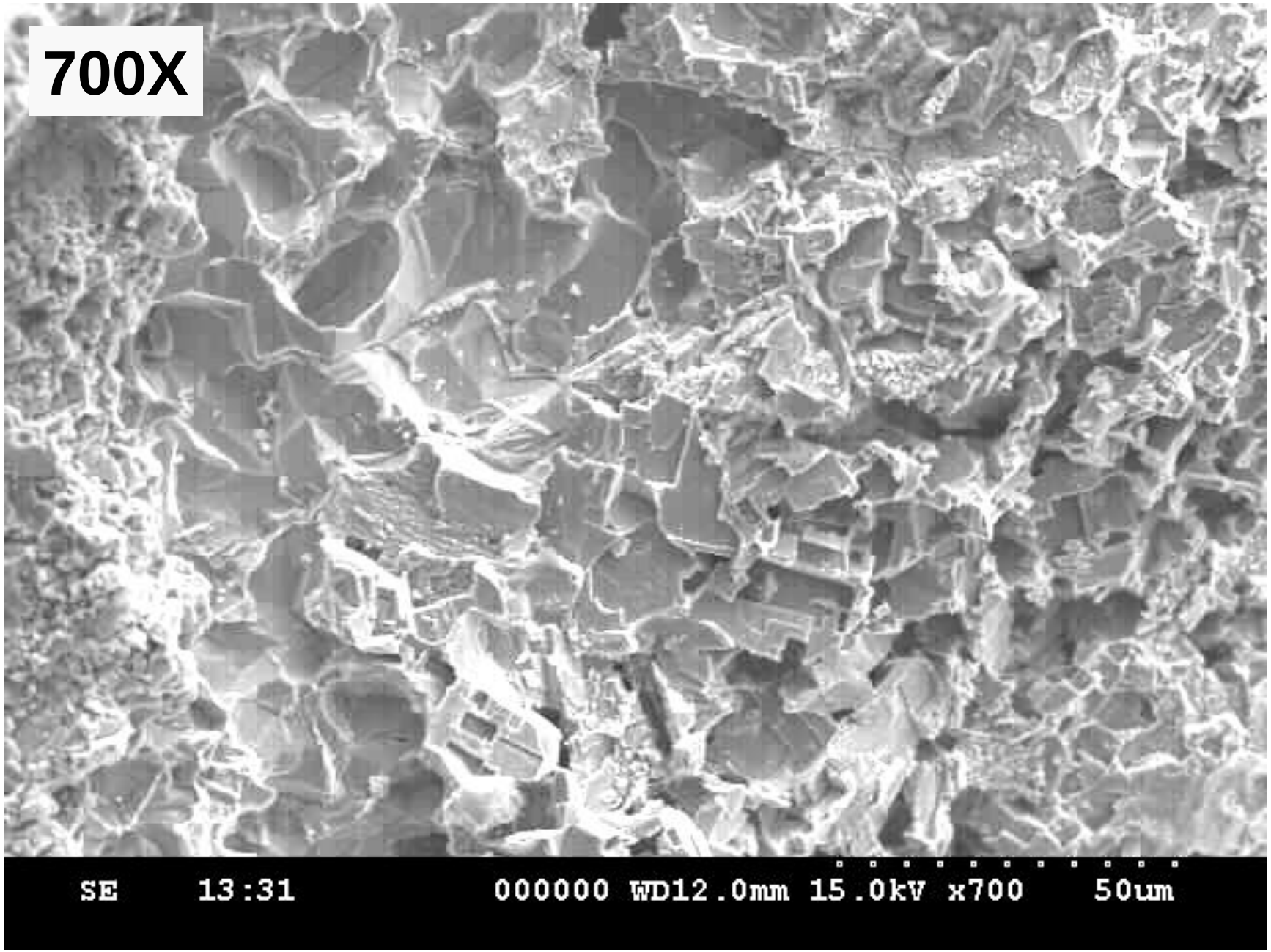
# Microscopic Observations

*differs from ‘traditional’ 2-phase FAC*

- exposed metal surfaces are faceted (intergranular, IG) and not smooth
- exposed metal in cross-section is faceted (IG)



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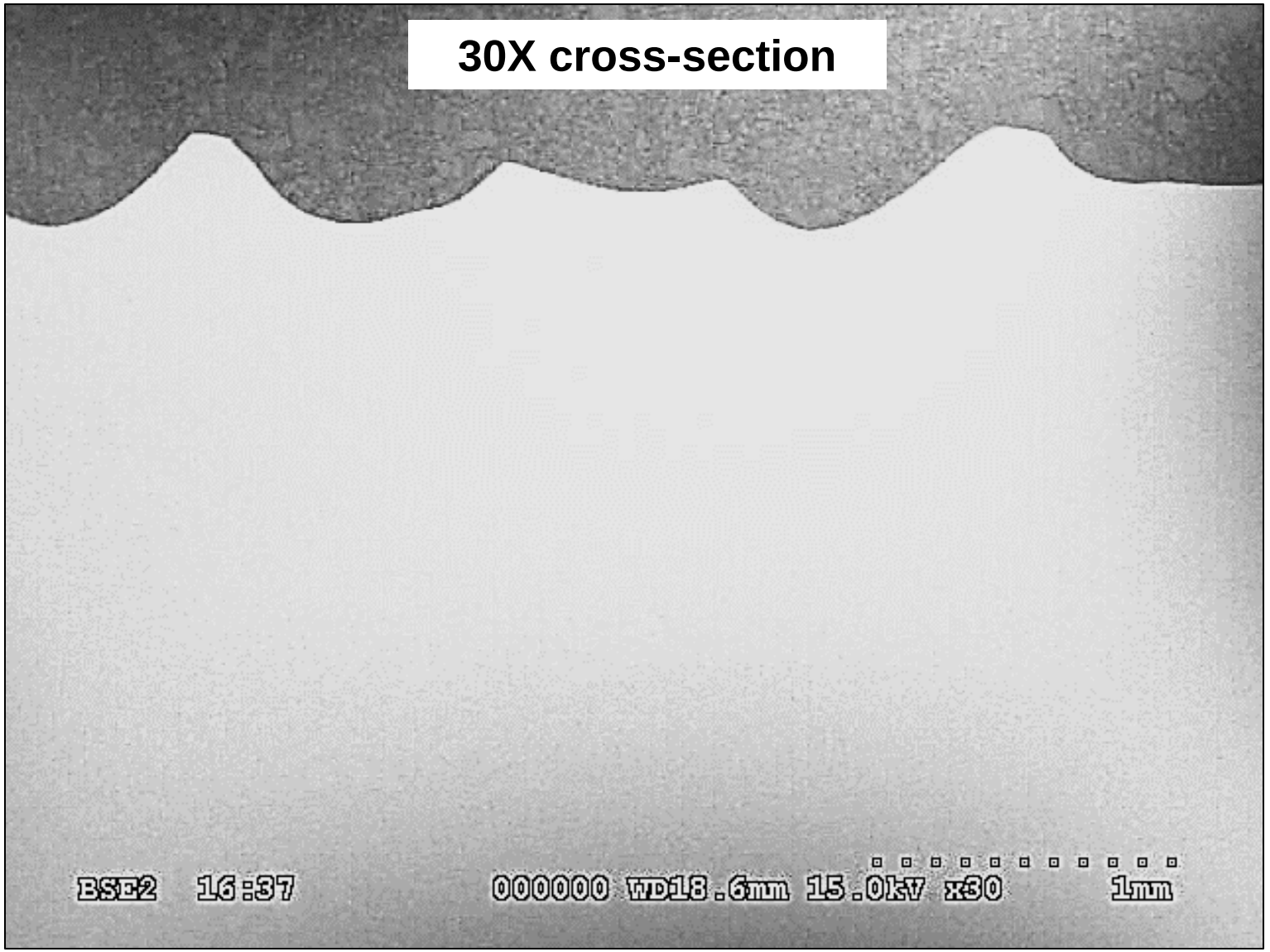
# Cross-section microstructure, traditional FAC



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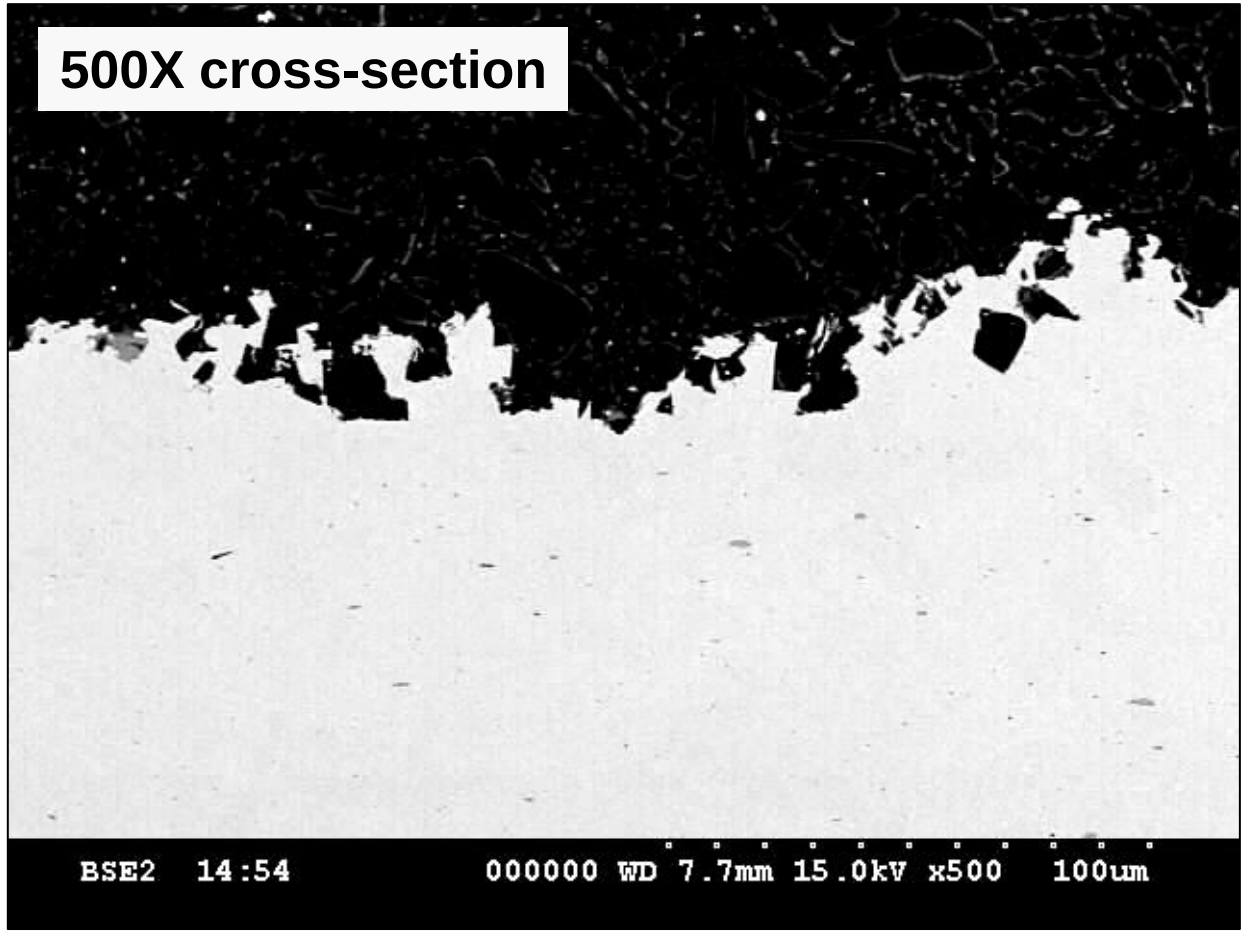
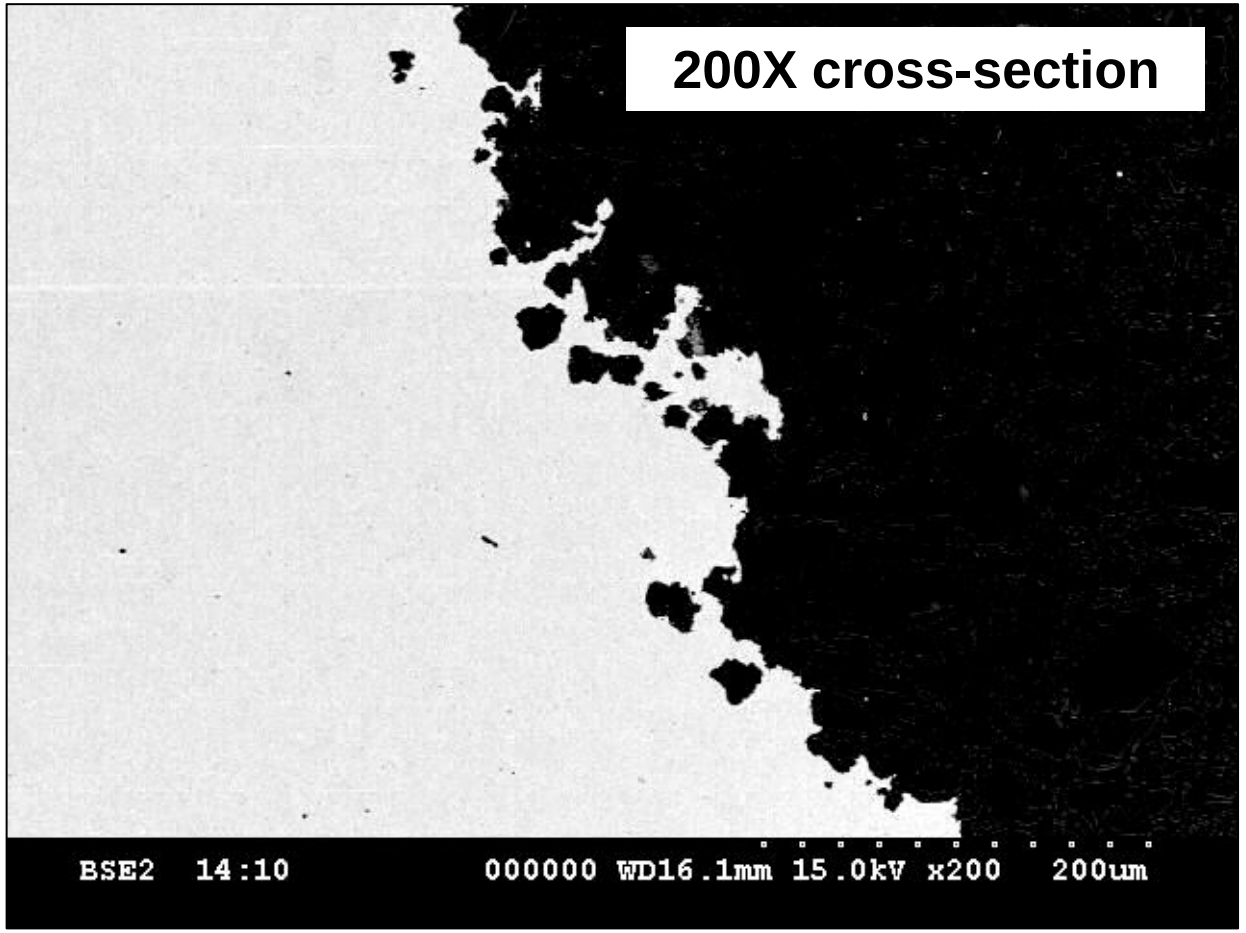
# Cross-section microstructures, FACC



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# Further Distinguishing Conditions

*besides intergranular corrosion mode -*

- Temperature lower than that optimal for single-phase or 2-phase FAC
- Under consistent conditions metal loss may halt

# Proposed Corrosion Mechanism: FACC

1. Magnetite forms thin layer on carbon steel
2. Oxidation of steel progresses beneath oxide: general / intergranular
3. Release of metal / oxide resulting from intergranular corrosion
   - flow influence
4. Relative stability may be reached in the corrosion process
5. Changes in pH may disrupt stability
   - *lower pH will accelerate FACC*
   - *higher pH will maintain or reverse FACC*



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# Carbon steel, air-cooled condenser interior

Minimizing FACC:

- pH elevation of early condensate
  - ammonium hydroxide to bulk pH ≥ 9.8
  - amines at lower bulk pH
- filming chemicals
- flow rate reduction
  - geometry to reduce turbulence
  - uniform flow distribution
  - bulk flow reduction



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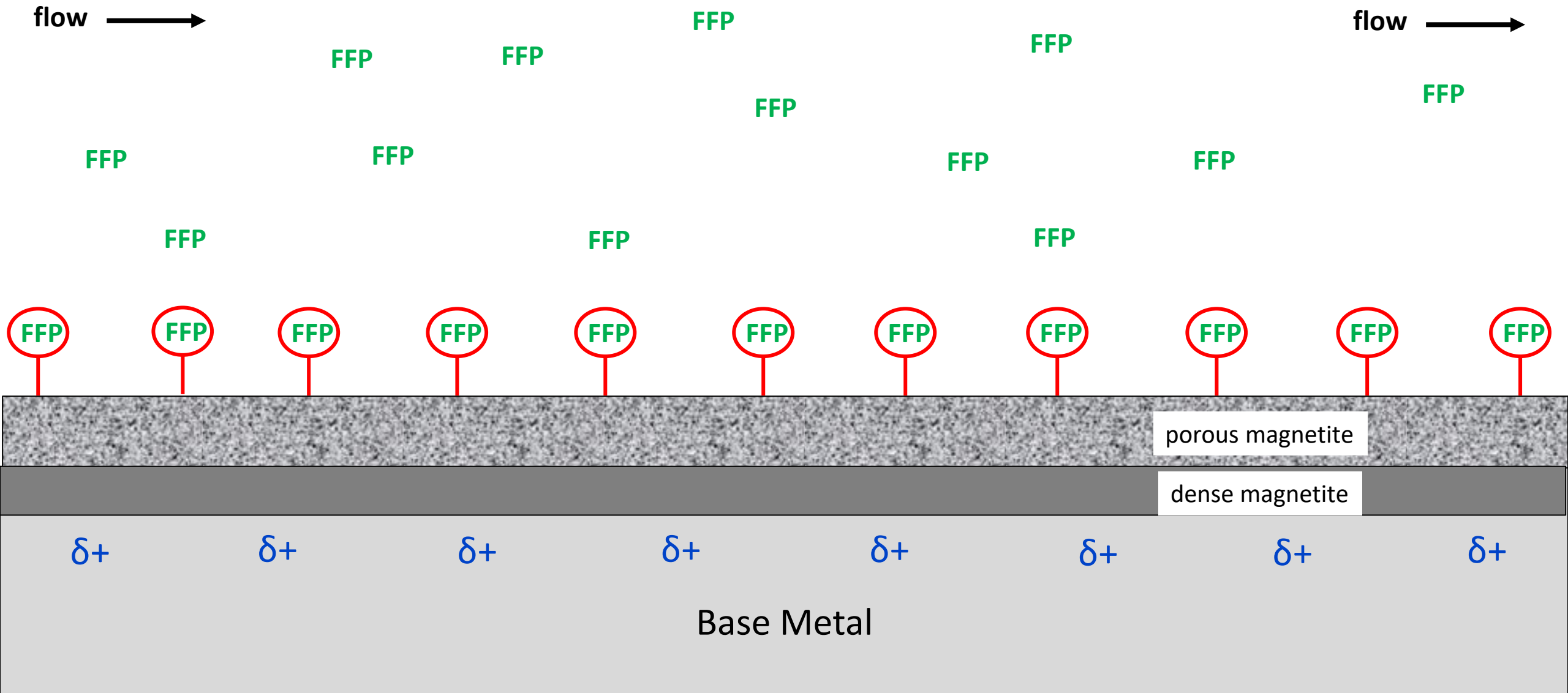
# Filming Process: equilibrium and surface chemistry

# Film-Forming Chemicals and equilibrium: adequate concentration in bulk water



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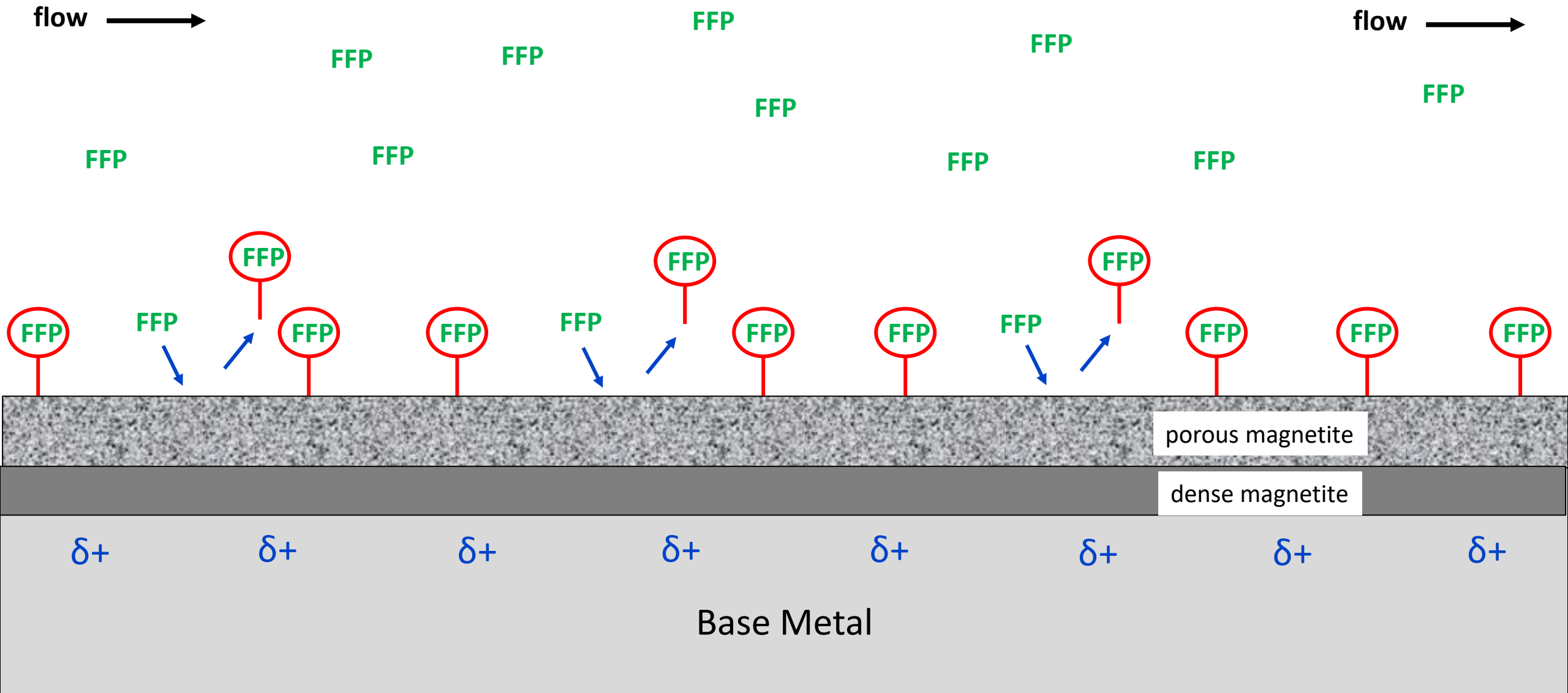
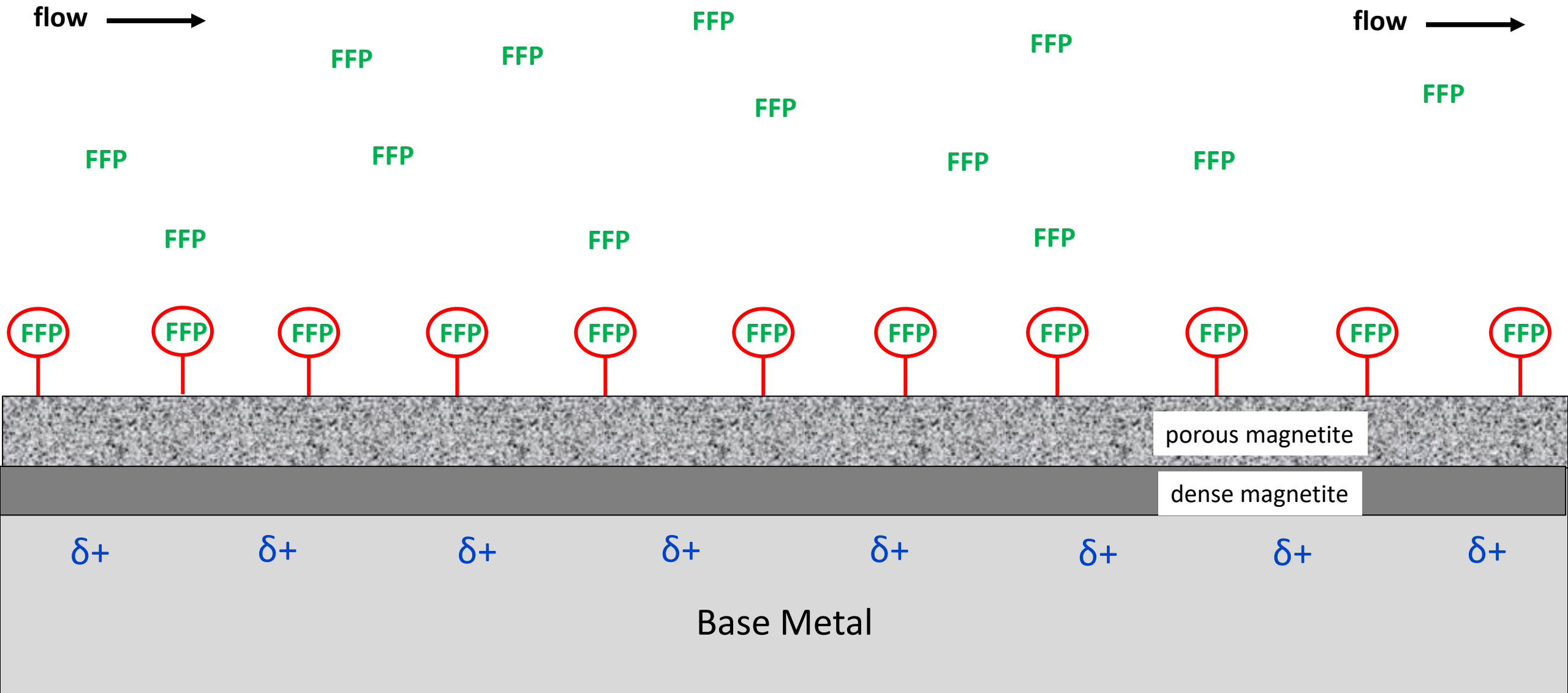


# Film-Forming Chemicals and equilibrium: adequate concentration in bulk water

*adequate corrosion protection*



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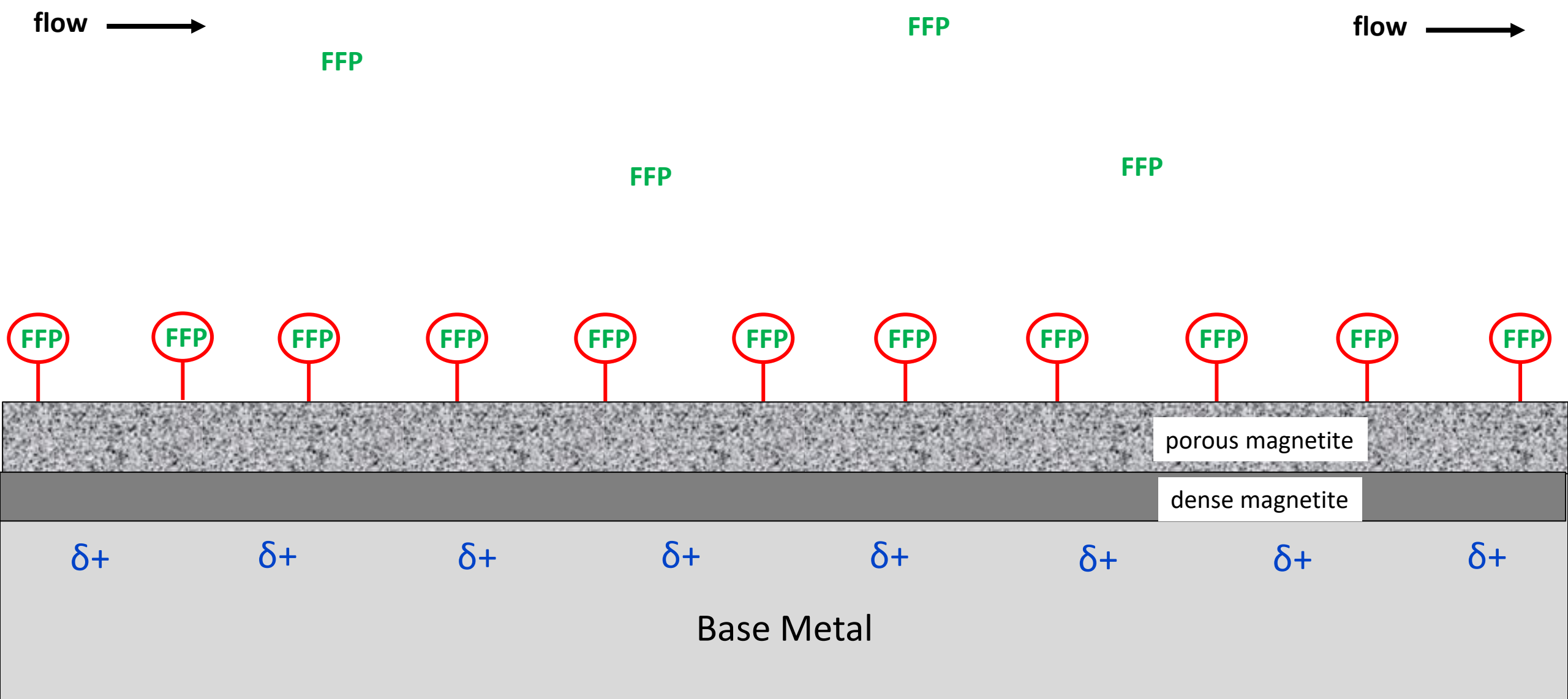

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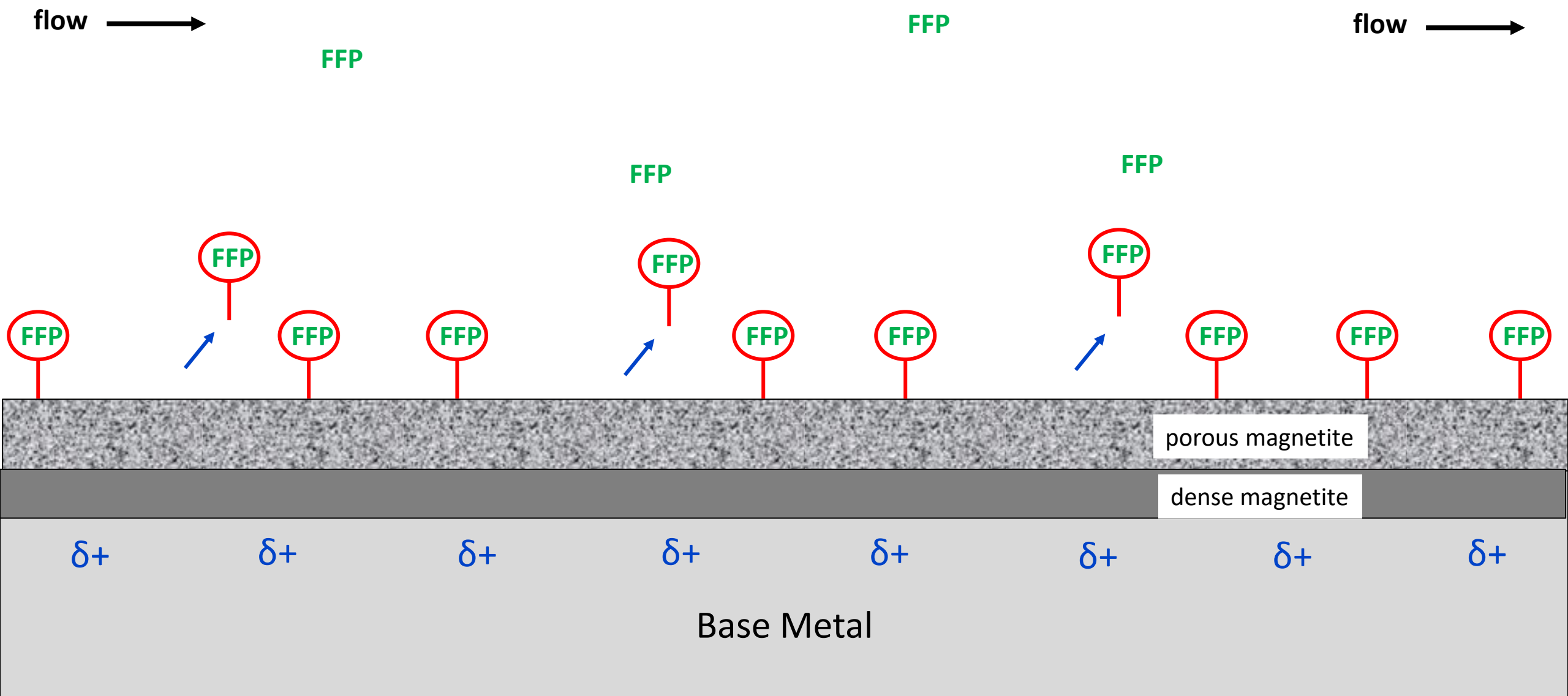
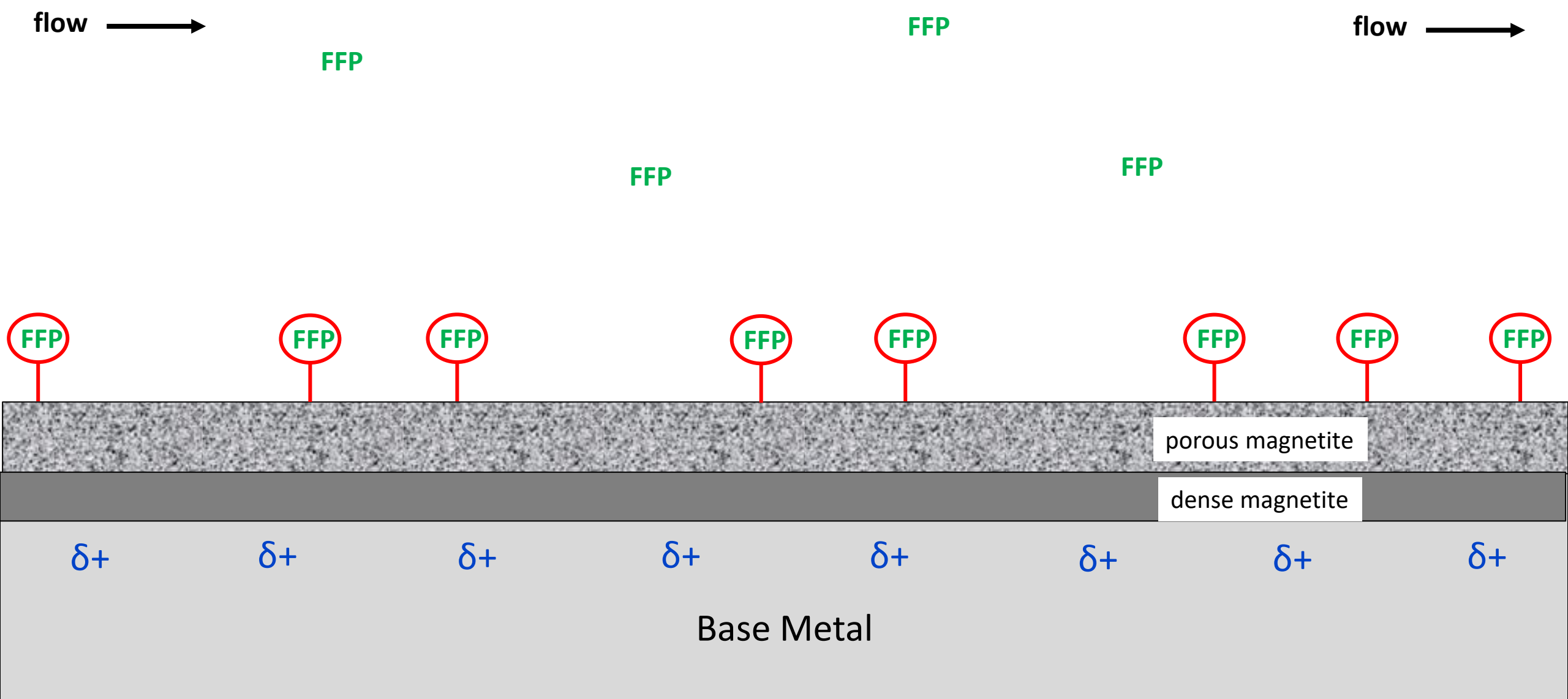


# Film-Forming Chemicals and equilibrium: inadequate concentration in bulk water

*inadequate corrosion protection*



# Application: equilibrium considerations

- drain & refill – must have adequate FFP in refill water
- lose feed or intentionally reduce feed below necessary residual
- different FFPs will have different equilibria
- potential for changing conditions to affect required residual
    - *pH*
    - *oxygen concentration*
    - *bulk flow rate*
    - *contamination*

- **EXCESS FFP BEYOND MINIMUM REQUIRED MAY BE PROBLEMATIC**



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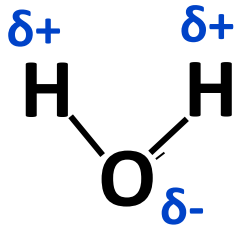
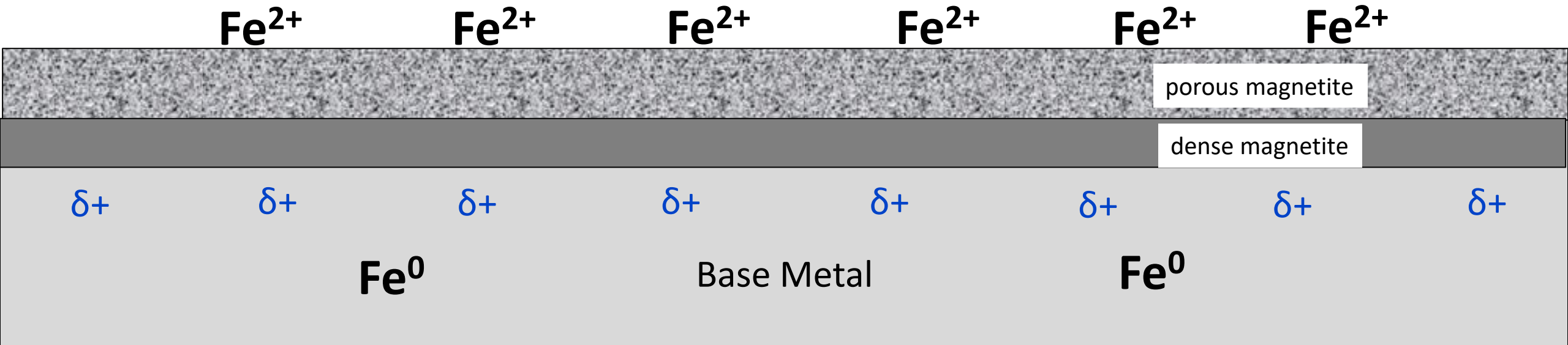
# Film-Forming Products and Surface Chemistry

**Magnetite = $Fe_3O_4$ = $FeO \bullet Fe_2O_3$**

**FeO = $Fe^{2+}O^{2-}$**



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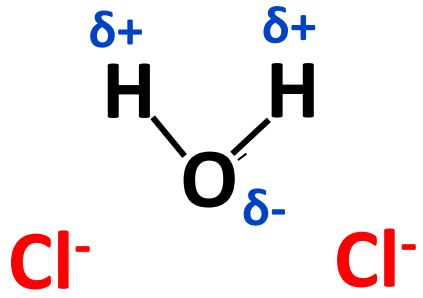



$Fe^{2+}$ $Fe^{2+}$ $Fe^{2+}$ $Fe^{2+}$ $Fe^{2+}$ $Fe^{2+}$

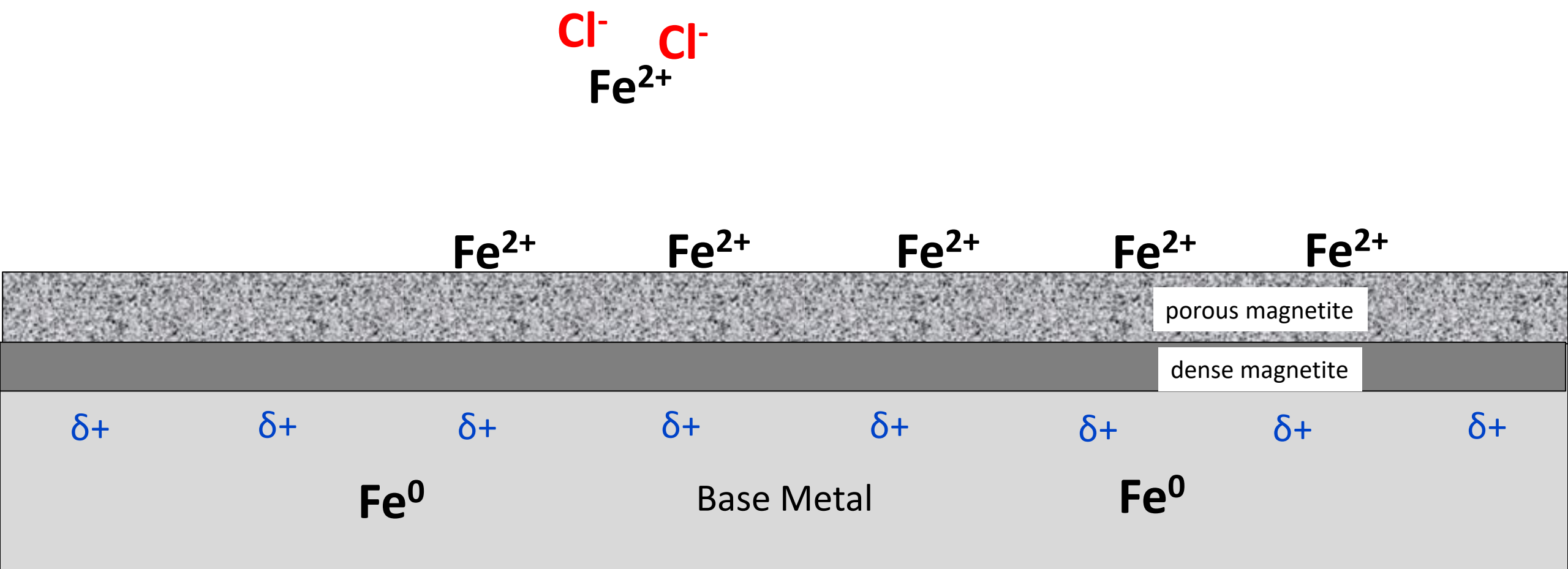
porous magnetite

dense magnetite

δ+ δ+ δ+ δ+ δ+ δ+ δ+ δ+

$Fe^{0}$ Base Metal $Fe^{0}$

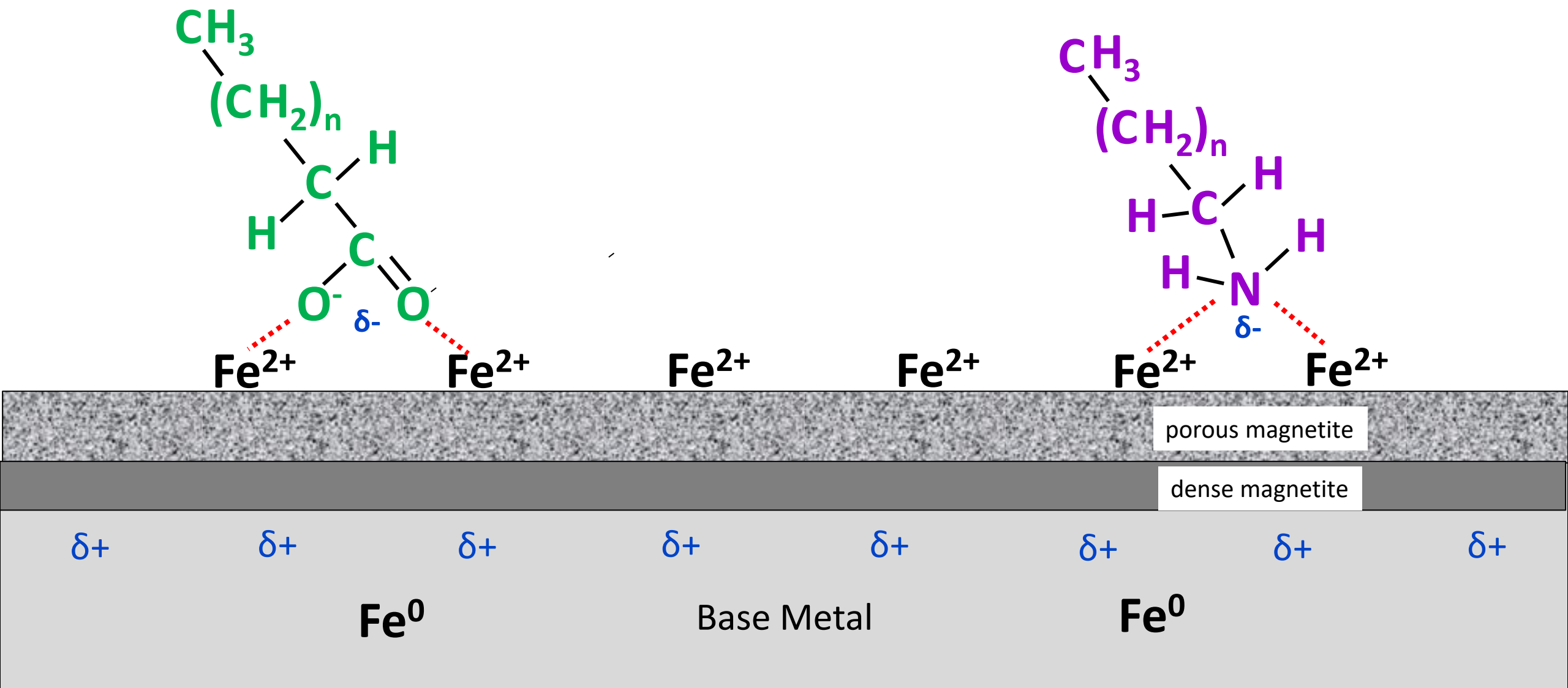
# Film-Forming Products and Surface Chemistry



# Film-Forming Products and Surface Chemistry

FFP: carboxylate

FFP: amine



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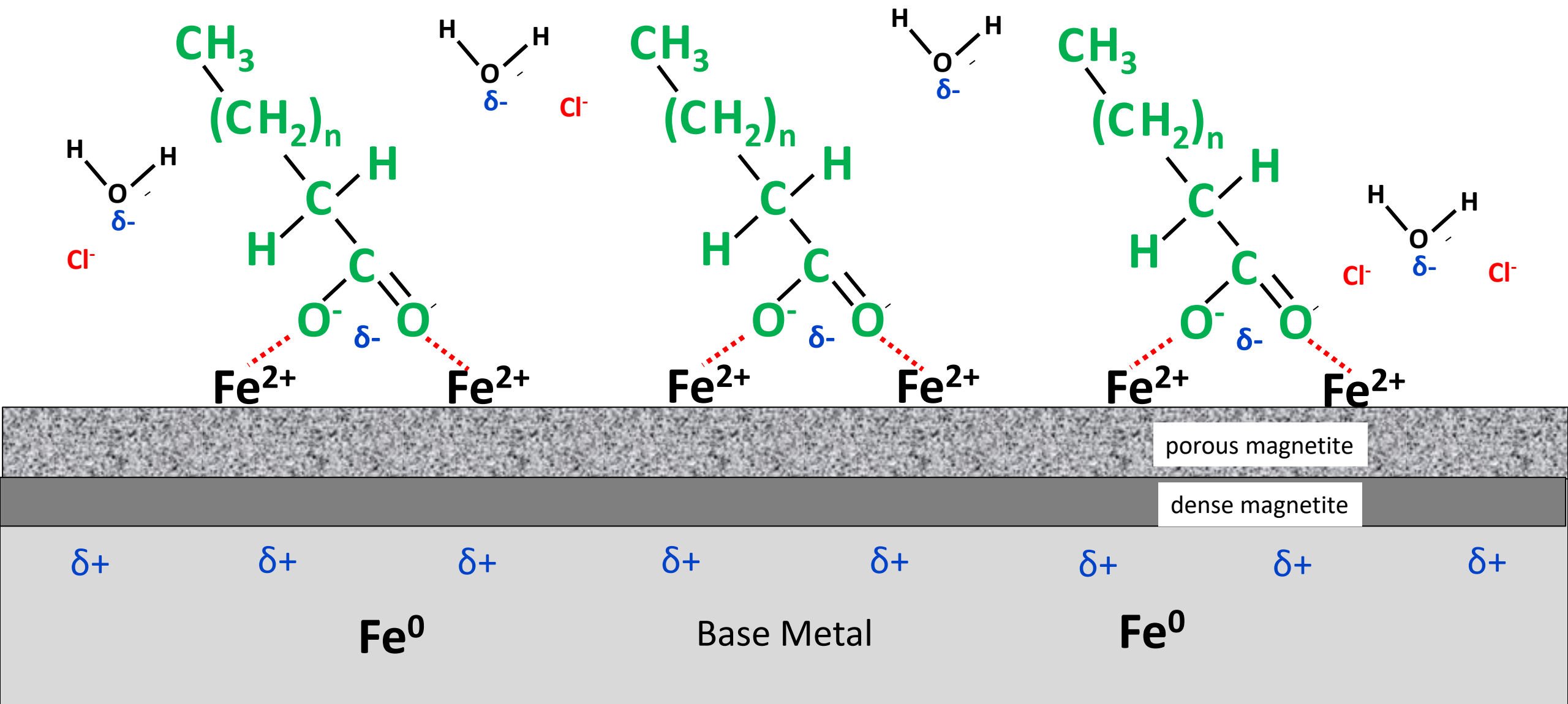

# Filming Process: surface chemistry

- the negatively-charged ends of filming chemical molecules adhere to positively charged iron atoms on the oxide surface
- water / corrosive anions compete with FFP for positively charged sites but FFPs that work well limit water from accessing those sites, and limit the opportunity for corrosive anions to concentrate and promote corrosion
- clearly different molecules will have different characteristics including bond strength to the surface and packing ability

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