MATERIA NOVA Materials R&D Center

Interreg France-Wallonie-Vlaanderen

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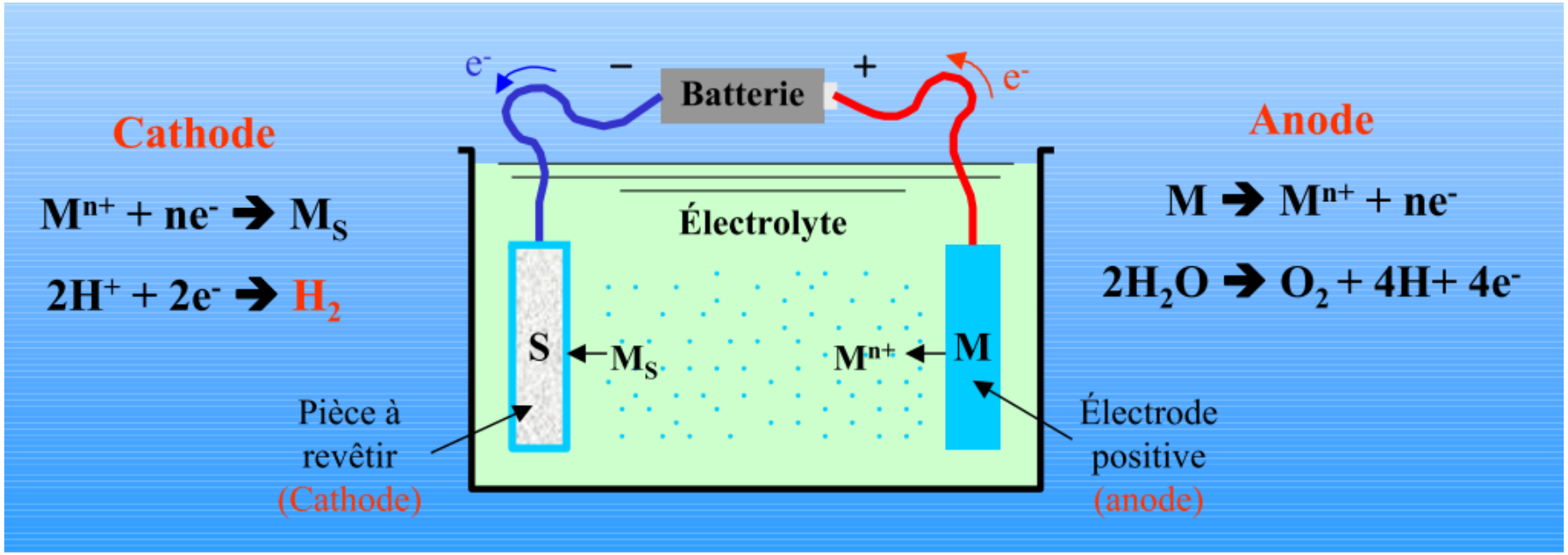
What is electroplating ?

Application of an electric current in an electrolyte between 2 electrodes :

- ❑ Reduction at the cathode
- ❑ Oxidation at the anode



The anode is not necessarily the metal to be deposited, it can be present in the form of metal salts

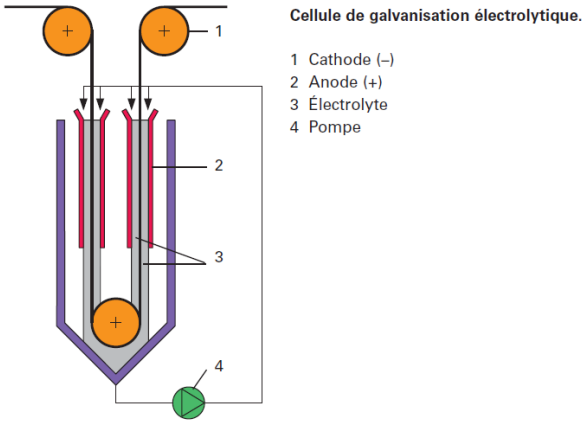
Electroplating

Advantages of the technique

- ❑ Wide variety of deposits:
  - ✓ Metals (Zn, Cr, Ni, Au, Ag, …)
  - ✓ Alloys (Bronze, brass, ZnNi, …)
  - ✓ Composites (Ni+ SiC)
- ❑ Wide variety of processes:
  - ✓ Rack
  - ✓ Barrel
  - ✓ Reel to reel
  - ✓ Selective (Pad-plating)
- ❑ Variable thickness (→ electroforming)
- ❑ Economy/Process reliability

Rack plating

Barrel plating



Reel to reel plating

Electroplating

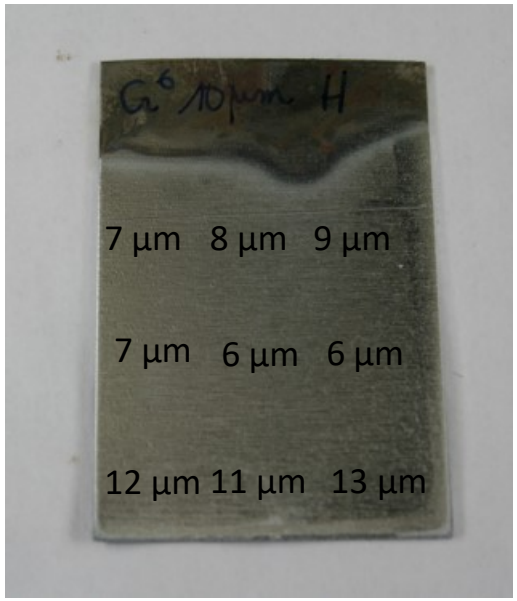
Drawbacks of the technique :

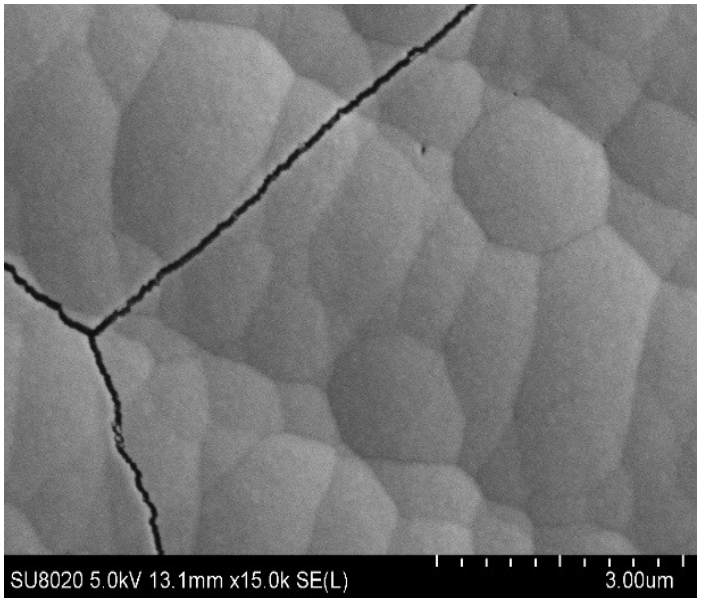
- ❑ Wet process → wastewater pollution
- ❑ Specific treatment programme (in relation to the substrate)
- ❑ Hydrogen embrittlement (→ metal's loss of ductility)
- ❑ Thickness repartition

Summary of work in progress : Cr6

- Realization of hard chromium reference deposits on ST37 steel (Kiesow commercial Bath) :
  - Thickness of 10 µm
  - Thickness of 50 µm

- Morphological characterization :





→ Heterogeneous thickness distribution
→ Micro-cracked structure

Summary of work in progress : Cr6

- Corrosion characterization :

System	Neutral Salt Spray (h)
10 µ Cr	24
50 µ Cr	150
5 µ Ni sulfamate + 50 µ Cr	300
15 µ Ni duplex (sulfamate/Watts) + 50 µ Cr	1000
15 µ NiP electroless + 50 µ Cr	1000

→ Need for a nickel underlayer to improve corrosion performance

- Mechanical and tribological characterizations :
  - In progress (ENSAM, Université Lille)

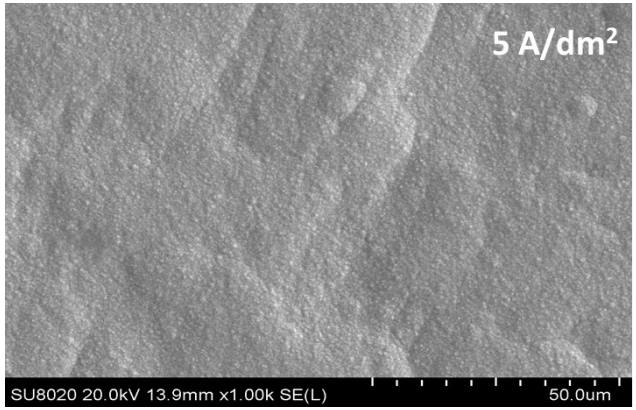
Summary of work in progress: Alternatives considered

- Tungsten alloys :
  - Tungsten properties :
    - Refractory metal → potential applications at high T
    - Excellent corrosion resistance
    - Good mechanical properties (hardness)
  - W can't be deposited alone by electrochemical way → codeposition induced with Ni, Co, Fe

➡ W promotes amorphous character and so corrosion resistance

- Chromium alloys :
  - Chromium deposit → micro-cracked structure
  - Solution : combining chromium with other elements to ductilise the coating :
    - FeNiCr
    - NiCr

NiW



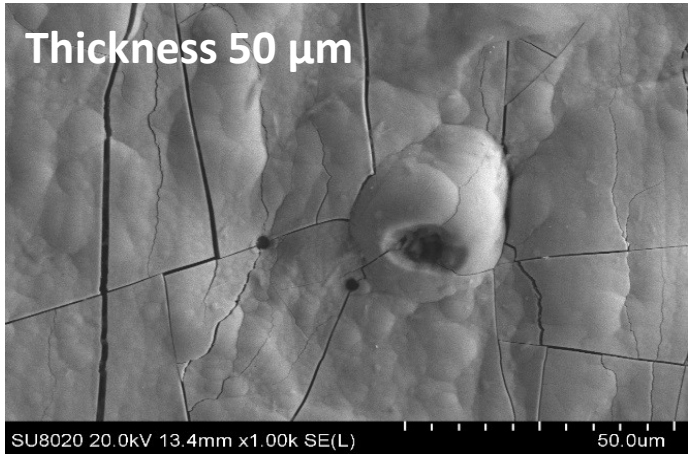
- Citrate-based formulation
- Ni/W 60/40 wt% *(thickness limited to 10 µm in DC)*
- Higher W content in the deposit → becomes brittle and cracked due to internal stresses
- Pulsed current or multilayer systems required for thicker ductile deposits

NiW Ni Cr^{6+} Cr^{3+}

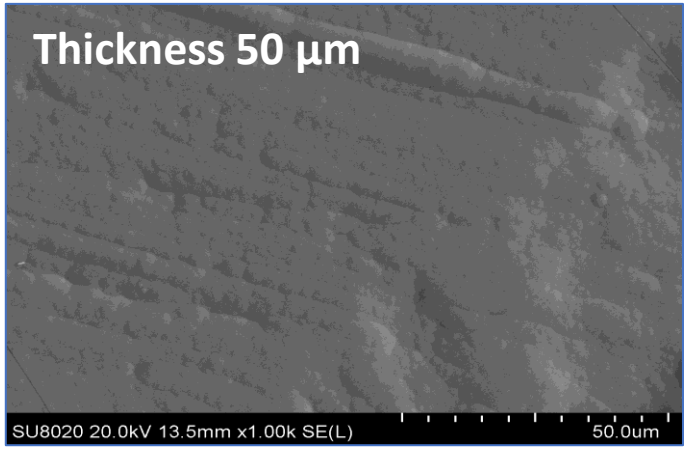
- 1000 h au BS
- Formation of a passive layer thanks to the presence of W

NiW

- Higher thickness without crack with **pulse plating**



Classical



Pulse plating

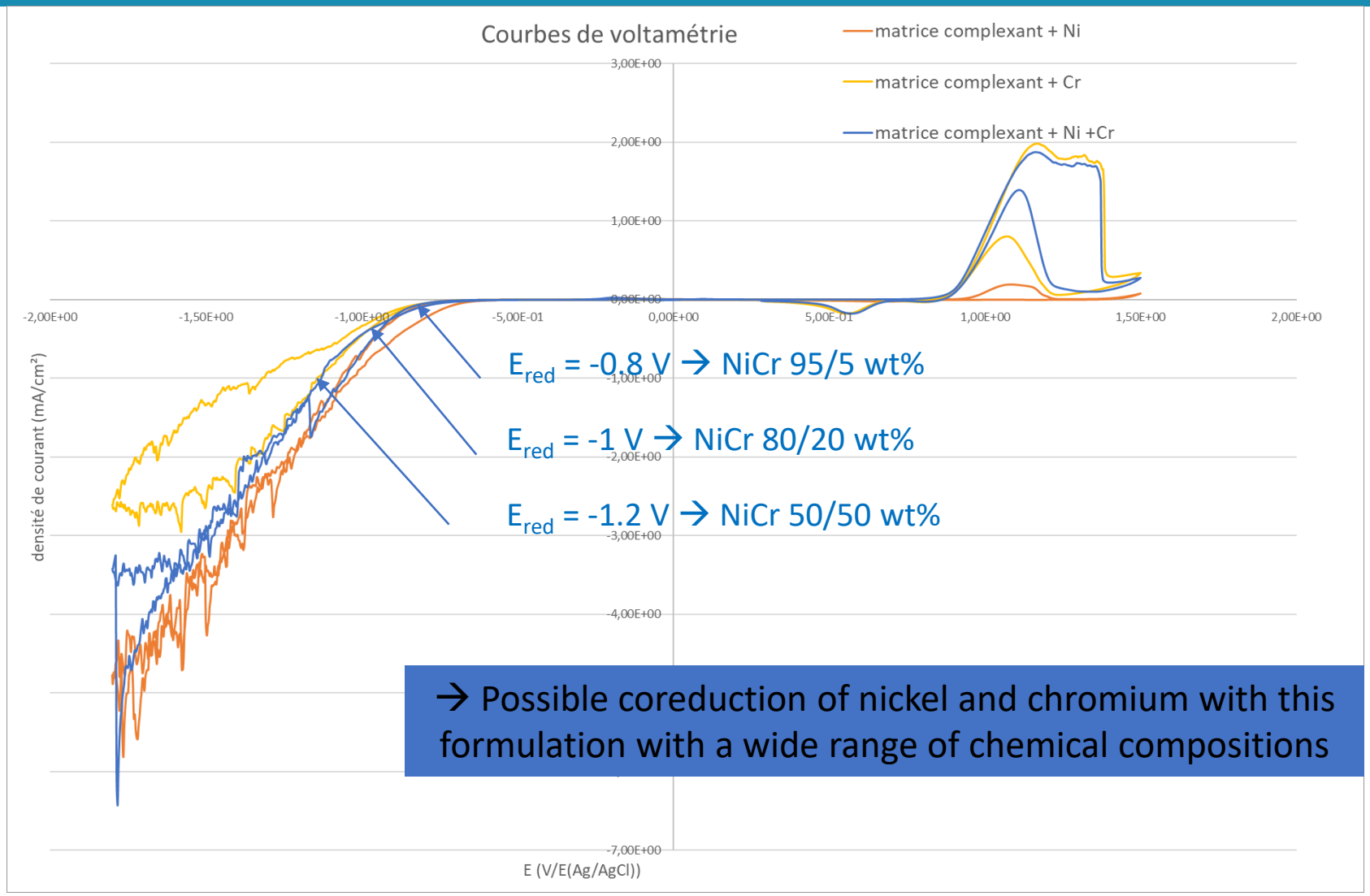
- Finer grains
- Lower porosity/Denser deposit
- Reduction in internal stress
- Reduction in H embrittlement
- Increase in throwing power
- Increase in Hardness

FeW

- Citrate-based formulation
- W content between 50 and 60 wt %
- Stability of the chemical composition of the deposit with current density
- Beneficial effect of the ammonia addition in the formulation :
  - pH buffer solution
  - ↗ faradaic efficiency (+30%)
- FeW (on copper) is corrosion resistant → no visible rust
- Density of the layer to be improved for corrosion R on mild steel
- FeW alternative to hard Cr for mechanical and tribological applications

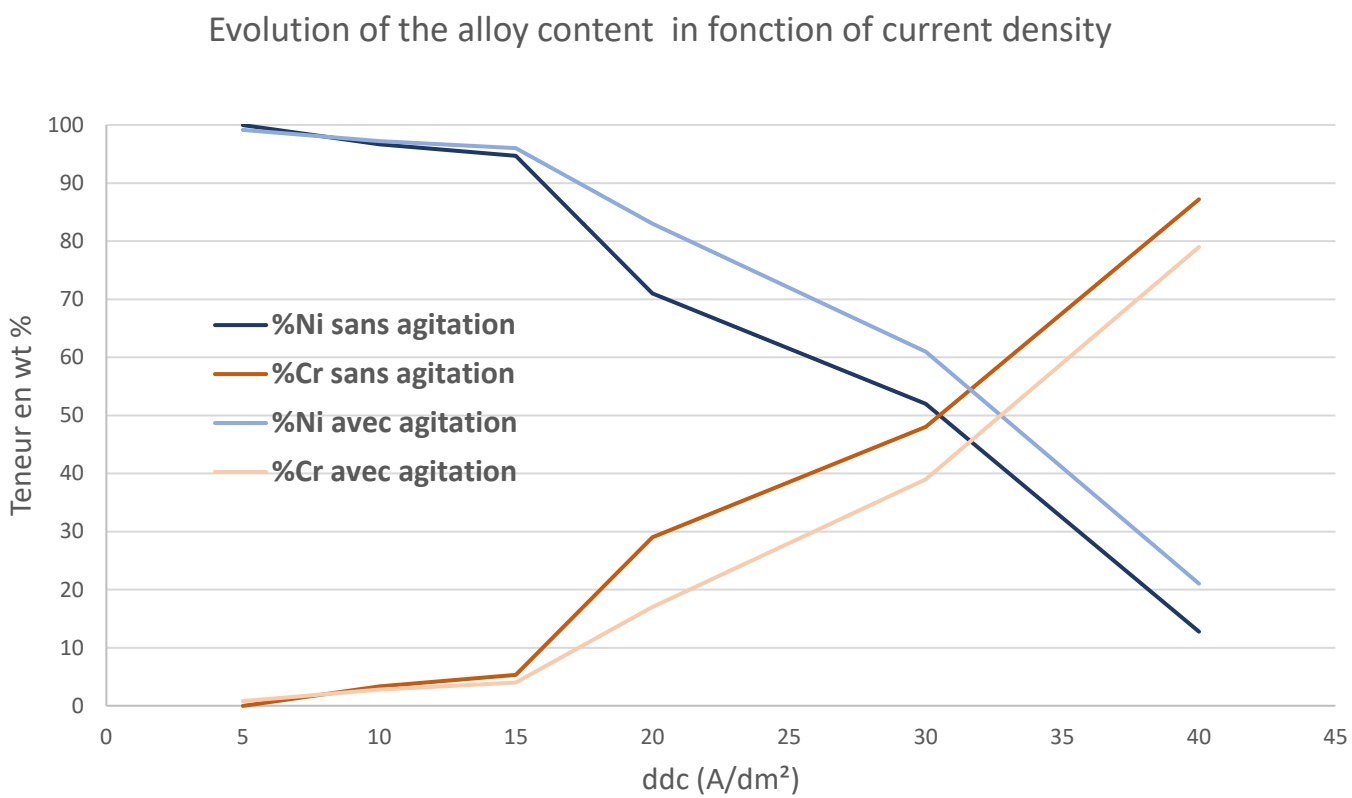
Après 6h BS

NiCr



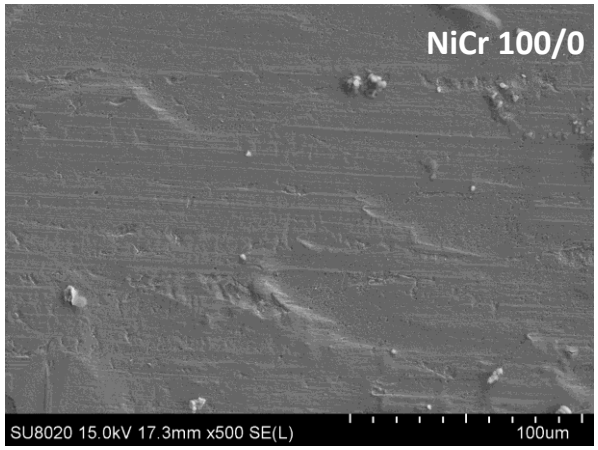
→ Possible coreduction of nickel and chromium with this formulation with a wide range of chemical compositions

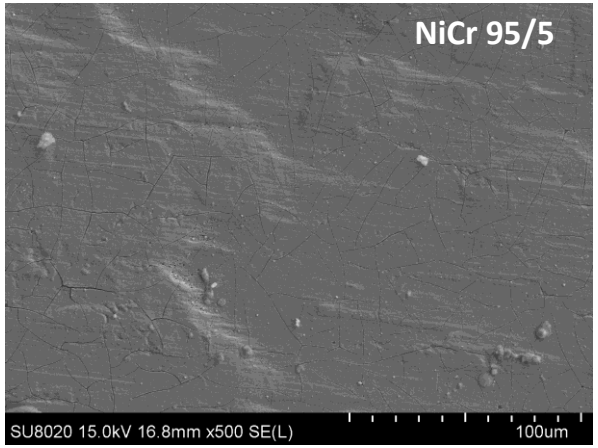
NiCr

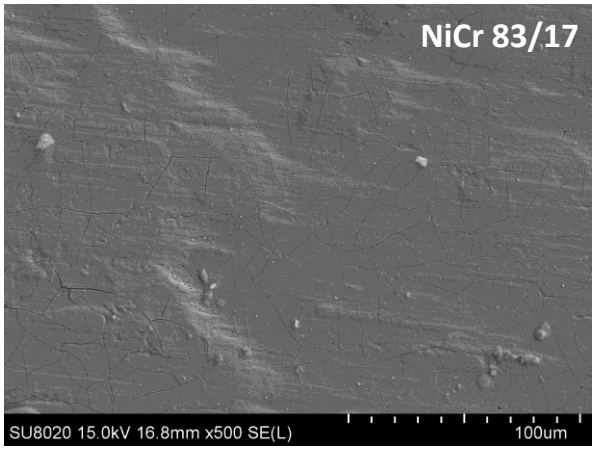


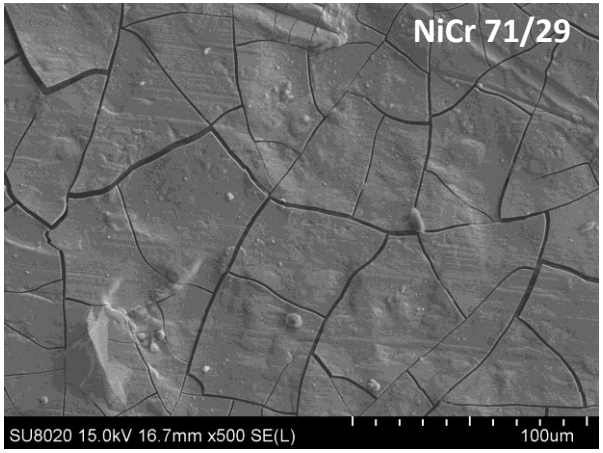
- ↗ ddc → ↗ [Cr] in the deposit
- Agitation → ↘ [Cr]
- Nickel reduction controlled by the diffusion

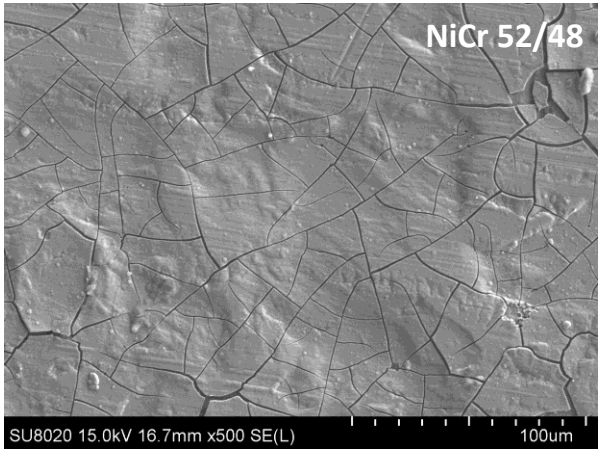
NiCr

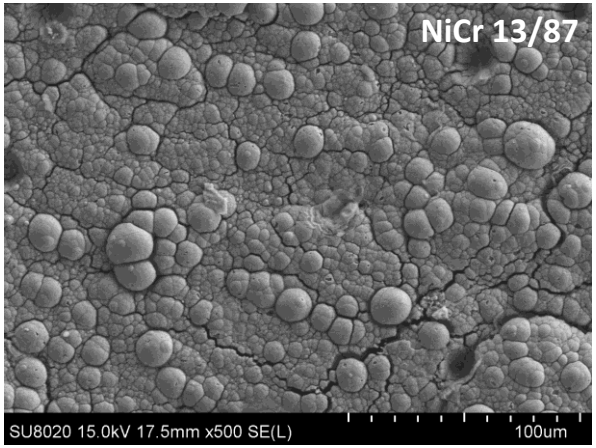






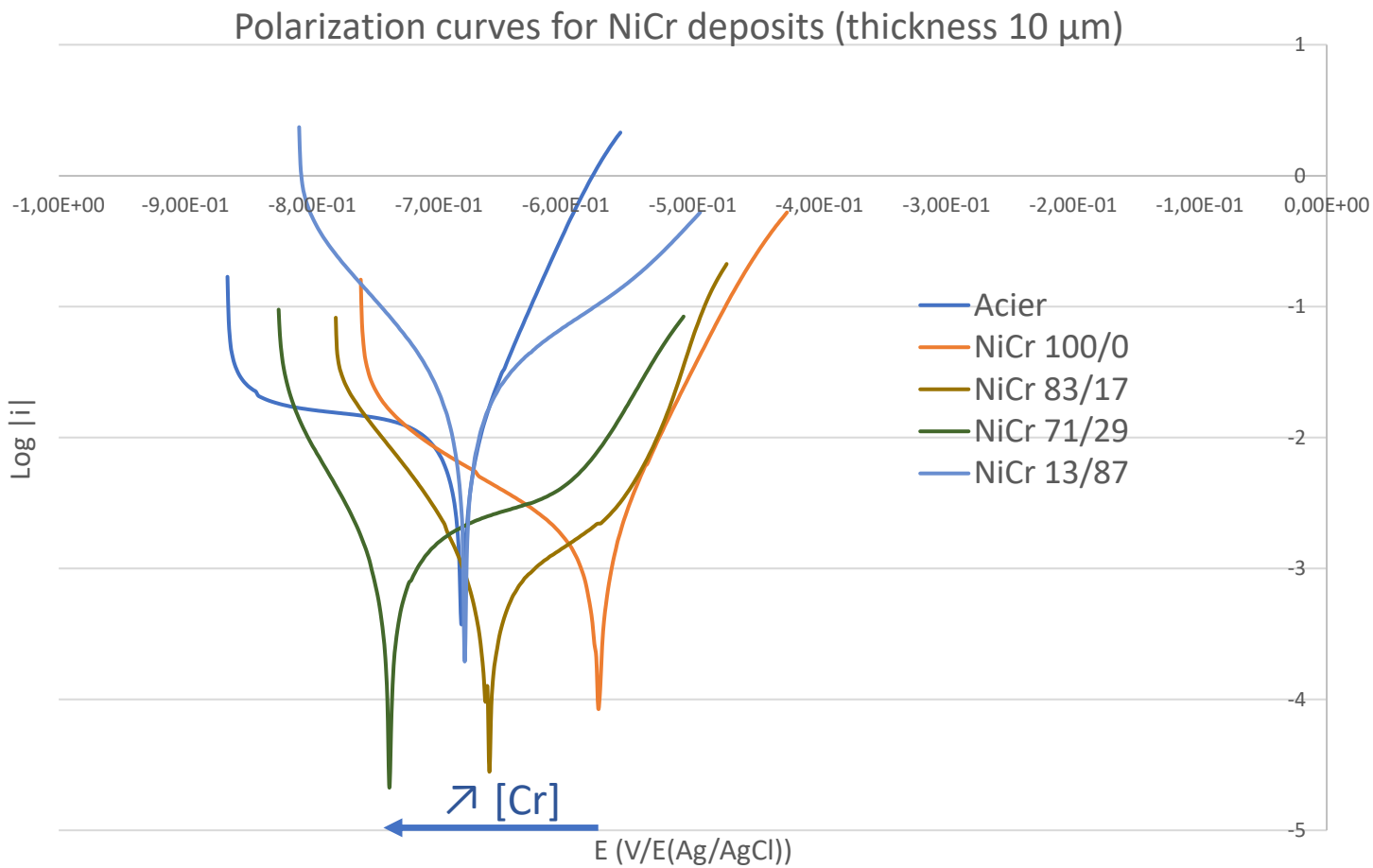






- Absence of cracks for deposits with Cr content ≤ 17%

NiCr



- Icorr ↘ with Cr content in the deposit except NiCr 13/87
- Increase in the passivation area for deposit with Cr
- Loss of corrosion properties for deposit NiCr 13/87 (through cracks ?)

Outlook

NiCr

- *Influence of pulsed current on morphology*

- *Multilayer deposits*
  - → Reduction in diffusion/corrosion paths (porosities, defects)
  - → Reduction in internal stresses
  - → Influence of monolayers periodicity and thickness

- *Corrosion*
  - → Neutral salt spray for multilayer deposits
  - → Polarization curves for multilayer deposits
  - → Increase in thickness without damage properties ?