Effect of heat treatment on the corrosion and mechanical properties of Nickel Tungsten alloy electrodeposits

G.Guilbert[1]*, M. Poelman[1], M.-G. Olivier[1,2].

1: Materia Nova ASBL, Rue de l'Epargne 56 B-7000 Mons, Belgium

2: Service de Science des Matériaux, University of Mons, Rue de l'Epargne 56 B-7000 Mons, Belgium

* Corresponding author. E-mail: Gregory.GUILBERT@MATERIANOVA.BE

• Context

Hard chromium coatings have found a wide range of engineering applications thanks to their excellent corrosion and wear properties. The need to develop efficient, low-cost alternatives to hard chromium plating is a major concern for many industrial sectors, due to the toxicity of chromium VI salts, which are widely regulated by the **REACH legislation**. In fact, they have been forbidden in many applications since 2017, and current authorizations for their use expire in 2024, with no guarantee, at present, of renewal.

Ni-W electrodeposition is a promising alternative and remains comparable to hard chromium plating in terms of process. It is well known that tungsten displays excellent corrosion resistance and mechanical properties and is suitable for high temperature applications but cannot be electrodeposited from an aqueous solution. However, it can be co-deposited in the presence of iron group elements (Ni,Co,Fe), this phenomenon was **called "induced co-deposition"** by Brenner. The presence of tungsten in nickel binary electrodeposits promotes also **amorphous structure**.

Binary Ni-W coatings display good mechanical, tribological and anti-corrosion properties, but are not able to reach the hard chromium coatings performances. **Heat treatment processes** were performed and evaluated in order to improve the Ni-W properties.

• Methods

Substrate

Mild Steel ST 37

NiW Coatings

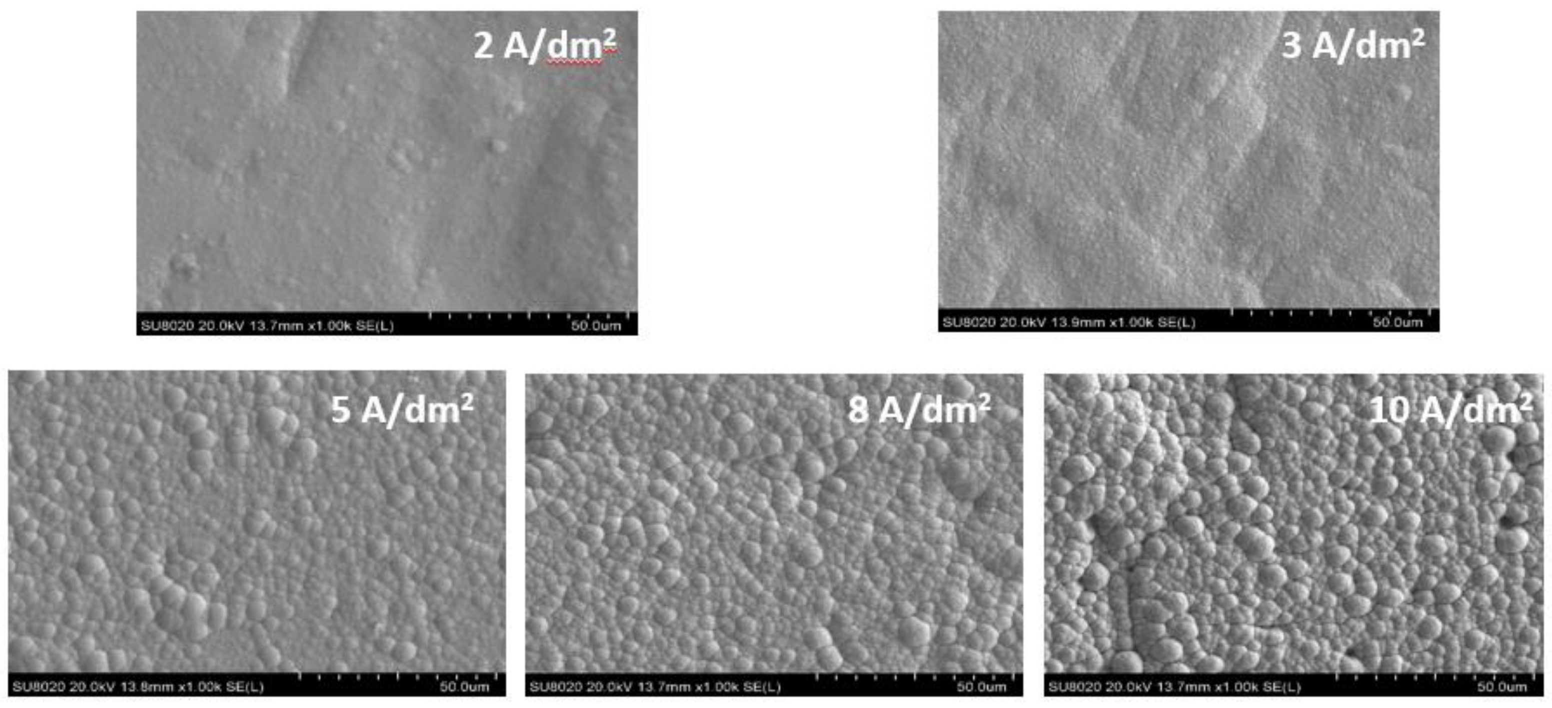
Current density
- 2 A/dm²
- 3 A/dm²
- 5 A/dm²
- 8 A/dm²
- 10 A/dm²

Heat Treatment 1h ($Ar95\%/H_25\%$)
- Without
- 300°C
- 500°C
- 700°C
- 900°C

Characterization
- Adherence
- Thickness (XRF/gravimetry)
- Corrosion (polarization)
- Hardness
- Micro structure XRD
- Nanoindentation
- Pin on disk

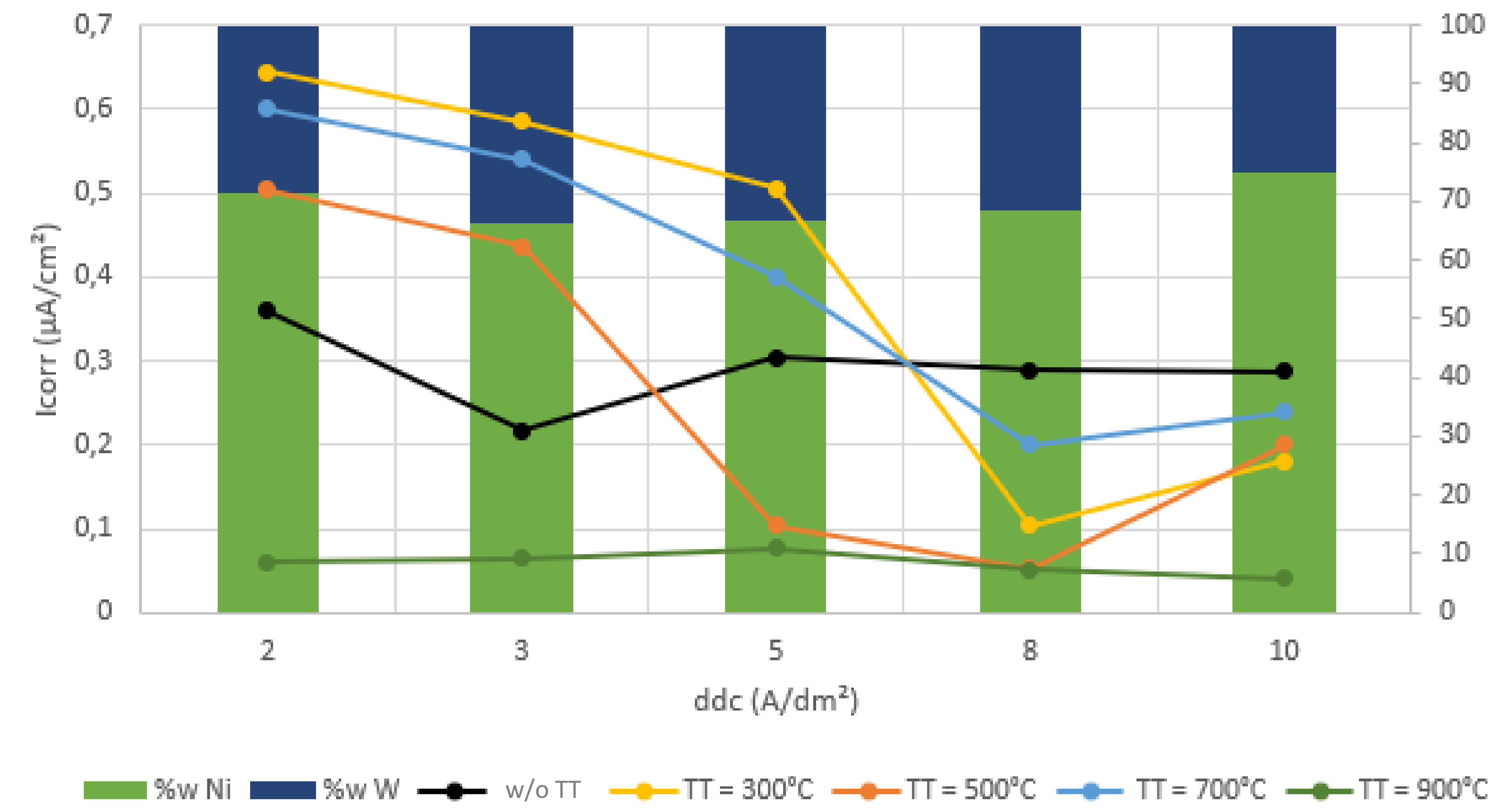
• *Results*

➢ Surface morphology of NiW deposits at different current densities



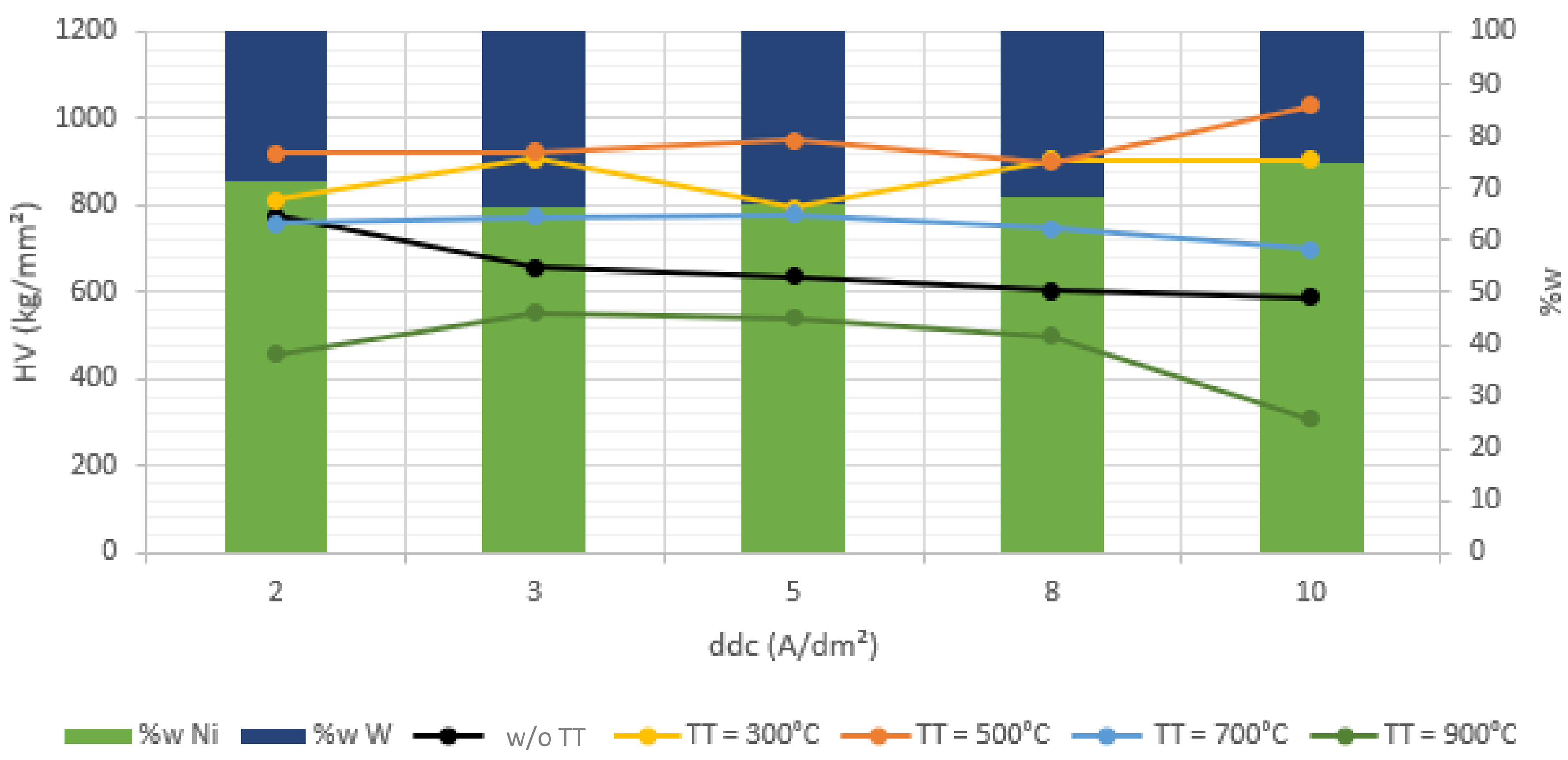
- Smooth coatings with compact morphology for low current densities
- Cauliflower morphology at high current densities
- No crack on the surface

➢ Evolution of corrosion current density in function of current density and heat treatment



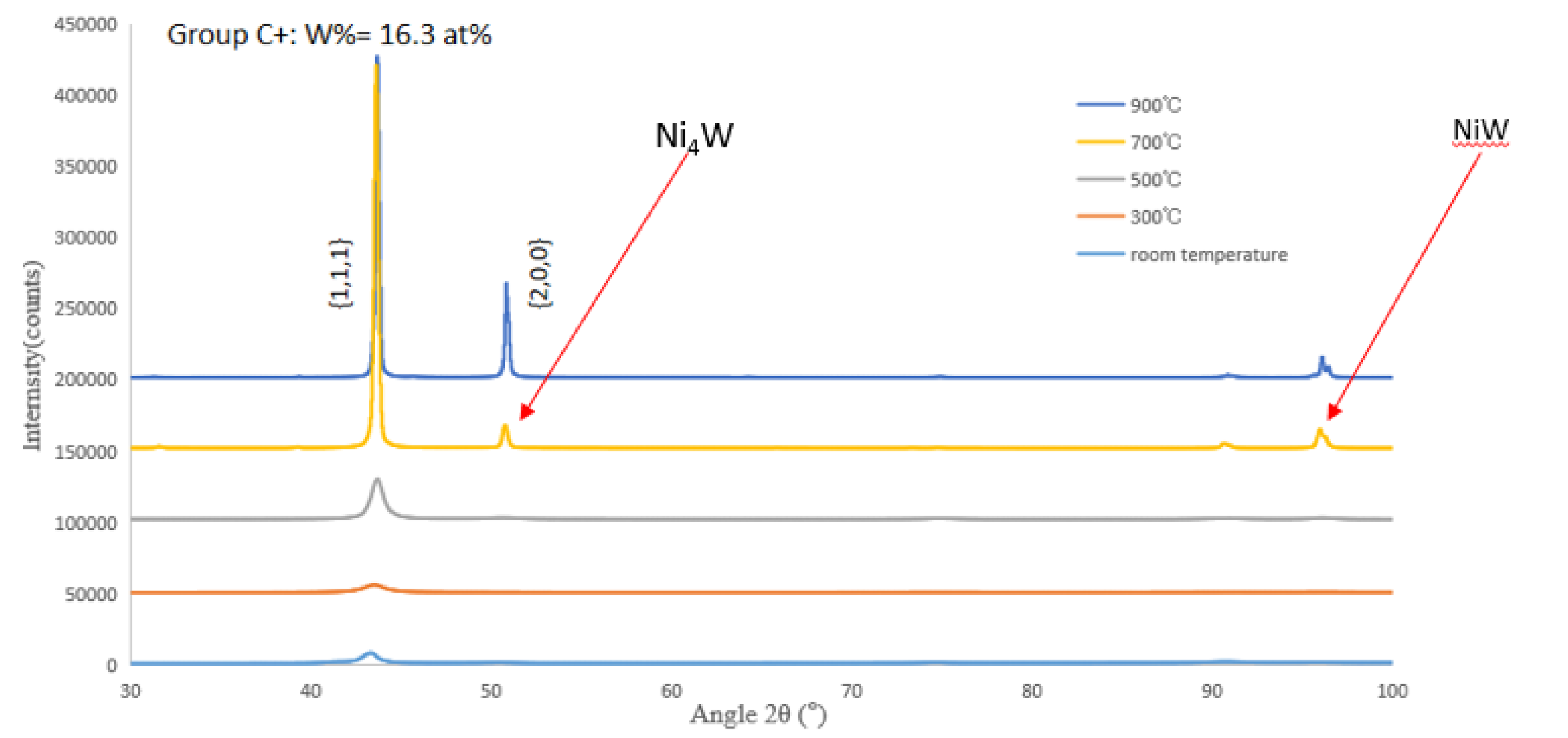
- Lowest corrosion current for NiW HT 900°C
- Decrease in corrosion current with current density especially for NiW followed by heat treatment

➢ Evolution of microhardness (HV_{50}) in function of current density and heat treatment



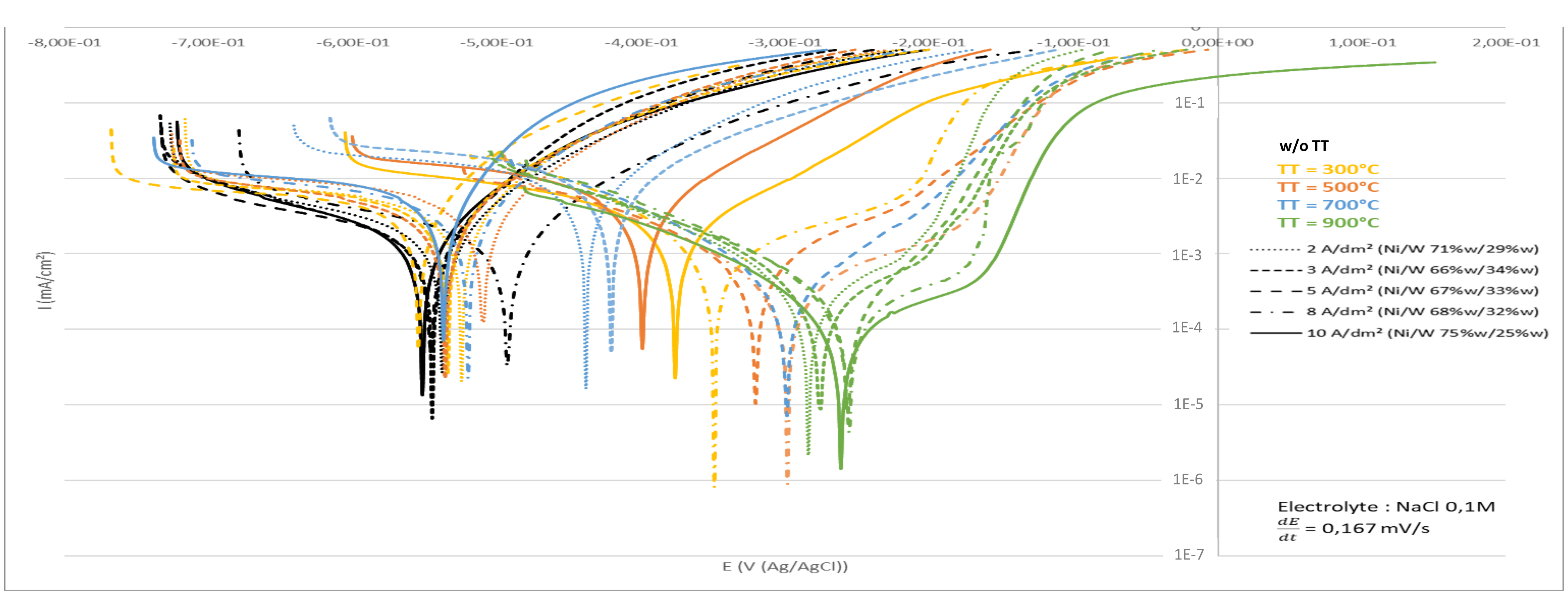
- Gradual increase in hardness with heat treatment temperature up to 500°C
- Decrease in hardness from 700°C with values at 900°C lower in comparison to NiW without heat treatment → grain size growth
- Best condition for NiW 10 A/dm² followed by HT 500°C

➢ X-ray diffraction pattern of NiW deposits



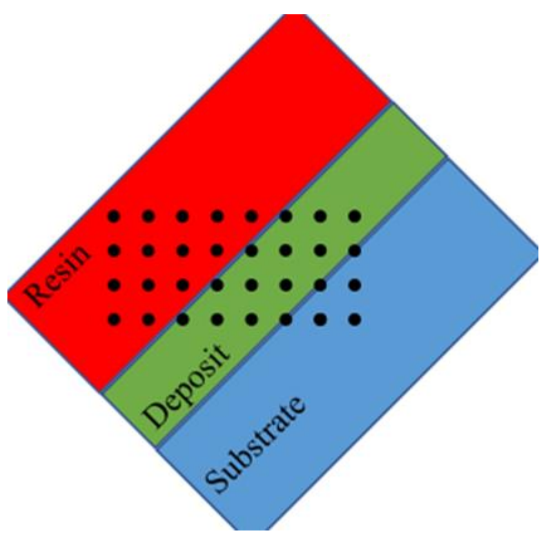
- Good thermal stability up to 500°C
- Phase transformations are occurring between 500 and 900°C → precipitation of Ni_4W and NiW intermetallic phases at 700°C
- Stress releasing due to the heat treatment → increase in the peak's height and decrease in the peak's width → lattice parameter and crystallite increase

➢ Potentiodynamic polarization behavior of NiW coatings at different current densities and heat treatments

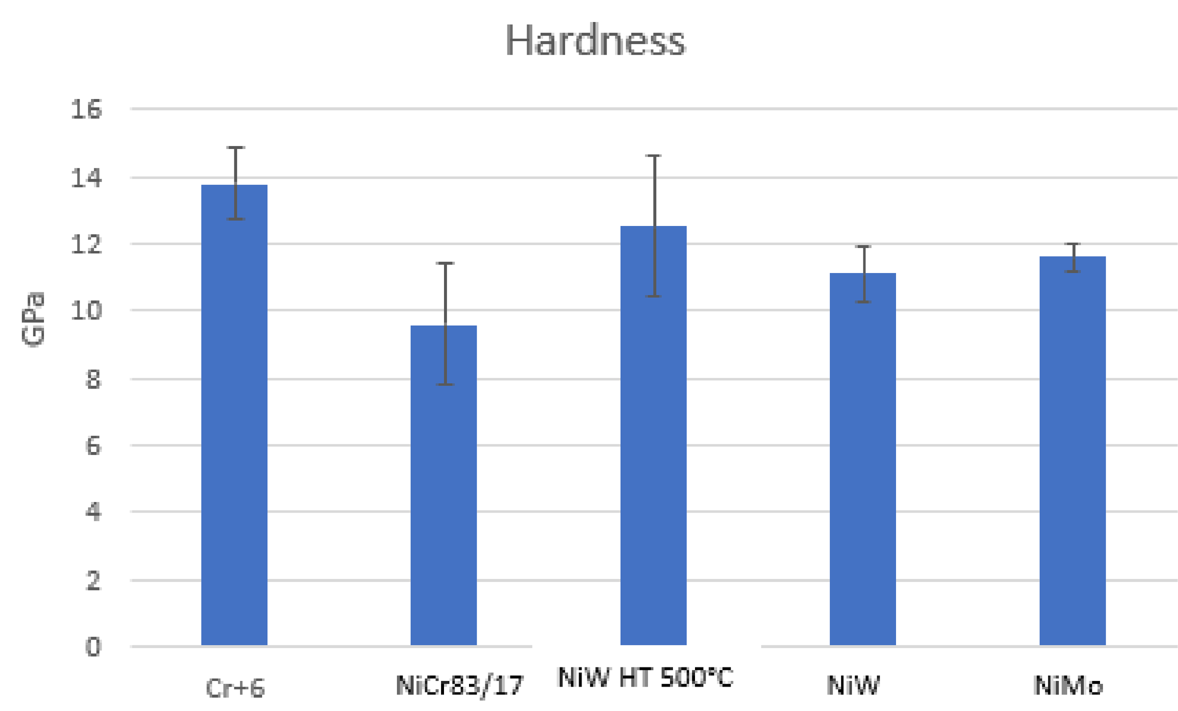


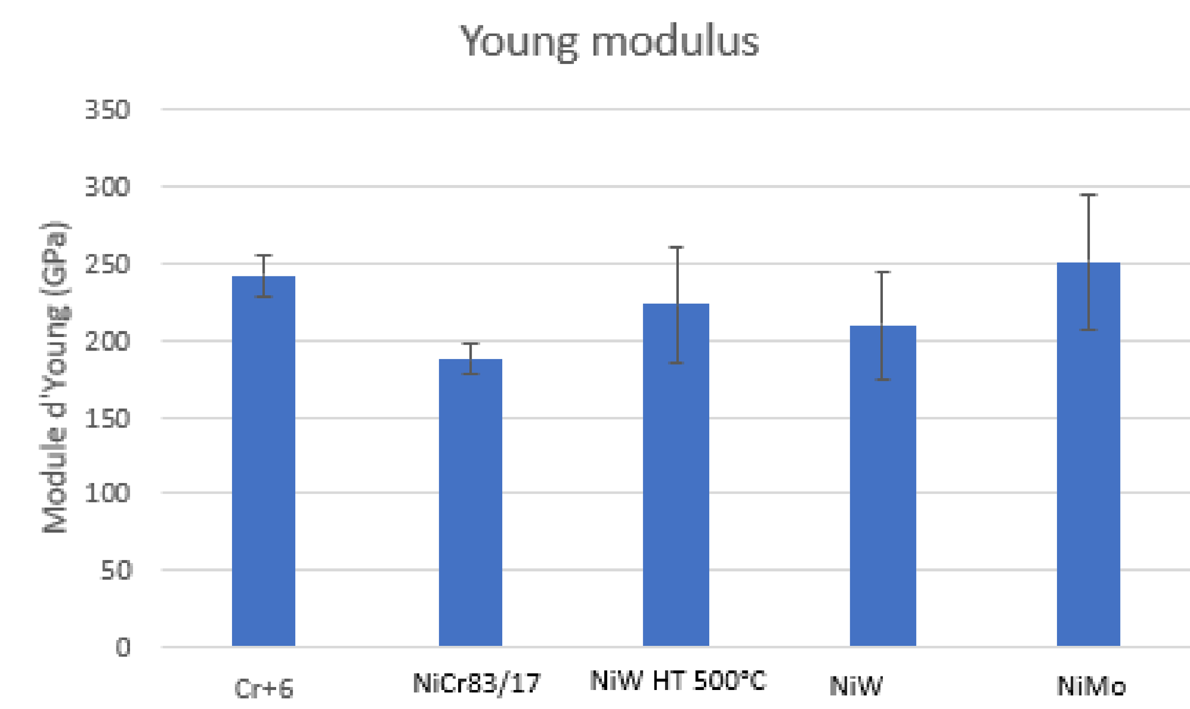
- NiW HT 900°C corrosion potential more noble than other conditions
- Increase in passivation area with increase in heat treatment temperature

➢ Nanoindentation test results



Load : 500 mN

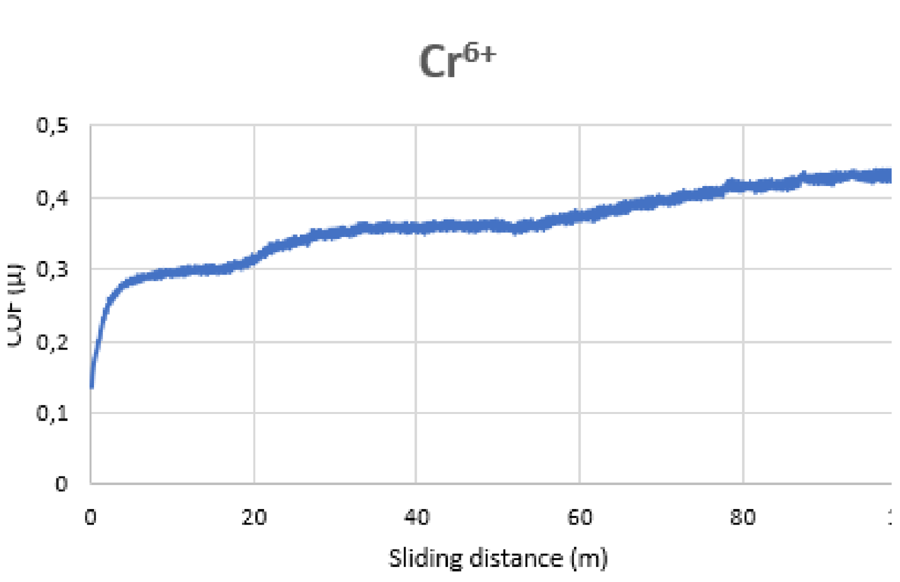


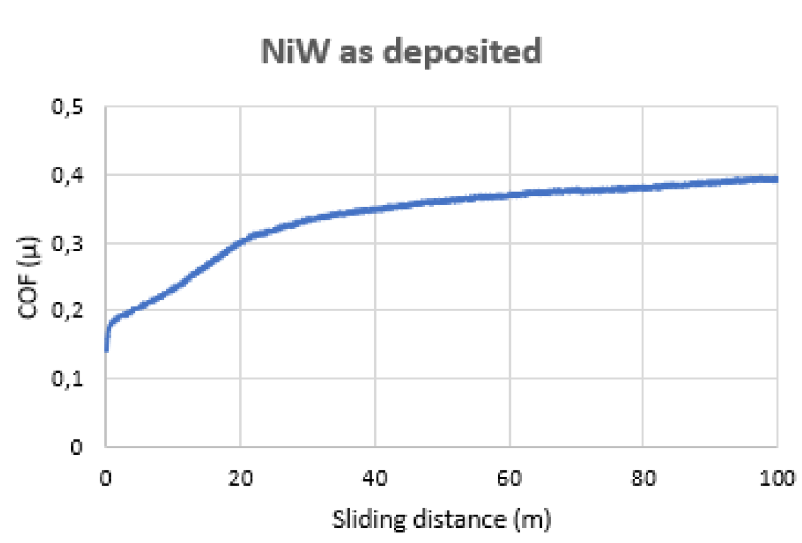


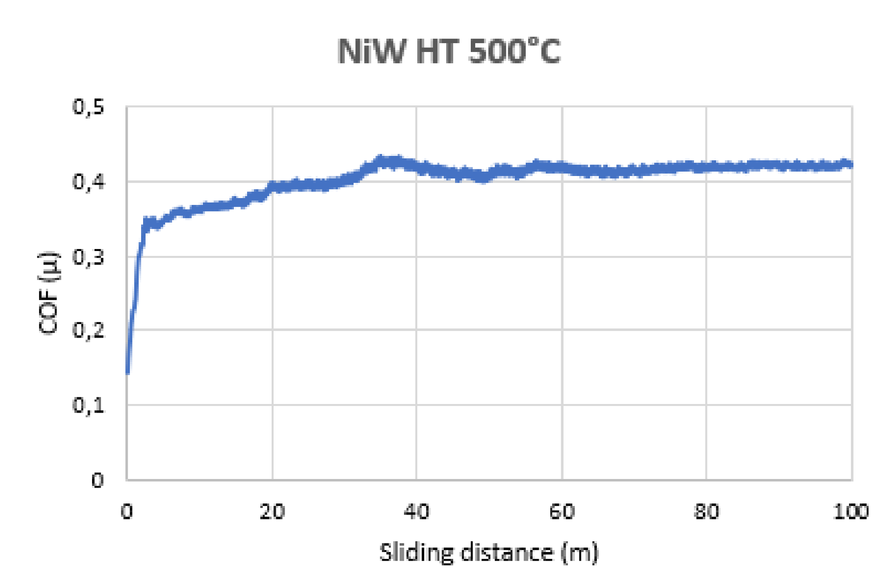
- NiW HT 500°C best alternative to hard chromium deposit in term of hardness
- Lower Young modulus for NiW HT 500°C than Cr deposit → ductility
- Ratio hardness/young modulus = toughness = ability of a material under mechanical constraint → NiW HT 500°C excellent behavior

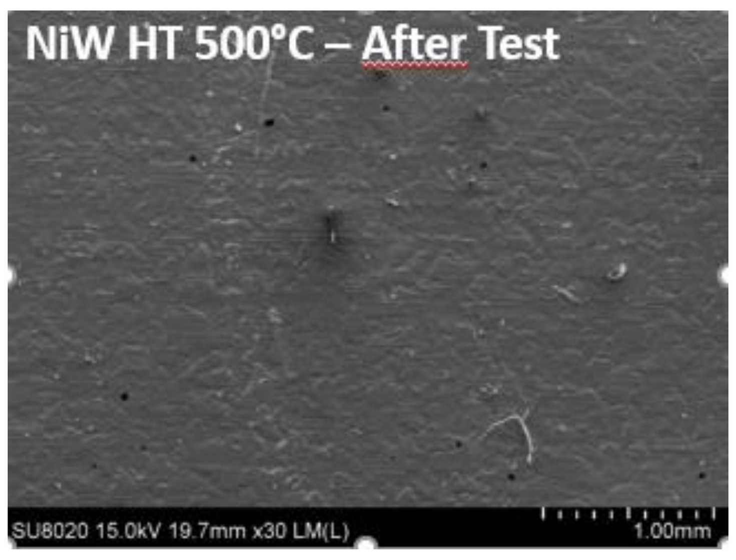
➢ Pin on disk test results

Parameters	
Load (N)	2
Sliding speed (cm/s)	10
Sliding distance (m)	100
Counter body	Al_2O_3
Counterbody diameter (mm)	6
Wear track (mm)	3 (radius)
Environment	Ambient









- NiW displays same friction coefficient profile than hard chromium coatings
- Higher stability of COF for NiW with heat treatment of 500°C

• *Conclusion*

❖ Based on the mechanical properties and corrosion resitance : **NiW at 5 A/dm² followed by 500°C heat treatment gives the best performance**

❖ NiW coatings could be considered as an alternative to the hard chromium coating : **hardness and wear resistances** close to hard chromium coating

❖ Coatings applied to industrial parts in **the textile and moulding sectors** currently under evaluation

• *Acknowledgments*

Interreg France-Wallonie-Vlaanderen
Alt Ctrl Trans

UMONS Université de Mons