

Smart coatings for tribological application

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CHEMICAL DEVELOPMENT & PRODUCTION

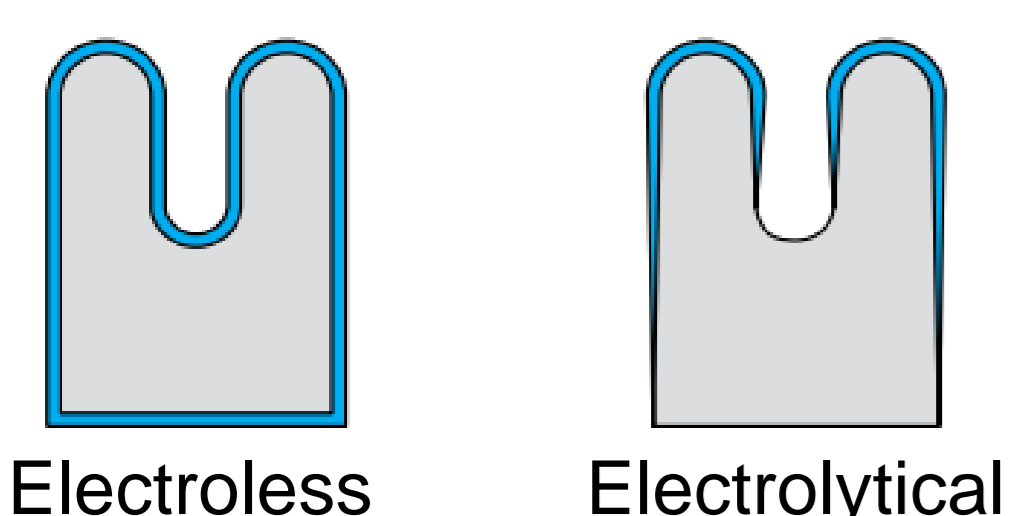
HEIA-FR

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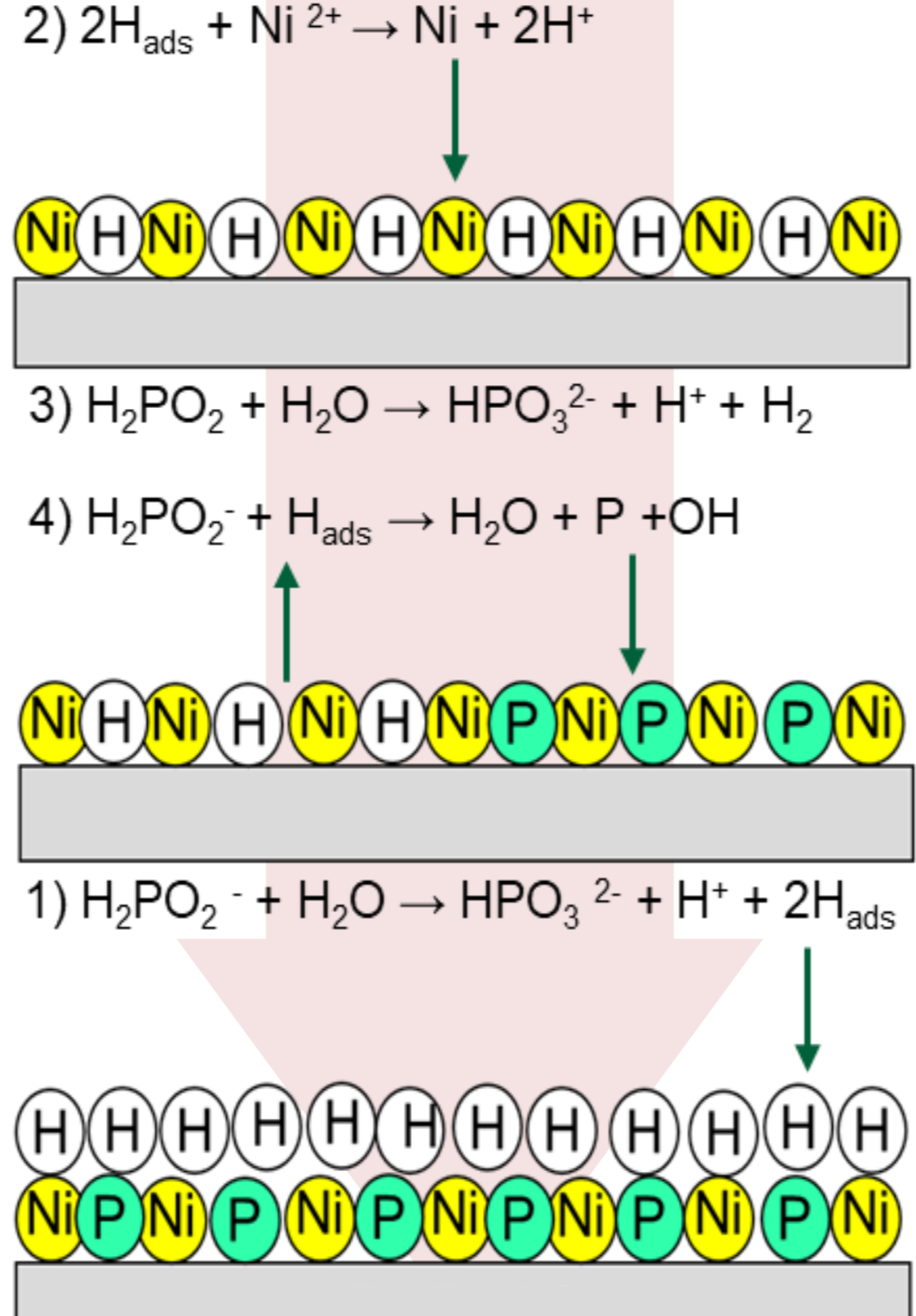
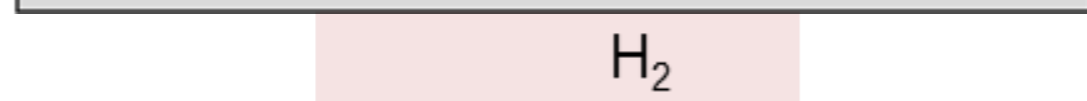
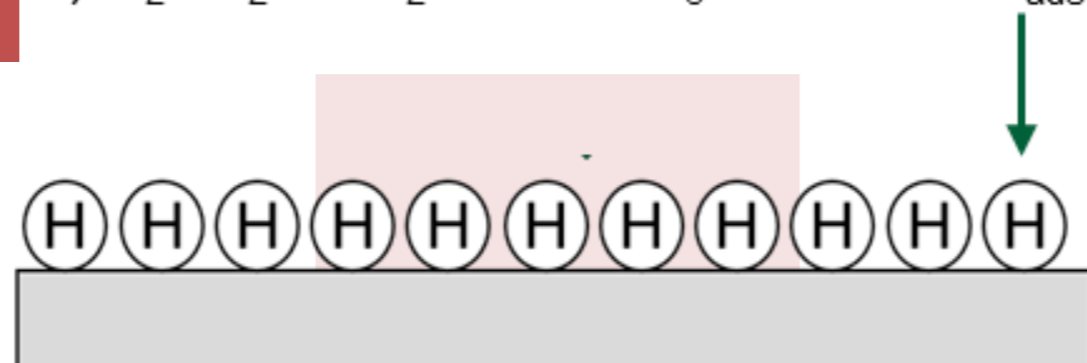
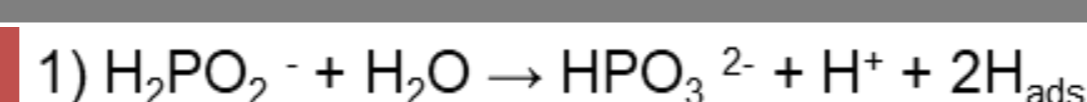
Watchmaking challenge

Challenging lubrication

Lubrication is a complex challenge in the watchmaking industry. Usually the lubrication is obtained by adding viscous liquids such as oil and grease to prevent the damages on the micromechanical components. The thesis studies the possibility to develop a dry film lubricant to avoid spillage and dirtying caused by the common lubricants. The auto-lubricant coating of NiP-PTFE has been developed on steel watch components. The electroless deposition process has been chosen to obtain homogenous thickness on the complexe geometry of the chronograph gear wheel.



Parameters	Values	Parameters	Values
NiSO ₄ · 6H ₂ O	40 [g/L]	Temperature	87 [°C]
NaH ₂ PO ₂ · H ₂ O	20 [g/L]	CTAB	412 [mg/L]
Na ₃ C ₆ H ₅ O ₇ · 2H ₂ O	90 [g/L]	CH ₃ COONa	17 [g/L]
PTFE 60% _m	25 [ml/L]	pH	5.5 [-]



OBJECTIVES

The thesis is divided in 4 parts.

Research and development :

The objective of this phase is to find a bath composition to obtain a coating that fits the given technical specifications

Optimization of the reaction :

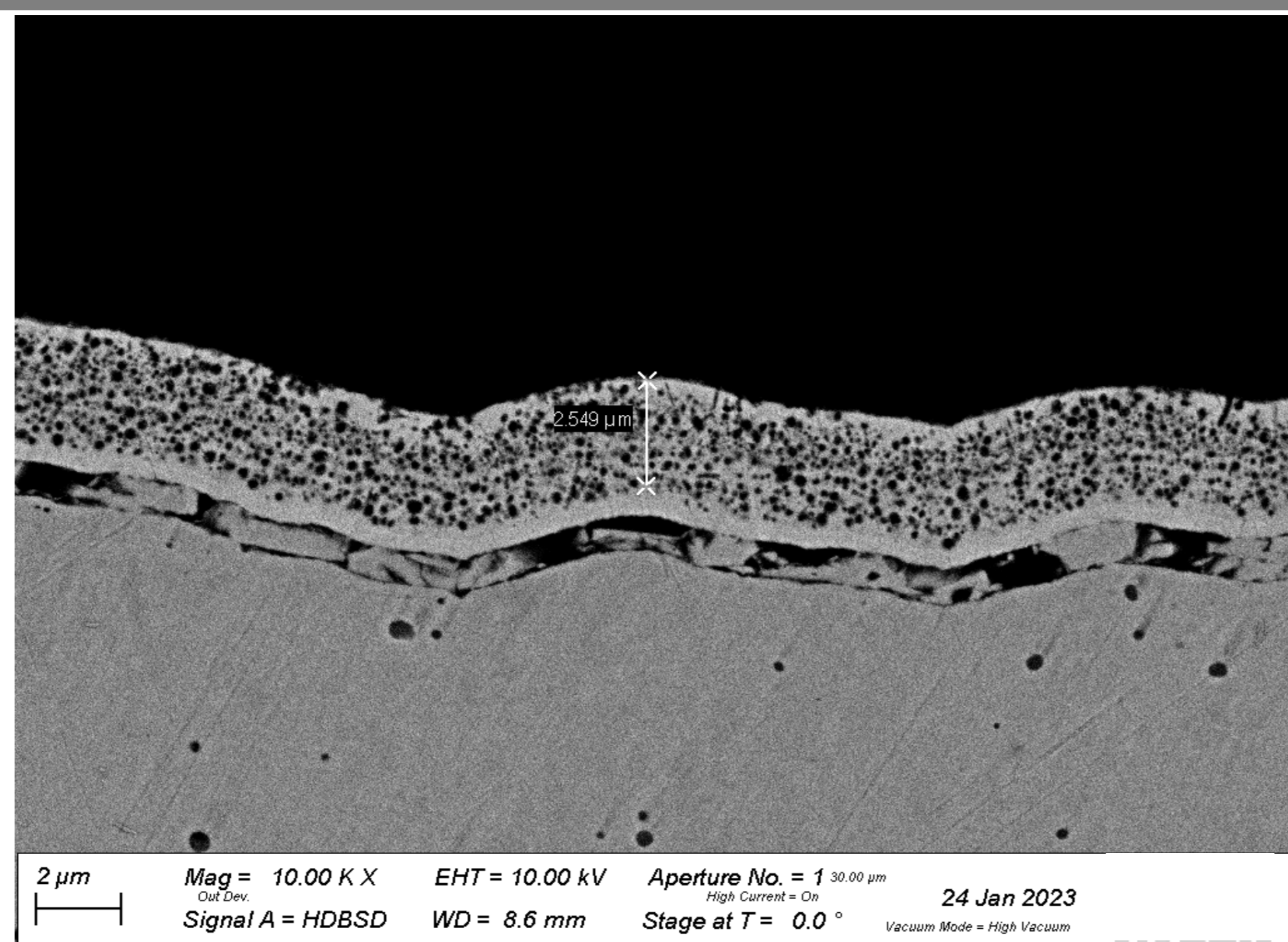
Two DOE have been made. First one was to find the meaningful parameters. The second one was to model the reaction of deposition based on thickness (rate of deposition, %v PTFE, %m P and Friction coefficient

Bulk deposition

One the reaction is optimized watch components can be coated. The mode of deposition is called bulk deposition because the watch component are too small to been hang by a wire

Coating charaterization

Determine the efficiency in terms of wear resistant and friction



Layers	Thickness	Limits	%v PTFE	%m P
Layer 1 NiP	>0.1 [μm]	4 ± 1 [μm]	-	> 8% _m
Layer 2 NiP-PTFE	>2.9 [μm]		20 ± 5% _v	> 8% _m

RESULTS

Fractional DOE : Define the meaningful parameter

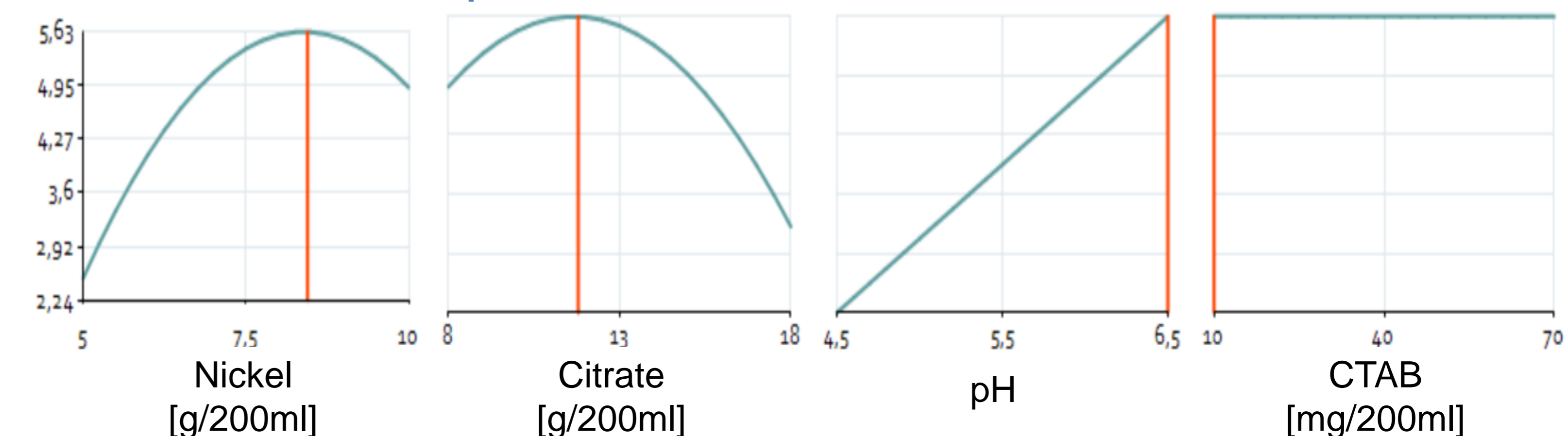
A fractional Taguchi L-12 with 12 experiment have been used to determine the meaningful parameters of the list :

C(Ni)	C(Hypo)	C(Cit)	C(CTAB)	C(Ace)	C(PTFE)	T °C	Surface	RPM	pH
○	×	○	○	×	×	×	×	×	○

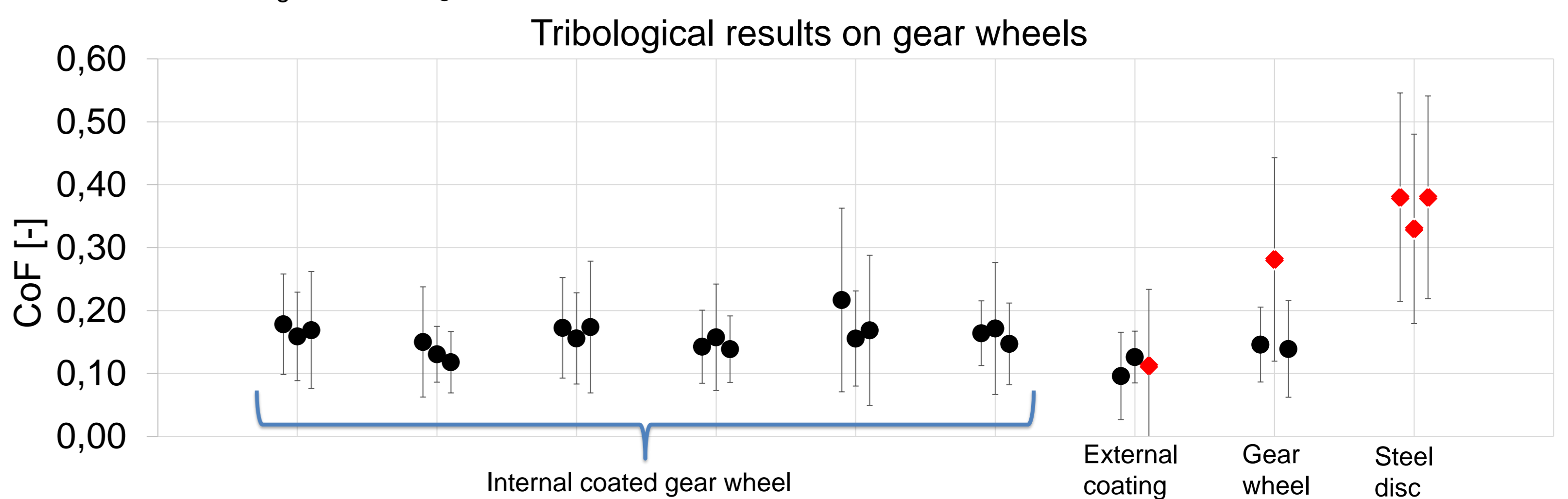
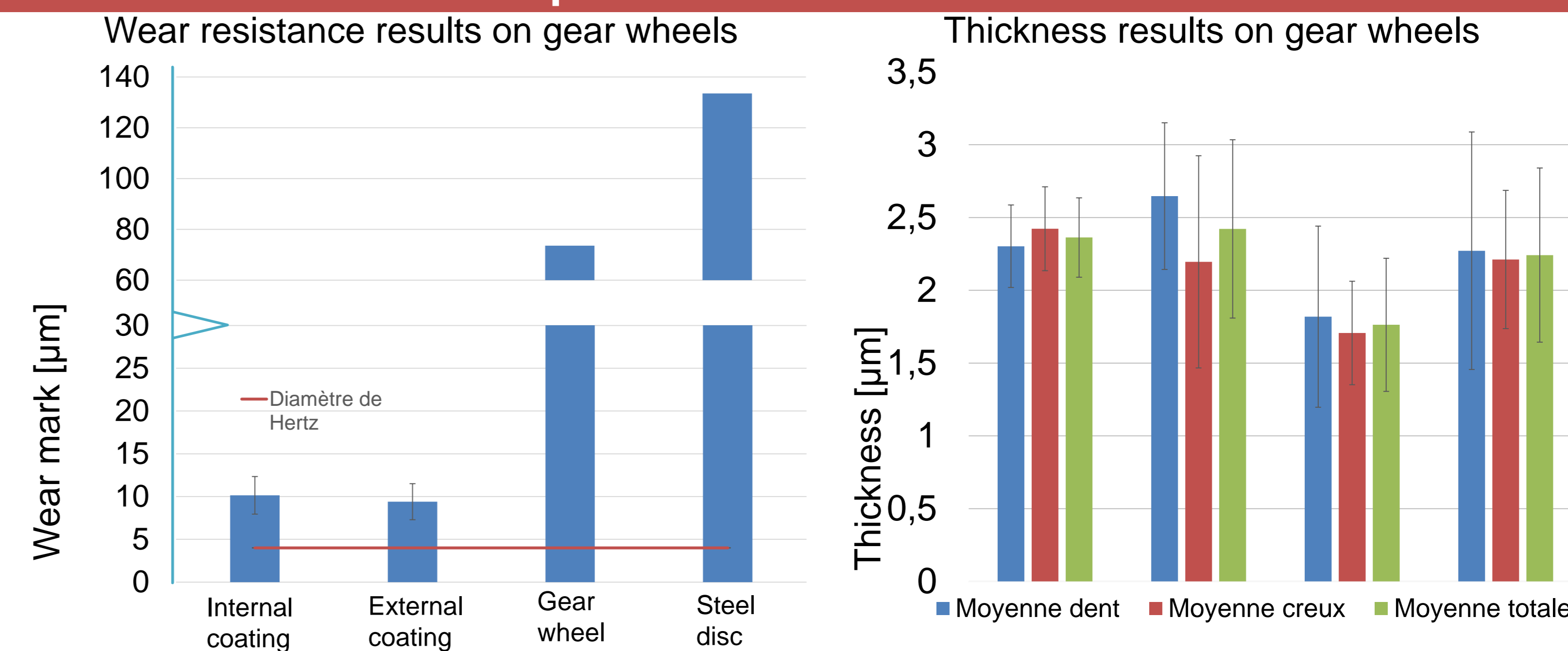
Ni : Rate of deposition / Friction coefficient / %m P
Citrate : Rate of deposition / Friction coefficient / %m P
CTAB : %v PTFE
pH : Rate of deposition / %m P

Complete DOE : System modeling

$$\text{Thickness } [\mu\text{m}] = -16.09 + 2.587 \cdot \text{Ni} + 1.694 \cdot \text{pH} - 0.2705 \cdot \text{Ni}^2 - 0.05993 \cdot \text{Citrate}^2 + 0.1655 \cdot \text{Ni} \cdot \text{Citrate}$$



Bulk deposition and characterization



CONCLUSION

Conclusion and perspective

- The main objectives of the project have been achieved.
- The research phase led to a process capable of providing the company a deposition bath in accordance with the specifications.
- The modeling of the reaction has been made and used in a practical test on the wheel gear and the results are as expected.
- The characterization has proven that the newly developed coating had the same coefficient of friction and resistance to wear than the external coating. The wear resistance of the raw component is too weak for the parts to be used uncoated. The coating is mandatory for the application
- Further investigation are need to see if the coating can be implemented in the industrial production : hardness, phosphorus limits, corrosion resistance are the main parameters to characterize before the scale u-up. In the current state ,the process needs 3 hours of deposition for the coating to achieve the specification of thickness. Rate of deposition , in other terms productivity is an issue.
- The company already has some ideas to implement such coating on a different type of substrate, most likely brass.