



**A process optimization tool for emerging
Plating on Plastics Processes**



EXELISIS

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**Toxic
FREE METallization process
for plastic surfaces**

Advances in Materials

**Modeling: From Atoms to
Industrial application**

**Joint Webinar
18 June 2025**



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CONTENTS

1. Etching technology introduction
2. Models development
3. Example



Plating on Plastics (PoP)

- **Plastics:** low density, lightweight, low cost
- **Metal coating:**
 - ✓ Protection: wear resistance and corrosion
 - ✓ shiny, polished, aesthetic

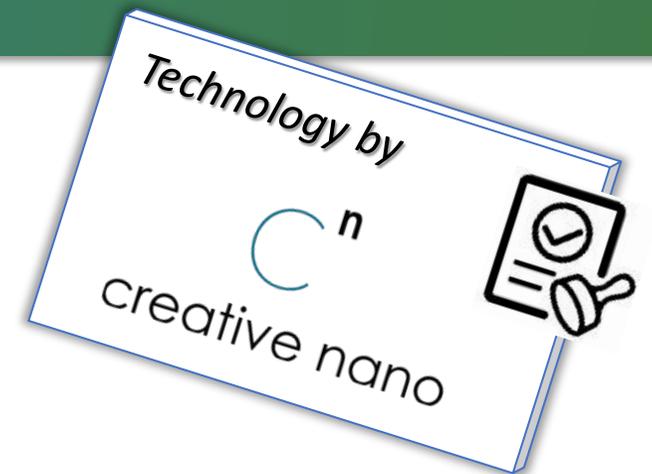
Everyday examples

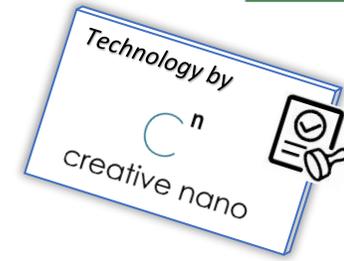


Plastic before/after plating

Plating baths

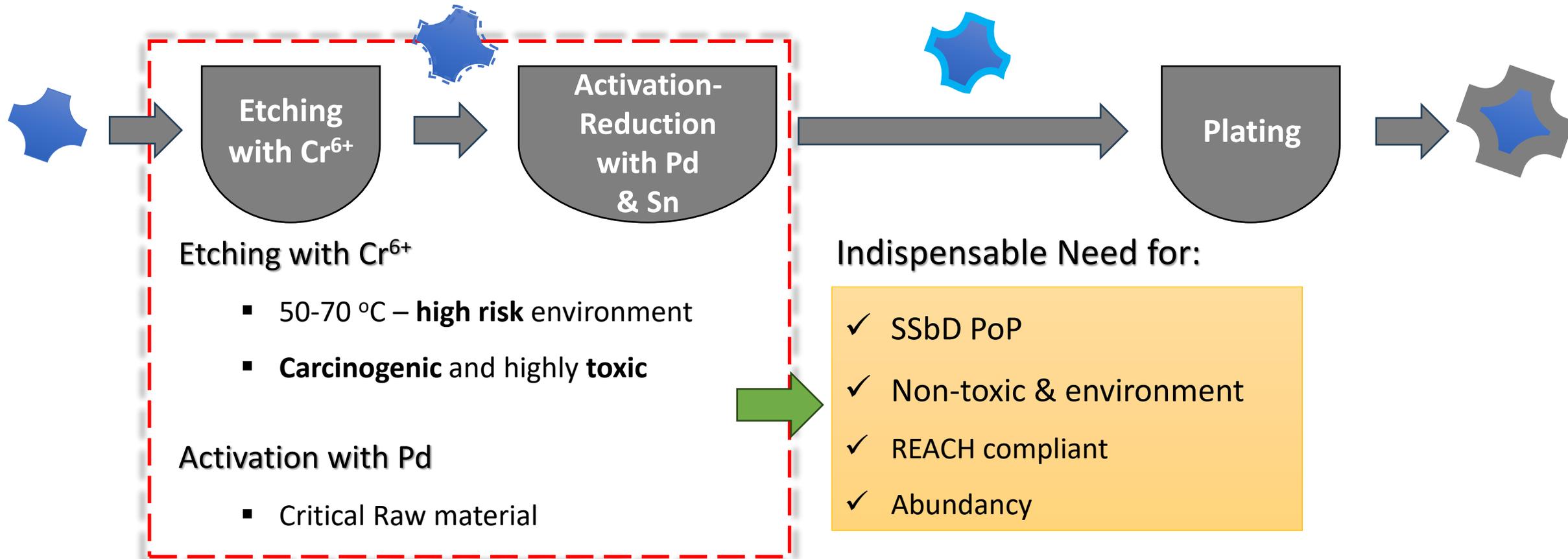
Plastics Etching Technology

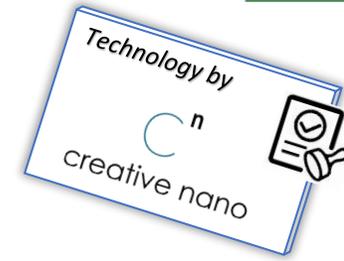




Plating on Plastics (PoP)

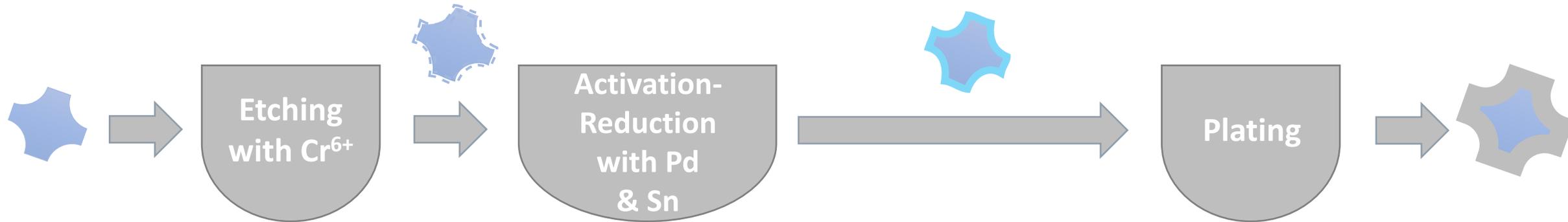
Conventional Approach



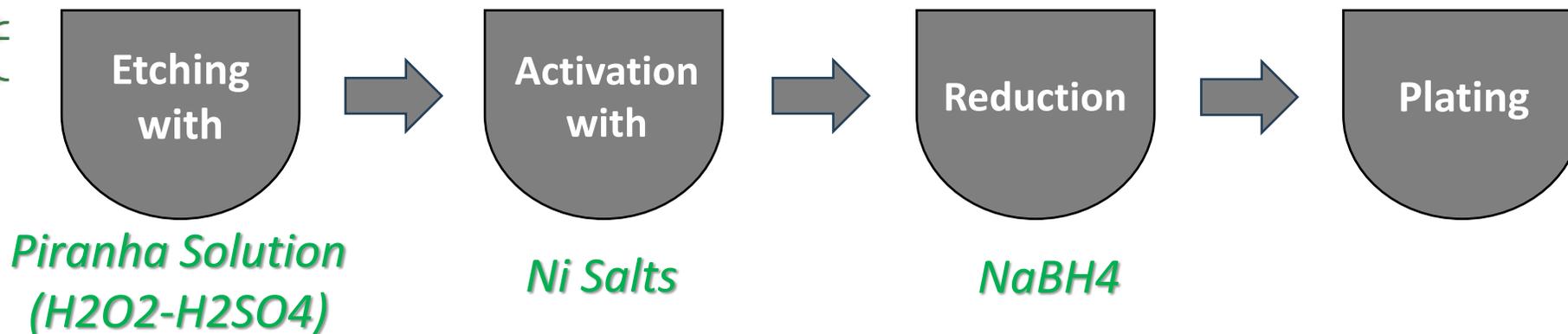


Plating on Plastics (PoP)

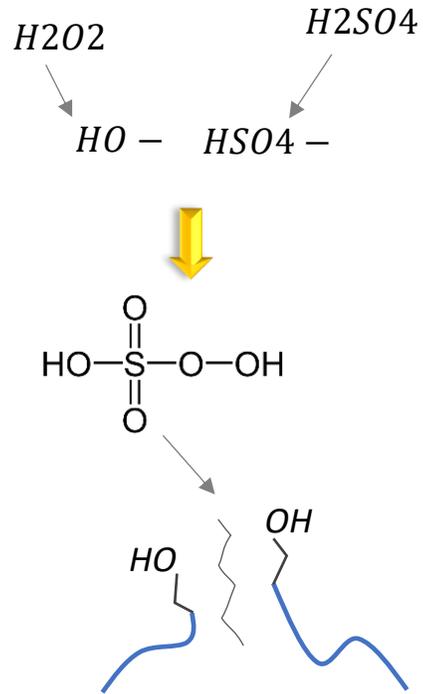
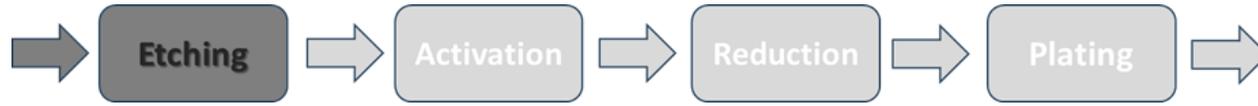
Conventional Approach



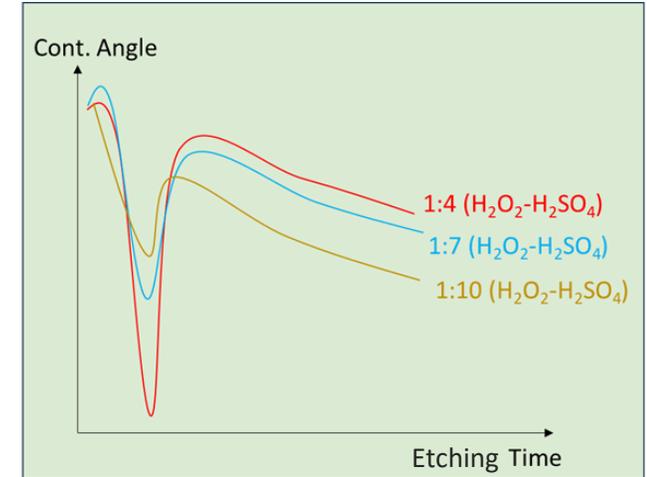
Novel Technology



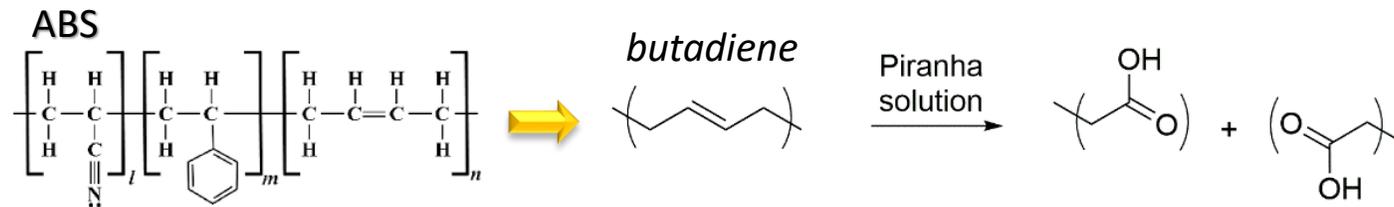
Etching with Piranha ($H_2O_2-H_2SO_4$)



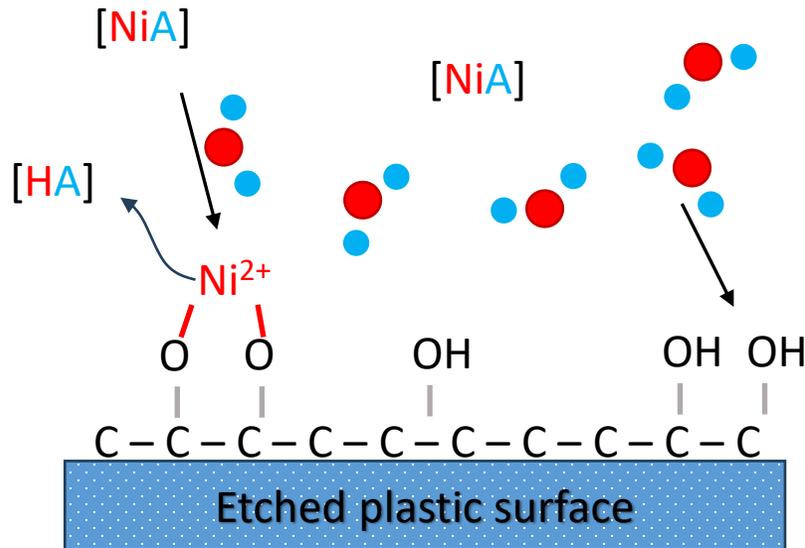
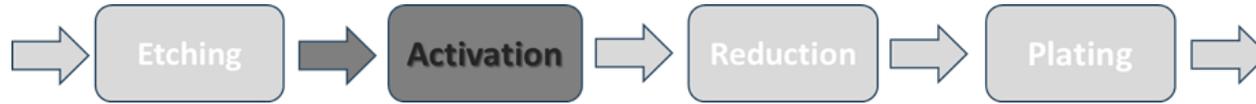
- Cleavage of double bonds
- Hydrophilic groups (-COOH, -OH)
- Further activation with metal ions
- micro-/nano-sized cavities
- surface area ↑



- ✓ Performance
- ✓ Hydrophilicity
- ✓ Contact Angle



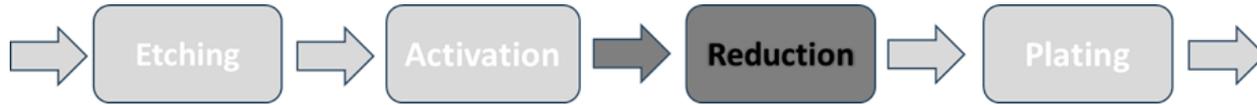
Activation with Ni Salts



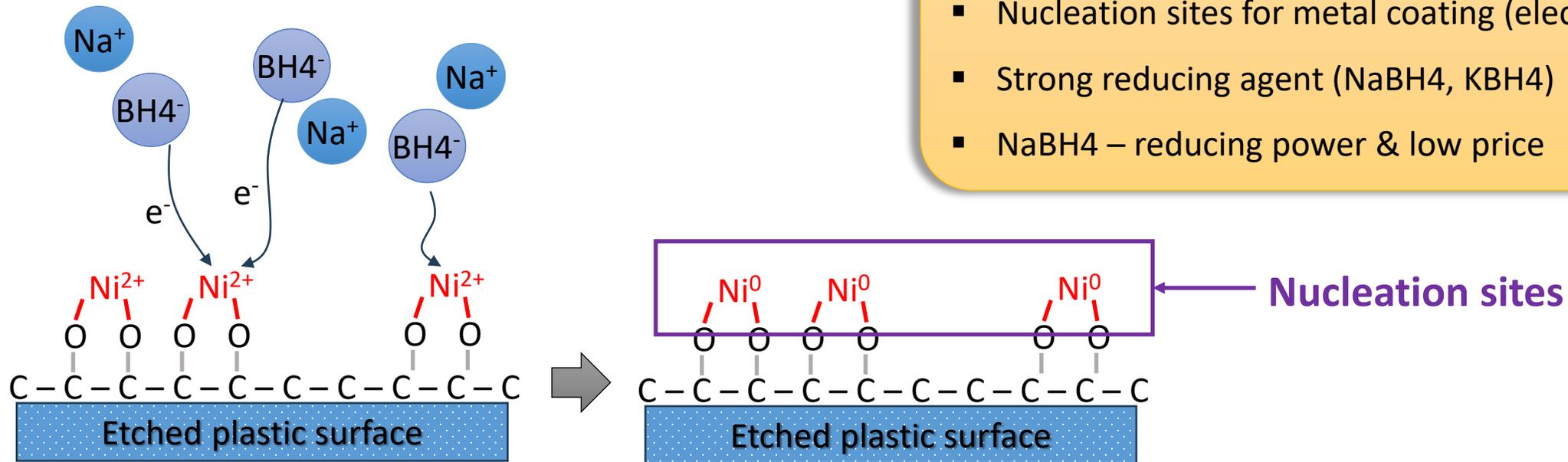
- ✓ Hydrophilic groups (-COOH, -OH)
- ↓
- ✓ Chemical adsorption
- ✓ Initial metal nucleation sites
- ✓ Chemical identity of metalization precursor (not binding)

- Uniform distribution
- Homogeneous growth

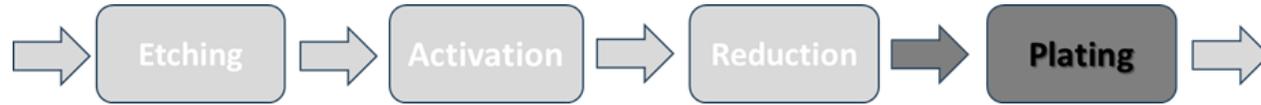
Reduction



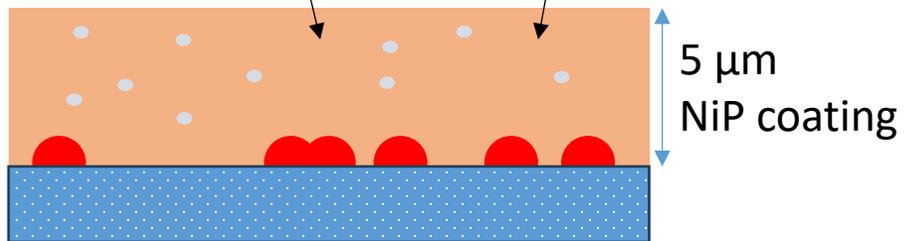
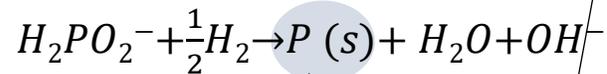
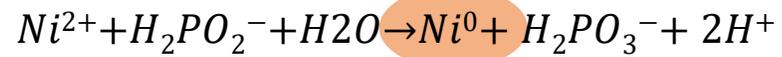
- Reduction to metallic state ($M^{X+} \rightarrow M^0$)
- Nucleation sites for metal coating (electroless step)
- Strong reducing agent (NaBH₄, KBH₄)
- NaBH₄ – reducing power & low price



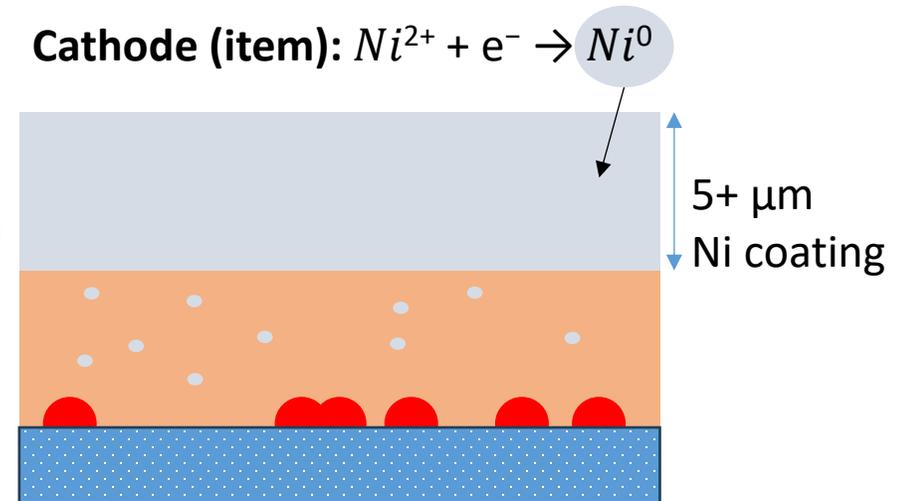
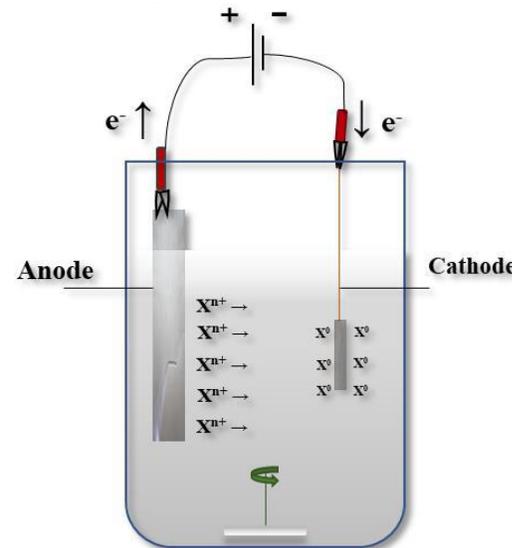
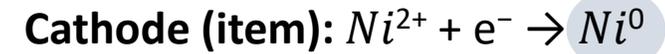
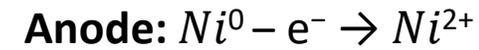
Plating



Step-1: NiP electroless plating



Step-2: Ni Electroplating





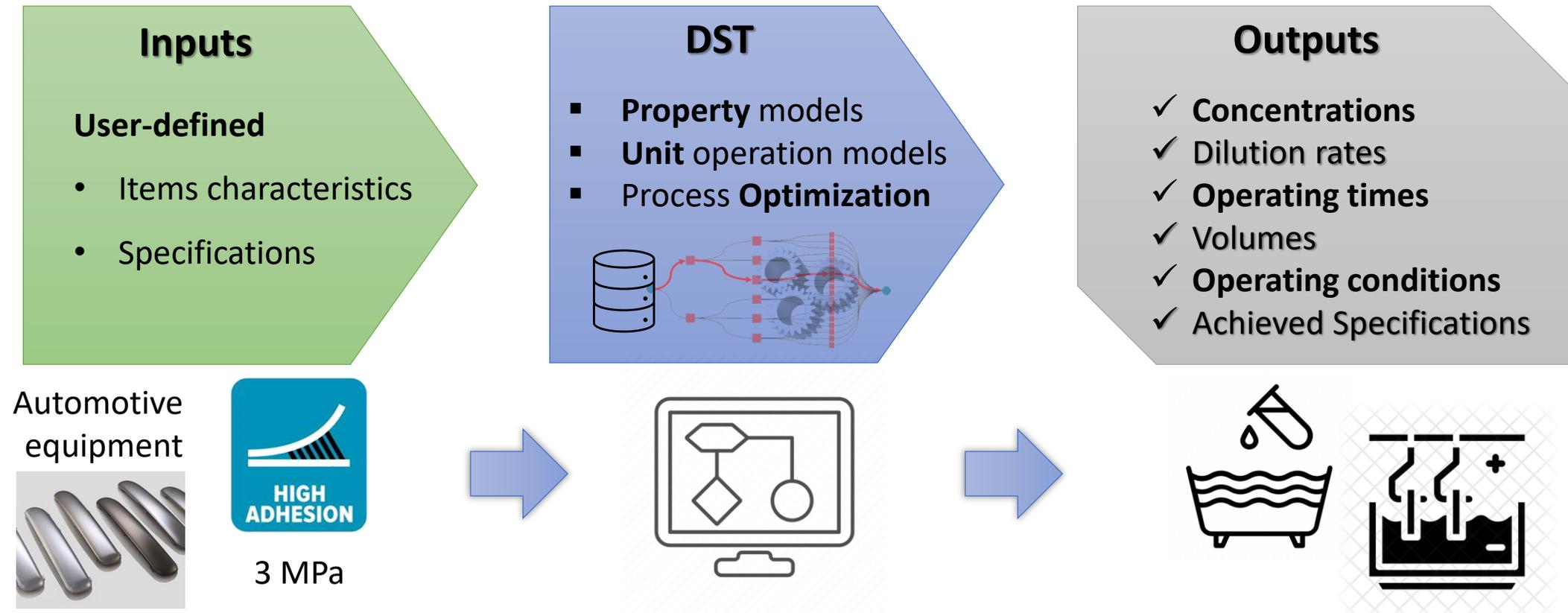
Modeling Etching Technology

From Lab to Computer



Decision Support Tool (DST)

Etching Technology



Decision Support Tool – Background

Fed with:

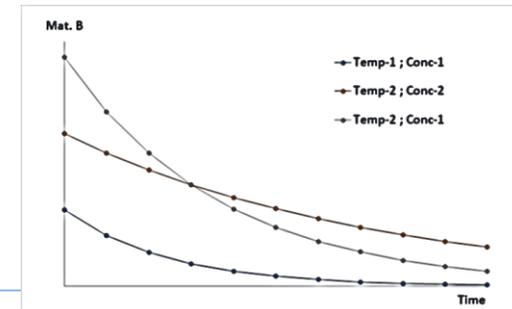
- *Experiments database*
- *Specifications (Contact Angel, Adhesion, Thickness)*
- *Conditions per Stage*

➤ $f(x_1, x_2, x_3, \dots, x_N)$

➤ $g(x_1, x_2, x_3, \dots, x_N)$



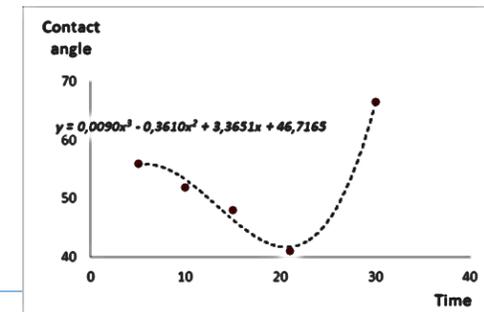
- Mass Balances
- Kinetics
- Electrochemistry



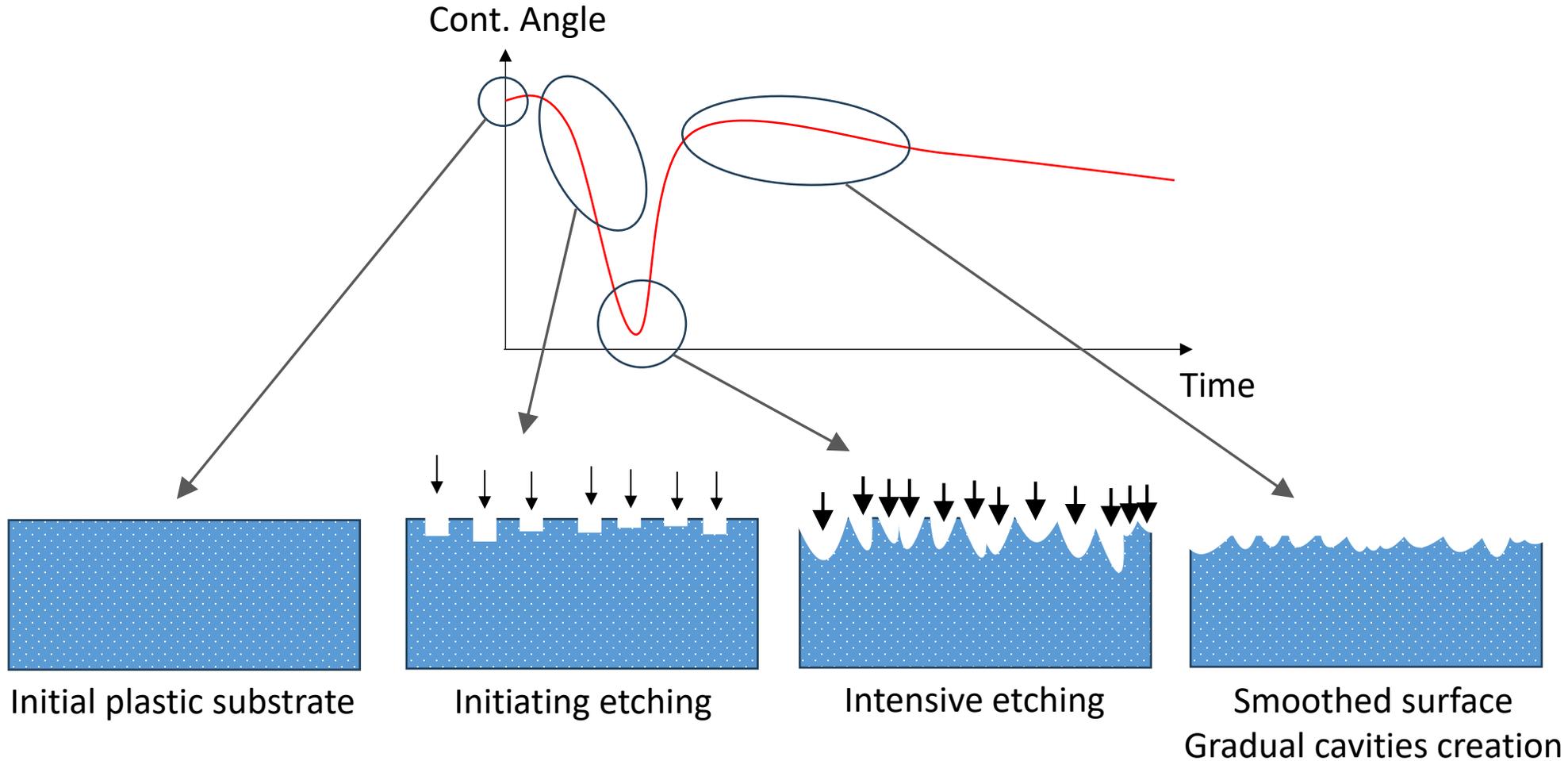
State of the Art Models

- Unconventional data
- Combinatorial insights
- Operating conditions → Outputs

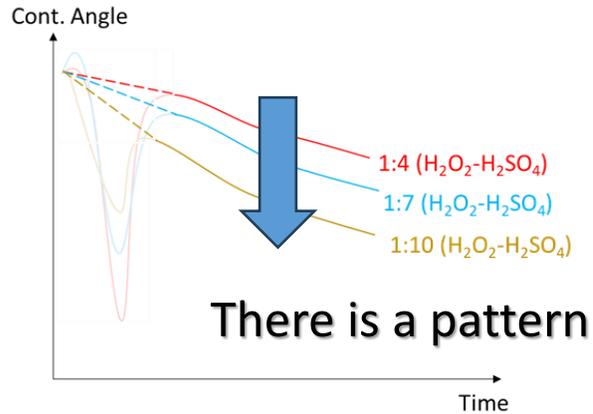
Regression Models



Contact Angle property model



Contact Angle property model

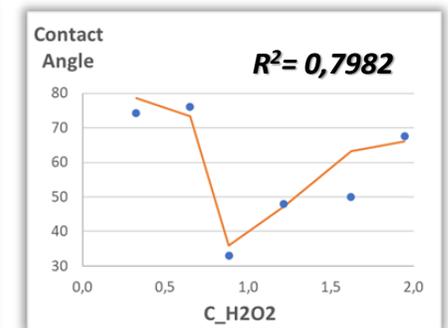
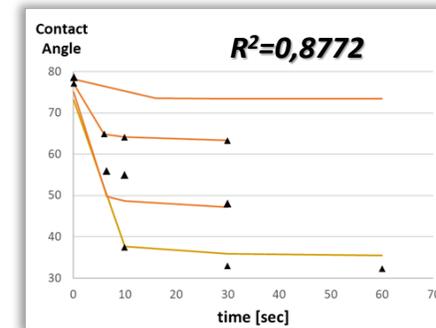
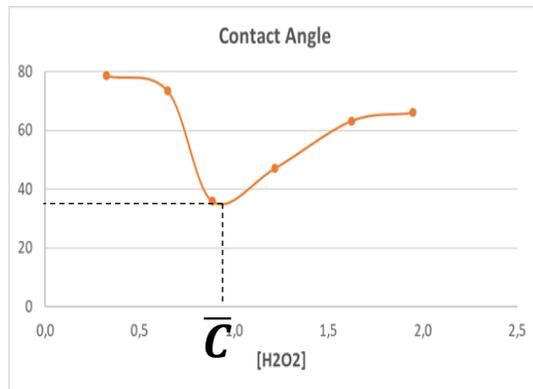


Contact Angle estimation model

- Modified **DIPPR Equation #115**

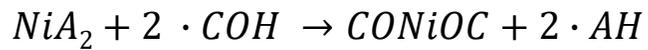
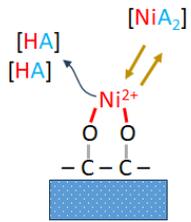
$$CA = CA^0 \cdot \exp\left(-\frac{B \cdot t}{t + 1}\right)$$

$$B = \exp\left(A' + \frac{B'}{C_{H_2O_2}} + C' \cdot \ln(C_{H_2O_2}) + C' \cdot C_{H_2O_2}^{D'}\right)$$

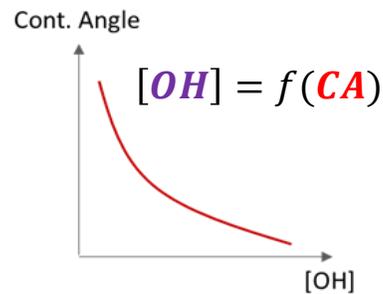


Activation stage

Equilibrium



[OH] vs Contact Angel

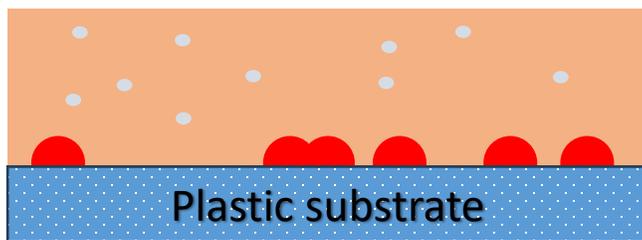


Reduction stage

$$Ni^{2+} + 2 \cdot BH_4^- + 6 \cdot H_2O \rightarrow Ni^0 + 2 \cdot B(OH)_3 + 7H_2$$

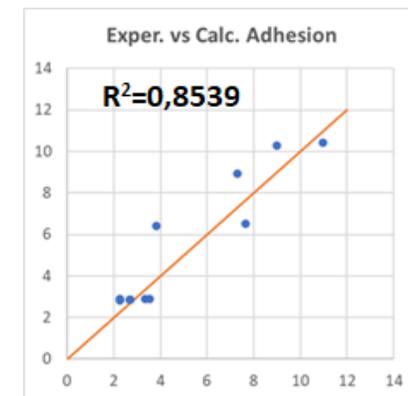
$$Ni^{2+} + BH_4^- \rightarrow NiB + H_2 + \text{byproducts } ([NaBH_4] \uparrow \uparrow)$$

Plating stage



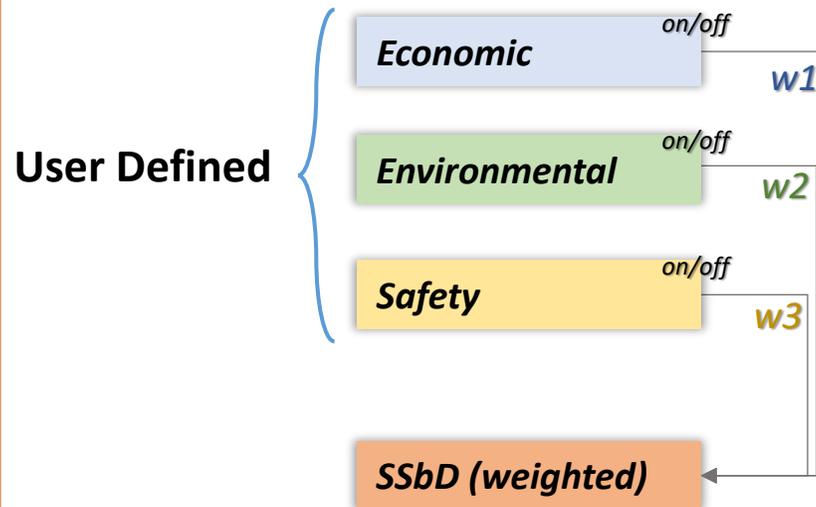
Fixed NiP Recipe
5 μ m

$$Adhesion = a \cdot C_{Ni^0}$$



Technology Simulation & optimization Model

Safe & Sustainable by Design Objective functions

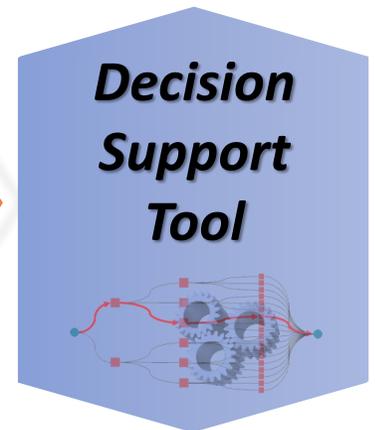


$$= \sum_i a_i X_i$$

i.e. $[H_2O_2]$, $[NiA_2]$, C_B

- *Economic Indicators*
- *Environmental Indicators*
- *Safety Indicators*

Optimization Framework
Genetic Algorithm



DST implementation

Automotive equipment



Inputs set by USER

Number of Items	100
Item surface	20 cm ² (2 x 10 x 1 cm)
Thickness Specification	10 μm
Adhesion Specification	2,5 MPa

33%-33%-33%

	Econom	Envir/Safety	SSbD
Piranha (H ₂ O ₂ -H ₂ SO ₄)	1:7,1	1:4	1:4
Dilution (Piranha-Water)	1:0,5	1:1,5	1:1,4
Volume (lt)	25	25	25
Etching time [sec]	21	120	120
Activation: NiA [gr/lt]	9,7	10	10
Reduction: NaBH ₄ [gr/lt]	10	10	10
Reduction time [sec]	300	300	300
Plating: I density [A/dm ²]	1,54	1,54	1,54
Plating time [hr]	2	2	2
Thickness [μm]	10	10	10
Adhesion [Mpa]	2,55	2,55	2,55



DST implementation

Automotive equipment



FreeMe Decision Support Tool

Solution <1 sec

- ✓ High throughput analysis
- ✓ Integrated with Real-time monitoring
- ✓ Live process optimization & management
- ✓ Everyday planning

Inputs set by USER

Number of Items	100
Item surface	20 cm ² (2 x 10 x 1 cm)
Thickness Specification	10 μm
Adhesion Specification	2,5 MPa

Piranha (H₂O₂-H₂SO₄)

Econom

Envir/Safety

SSbD

1:7,1

1:4

1:4

1:1,5

1:1,4

25

25

Etching time [sec]

21

120

120

10

10

10

10

300

300

1,54

1,54

2

2

Thickness [μm]

10

10

10

Adhesion [Mpa]

2,55

2,55

2,55

33%-33%-33%





THANK YOU!

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