

## Tungsten as a versatile element for thin coatings for mechanical applications

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MIICS 2006

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### Outline

- ◆ Introduction
- ◆ W-N(O) System
  - Mechanical and decorative properties
- ◆ W-S-C/N System –
  - Hardness and tribological behaviour
- ◆ W-Si-N System
  - Hardness and thermal stability
  - Oxydation resistance
- ◆ W-Ti-N System
  - Hardness and tribological behaviour
  - In service behaviour
- ◆ Conclusions.

# Research Group



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# Coimbra University



Old part of the town

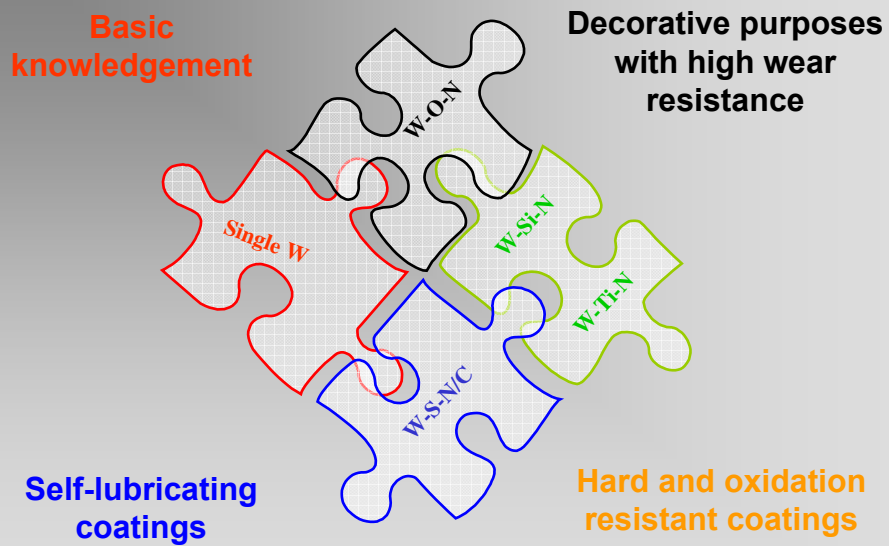
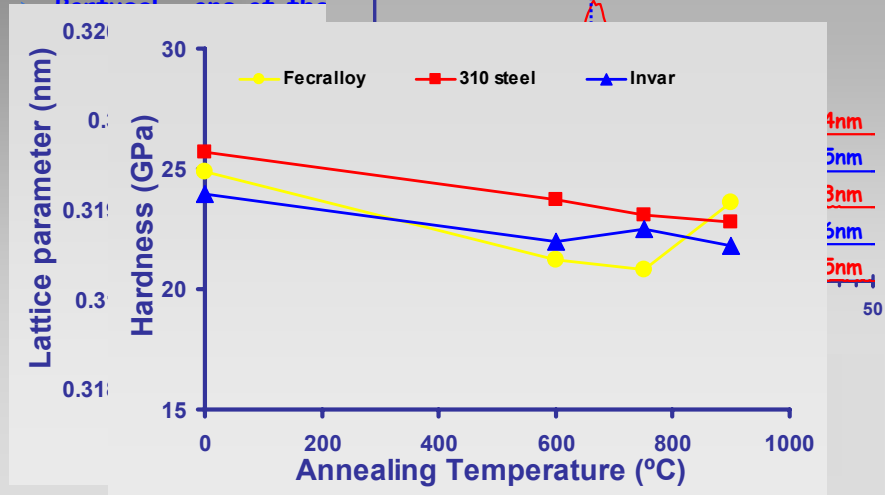


Old University



New part of the University

# Introduction



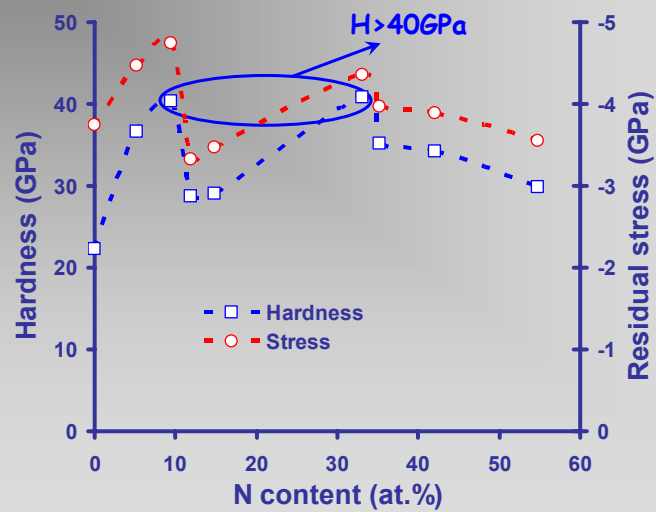
## • W-N(O) System

### OBJECTIVES

- Hard and decorative coatings
- Technique - Reactive sputtering with controlled flow of the reactive gases in conventional and pulsing modes

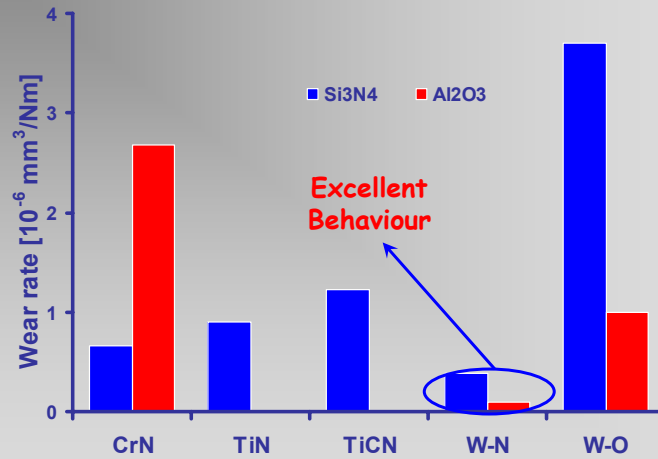
### Results (Hardness and residual stresses)

#### Coatings W-N



### Results (Comparing tribological behaviour )

#### Coatings W-N(O)

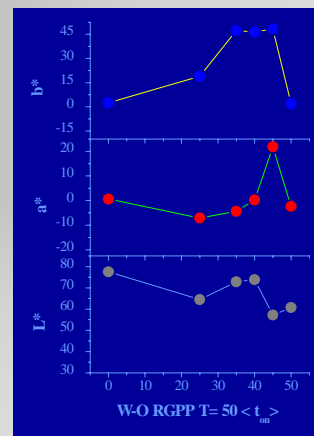
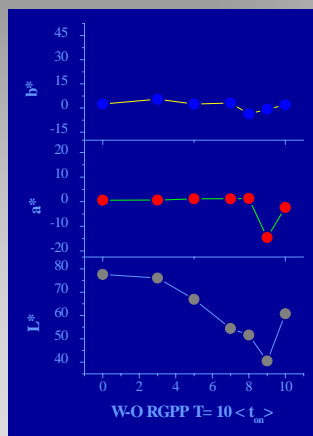


### Results (Decorative - color - optical filters)

#### Coatings W-O-N

T = 10 s

T = 50 s



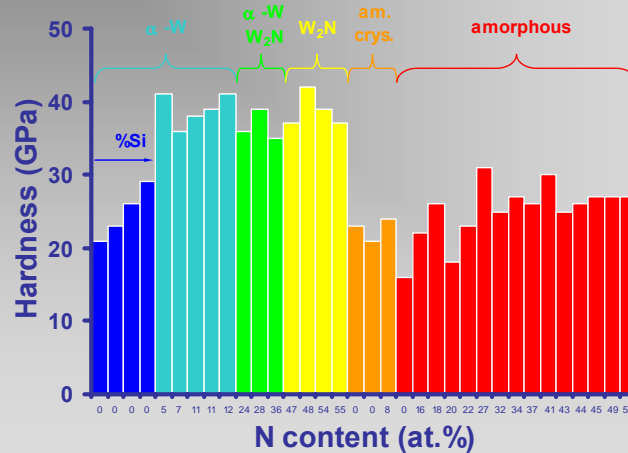
## • W-Si-N System

### OBJECTIVES

- Hard coatings oxidation resistant
- Nanocomposite structures of WN + Si<sub>3</sub>N<sub>4</sub> type
- Technique - Reactive sputtering from a W target incrusted with Si pellets

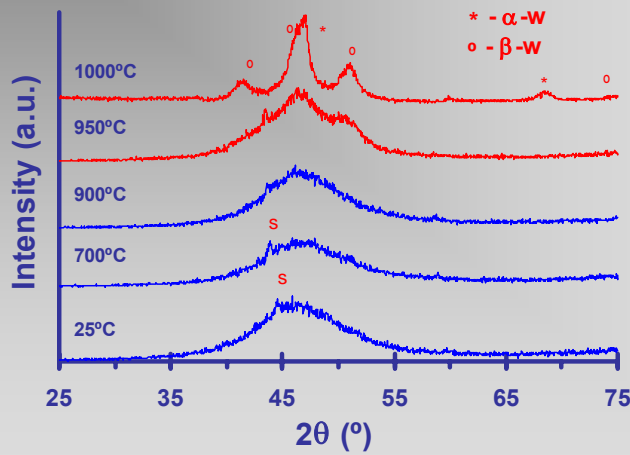
## Results (Hardness)

As-deposited conditions



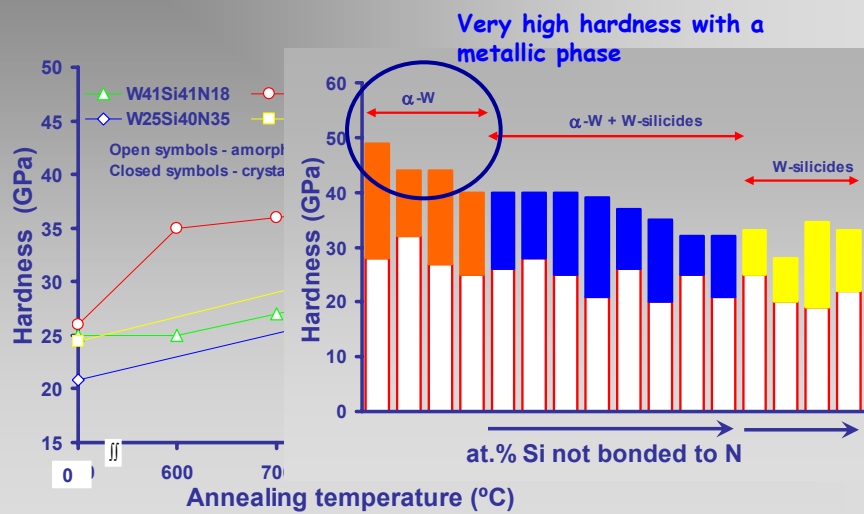
### Thermal stability (protective atmosphere)

Coating  $W_{26}Si_{30}N_{44}$



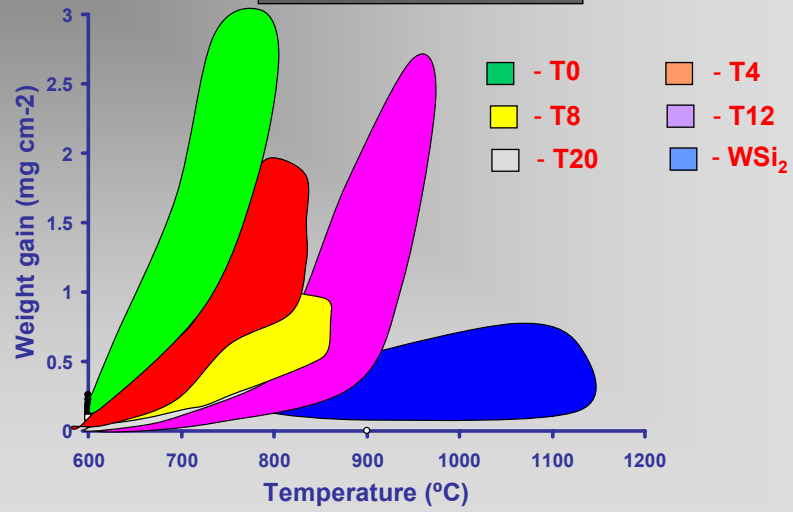
### Thermal stability (protective atmosphere)

Hardness



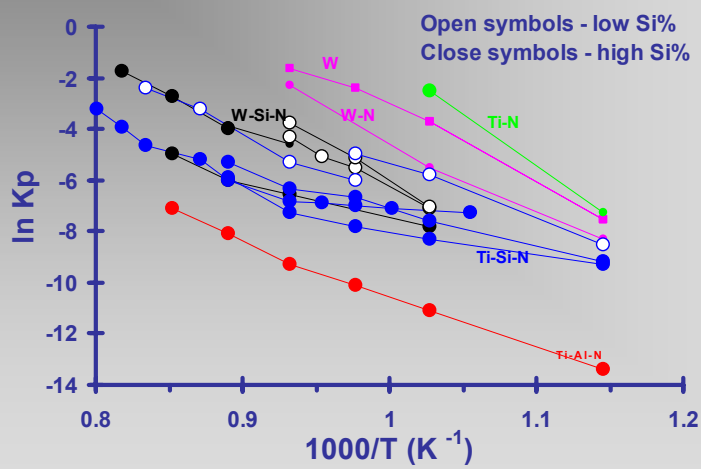
### Thermal behaviour (Oxidation atmosphere)

time = 30 min



### Thermal behaviour (Oxidation atmosphere)

➤ Comparing results with Ti-Si-N system



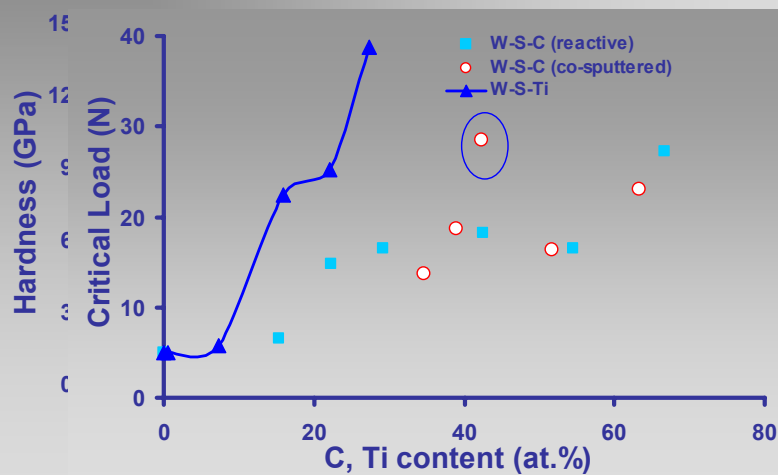


## • W-S-C/N System

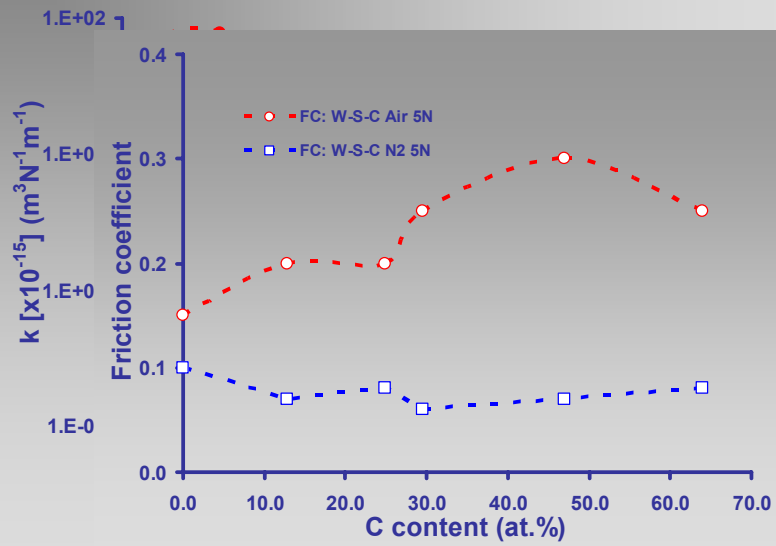
### OBJECTIVES

- Self lubricating coatings with high loading bearing capacity
- Self lubricating coatings with suitable tribological behaviour in different environments
- Technique - sputtering
  - reactive with  $N_2$  et  $CH_4$  from a  $WS_2$  target
  - co-sputtering of C and  $WS_2$  targets
  - Co-sputtering a C target incrusted with  $WS_2$  pellets

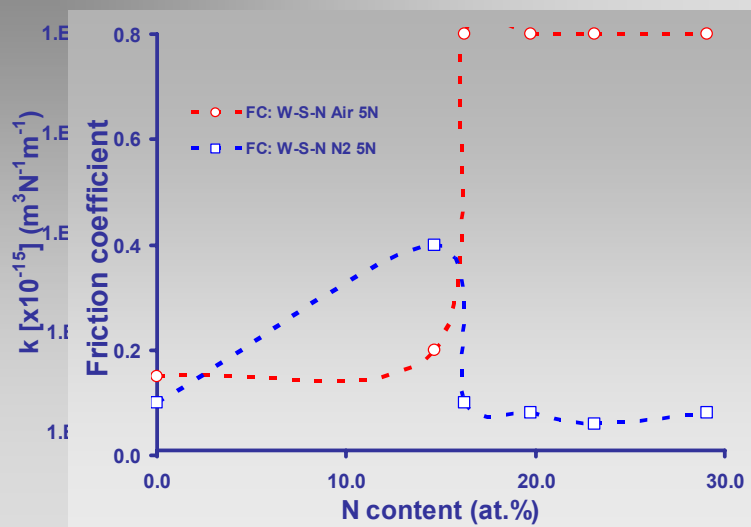
### Results (Hardness and critical load)



### Results W-S-N (Pin-on-disk)



### Results W-S-N (Pin-on-disk)

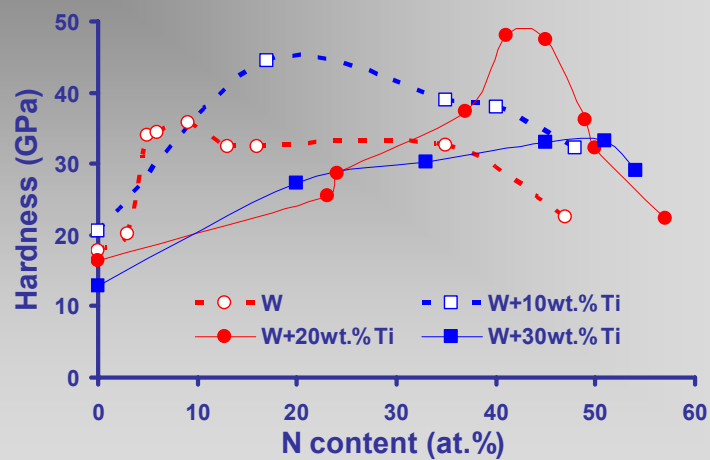


## • W-Ti-N System

### OBJECTIVES

- Hard and tough coatings
- Technique - reactive sputtering with N<sub>2</sub> gas from W targets alloyed with different Ti contents from 10 to 30wt.%

### Hardness



## Tribological tests

**Pin-on-disk: Lubricated and dry tests**

**Ball: 100Cr6 Ø10mm coated with W-Ti-N films**

**Conditions: pN<sub>2</sub>/pAr = 0, 1/5, 1/5\*, 1/3), \* with ion gun assistance**

**Disks: Sheet metal for deep drawing**

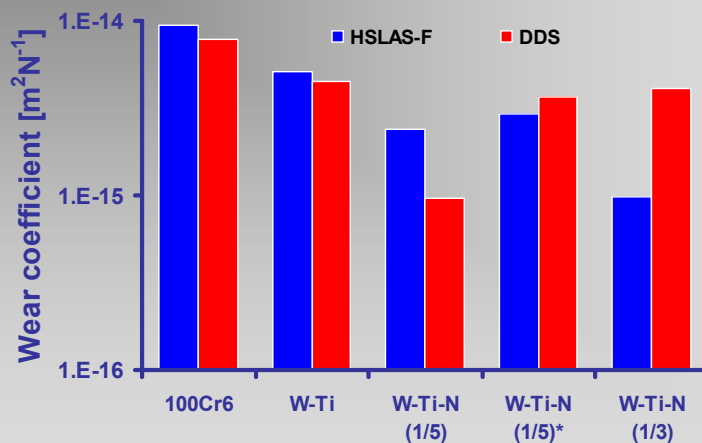
Sheet Material ASTM and (EN)	Material type	Yield Strength [MPa]	Thickness [mm]	Hardness [HV1]
<b>HSLAS-F (S355MC)</b>	High Strength Low-Alloy Steel for Cold Forming with improved formability	340	2.00	159 ± 21
<b>DDS (DC04)</b>	Cold Rolled Steel for Deep Drawing	200	0.90	108 ± 7
<b>DDS 04Z (DC04+ZE)</b>	Electrogalvanised Cold rolled Steel	200	1.50 <i>t(Z) = 10µm</i>	82 ± 3
<b>AA6016 - T4</b>	Aluminium-Magnesium-Silicon alloy (AlMgSi); T4 = Solution heat-treated and naturally aged.	90	1.20	74 ± 5

Dry tests - 10N / 0.1ms<sup>-1</sup> / 20m

Lubricated tests - 10N / 0.1ms<sup>-1</sup> / 100m

## Results (Pin-on-disk) dry

**Strong adhesion between the Al and Zn-coated metal sheets and the coated balls**



Friction coefficients between 0.3 and 0.6

## Results (Pin-on-disk) lubricated

Lubricants:

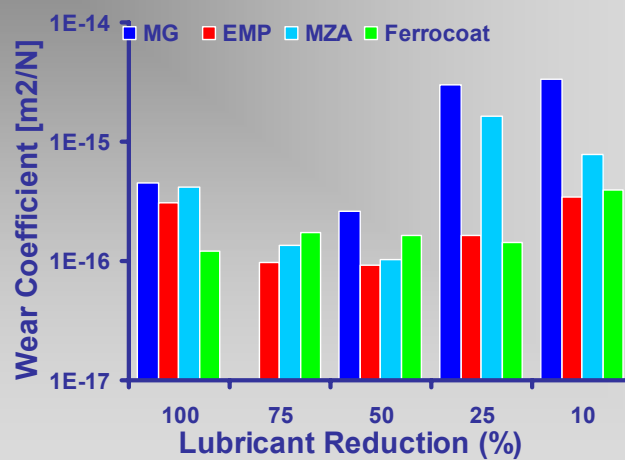
Lubricants	Producer	Type of lubricant	Quantity currently used (g/m <sup>2</sup> )
Montgomery (12:1) DB 4265 BW	Fuchs	Deformation support Emulsion: water based	3
Renoform EMP 549P	Fuchs	Deformation support	3
Renoform MZA 08T	Fuchs	Deformation support	3
Ferrocoat N 6130	Quaker	Corrosion protection	2

The tests were performed with:

100%, 75%, 50%, 25% et 10% lubricant

## Results (Pin-on-disk) lubricated

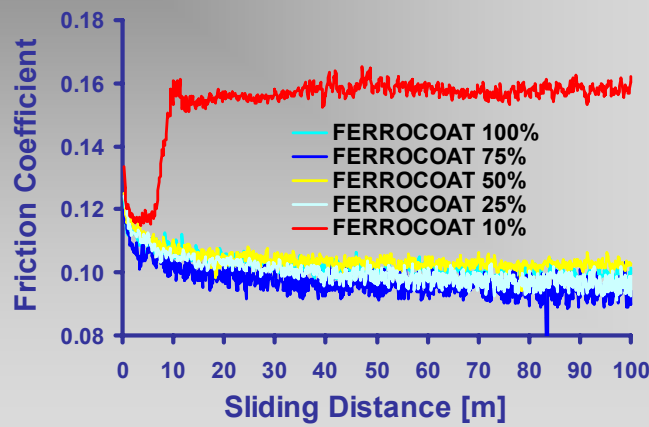
W-Ti coating and HSLAS-F sheet metal



### Results (Pin-on-disk) lubricated

Friction coefficient - case of Ferrocoat N6130 lubricant

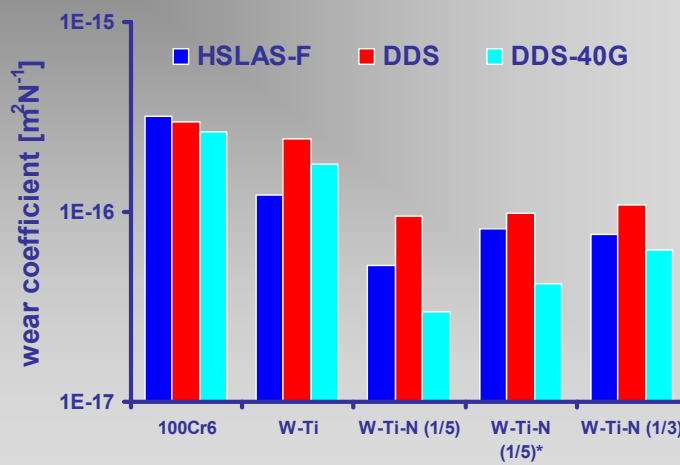
W-Ti coating and HSLAS-F sheet metal



### Results (Pin-on-disk) lubricated

Lubricant Ferrocoat N6130 - Quaker

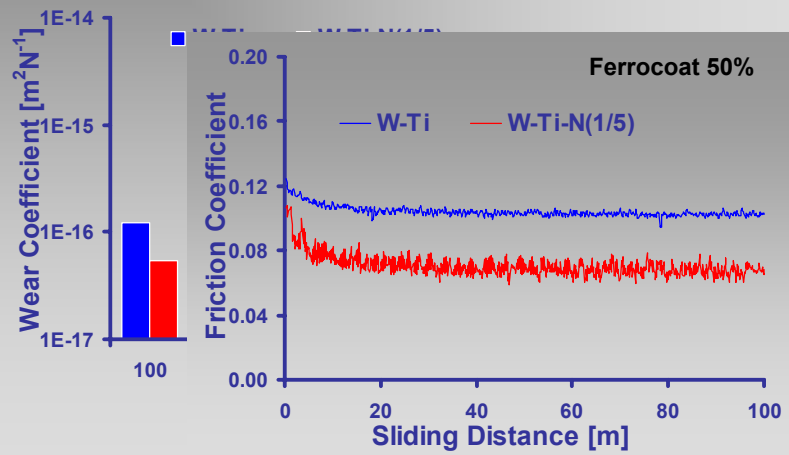
100% lubrication



## Results (Pin-on-disk) lubricated

Lubricant Ferrocoat N6130 - Quaker

HSLA steel



## Results (Pre-industrial tests)

Deep drawing with coated tools

→ Detection of cracks

**Sheet metal:**

DDS  
AA 6016

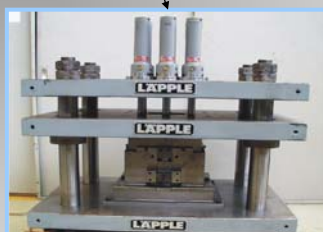
**Tool material**

1.2379i

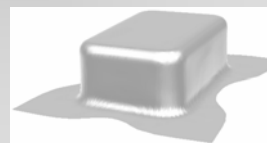
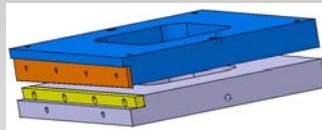
**Coatings:**

W-Ti-N 1/5  
Industriel

Equipment



*Dimensions of the tool:*  
150 mm x 100 mm










### Results (Pre-industrial tests)

Sheet Stamping Material: DDS; Tool: 1.2379; Lubricant: Ferrocoat

Blankholderforce: 250 kN

Drawing Depth: 40 mm

Uncoated 1.2379 Tool	Industrial coated 1.2379 Tool	W-Ti-N coated 1.2379 Tool
 <p><b>Crack</b></p> <p>a) 1,5 g/m<sup>2</sup> Ferrocoat</p>	 <p><b>Crack</b></p> <p>a) Without Lubricant</p>	 <p><b>Small Crack</b></p> <p>a) Without Lubricant</p>
 <p><b>No Crack</b></p> <p>b) 3 g/m<sup>2</sup> Ferrocoat</p>	 <p><b>Crack</b></p> <p>b) 1 g/m<sup>2</sup> Ferrocoat</p>	 <p><b>No Crack</b></p> <p>b) 1g/m<sup>2</sup> Ferrocoat</p>
	 <p><b>No Crack</b></p> <p>c) 2 g/m<sup>2</sup> Ferrocoat</p>	

Source:IFU University of Stuttgart DE

### Results (Pre-industrial tests)

Sheet Stamping Material: AA6016; Tool: 1.2379; Lubricant: Renoform

Blankholderforce: 100 kN

Drawing Depth: 25 mm

Uncoated 1.2379 Tool	Industrial coated 1.2379 Tool	W-Ti-N coated 1.2379 Tool
 <p><b>Crack</b></p> <p>a) 1,5 g/m<sup>2</sup> Renoform</p>	 <p><b>No Crack</b></p> <p>a) Without Lubricant</p>	 <p><b>No Crack</b></p> <p>a) Without Lubricant</p>
	 <p><b>No Crack</b></p> <p>b)1,5 g/m<sup>2</sup> Renoform</p>	
	 <p><b>No Crack</b></p> <p>c) 3 g/m<sup>2</sup> Renoform</p>	

Source:IFU University of Stuttgart DE



### Results (Pre-industrial tests)

Sheet Stamping Material: AA6016; Tool: 1.2379; Lubricant: Renoform

Blankholderforce: 120 kN

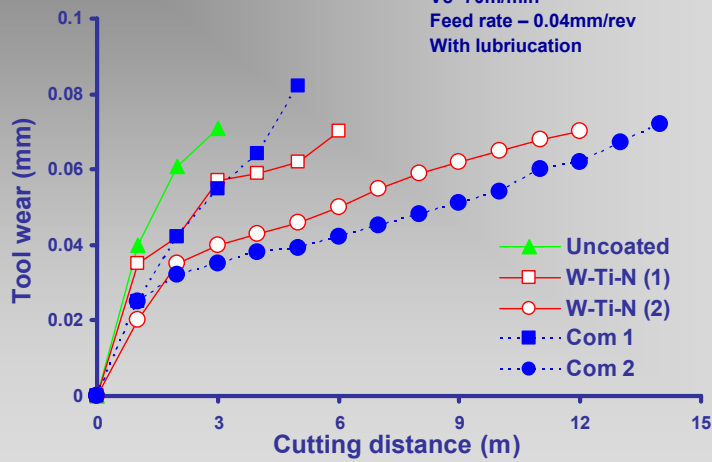
Drawing Depth: 25 mm



Source:IFU University of Stuttgart DE

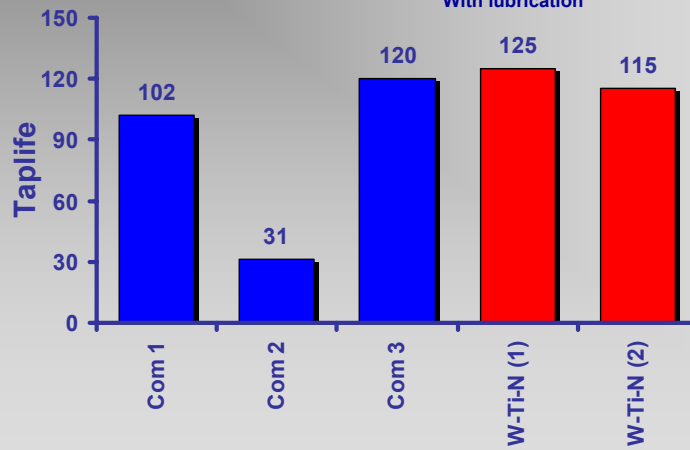
### In-service tests - milling

♦ **Cutting conditions:**  
 Substrate – cemented carbides  
 Material – 42 Cr Mo 4 (1200N/mm<sup>2</sup>)  
 Vc=70m/min  
 Feed rate – 0.04mm/rev  
 With lubrication

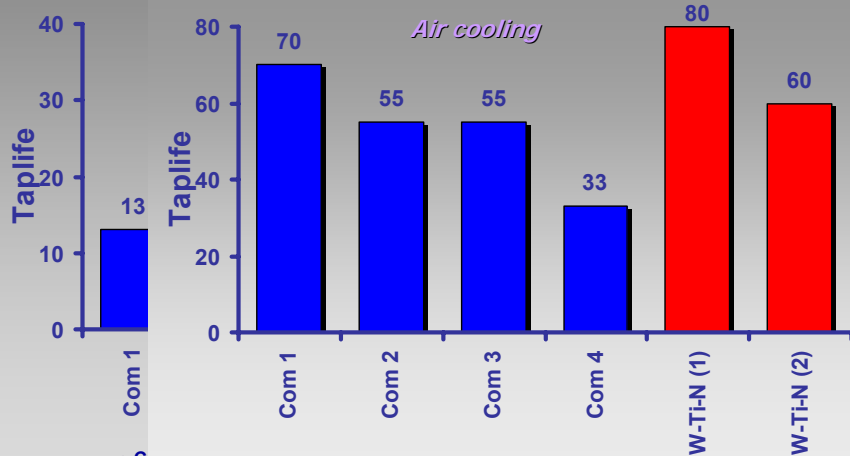


### In-service tests - Taps

Cutting conditions  
 Substrate - HSS steel  
 Material - 42 Cr Mo 4 (1200N/mm<sup>2</sup>)  
 Vc=15m/min  
 Depth - 16mm  
 With lubrication



### In-service tests - Taps



Substrate - cemented carbides  
 Material - 42 Cr Mo 4 (1200N/mm<sup>2</sup>)  
 Vc=150m/min  
 Feed rate - 0.025mm/rev

## Conclusions

With an element such as W, it is possible to deposit coatings with interesting properties for a large range of mechanical applications

Alloying W with N and O hard coating with many different colors can be deposited

The addition of Si to W-based films allows to deposit more oxidation resistant coatings without losing their high hardness

The self lubricant character of tungsten disulphide can be associated to high hardness by alloying them with C or N in order to reach much higher loading bearing capacity

The tribological behaviour and the semi-industrial performance of W-Ti-N type coatings allows envisaging an excellent in-service performance in cutting and forming tools

## Acknowledgments

- My colleagues and PhD students involved in the experimental work:
  - Cristina Louro
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