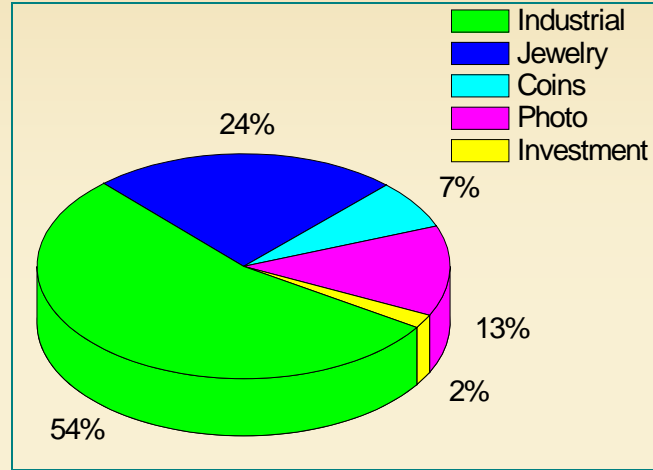


# **Tribology investigation of silver and gold electroplated in presence of nano-diamonds and nano-alumina**



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# Use of Silver and Gold for Plating



**Musik Instruments**





# Silver consumption for electric electronics industries worldwide

Year	2001	2002	2003	2004	2005	2006	2007
<b>Ag consumption for electronic and electric industries worldwide (tons)</b>	4.258	4.479	4.711	4.956	5.640	5.901	6.207
<b>Price (in Mio. EUR)</b>	809	851	895	942	1.072	1.121	1.179

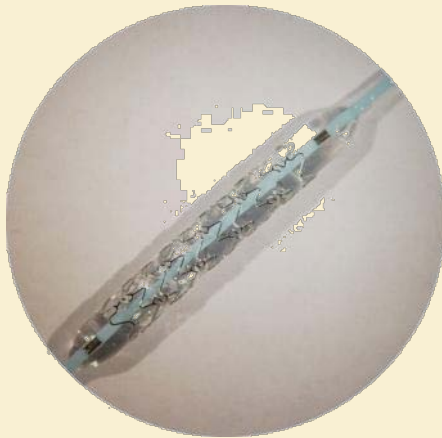
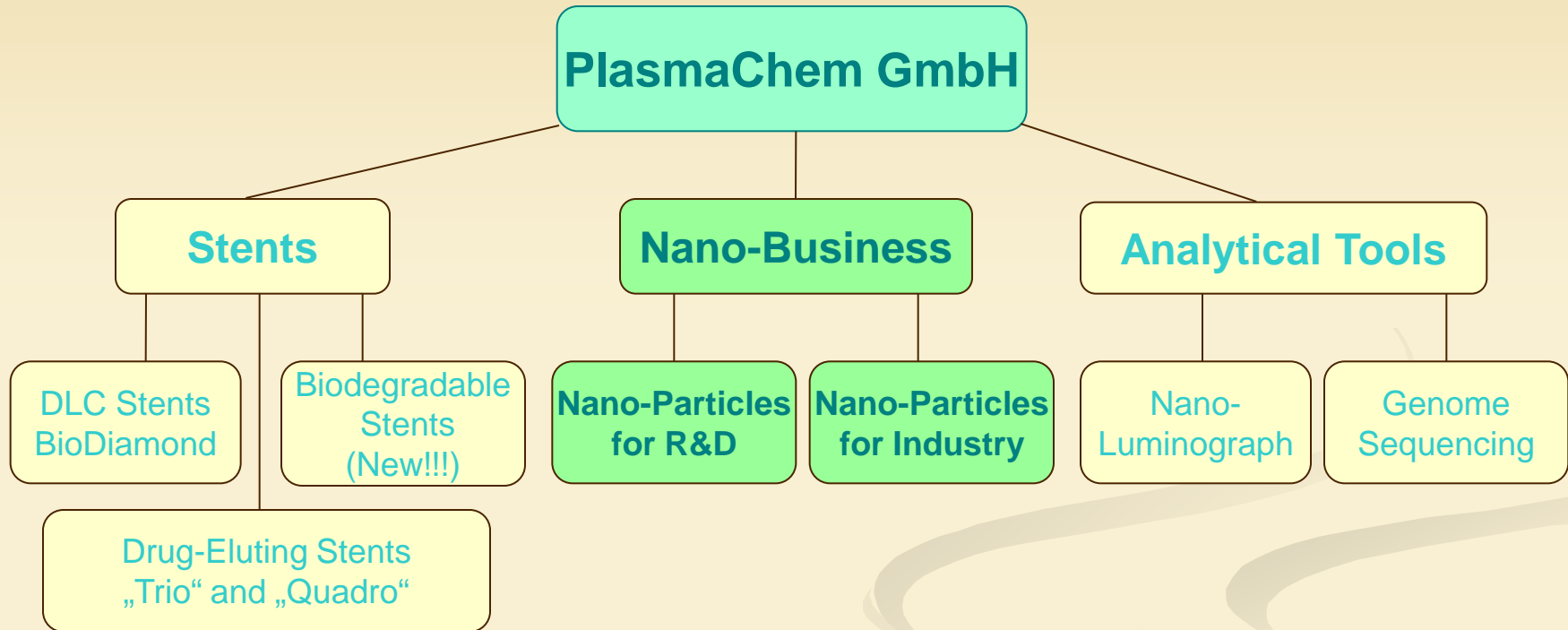


Silver and gold are noble,  
silver has the highest conductivity

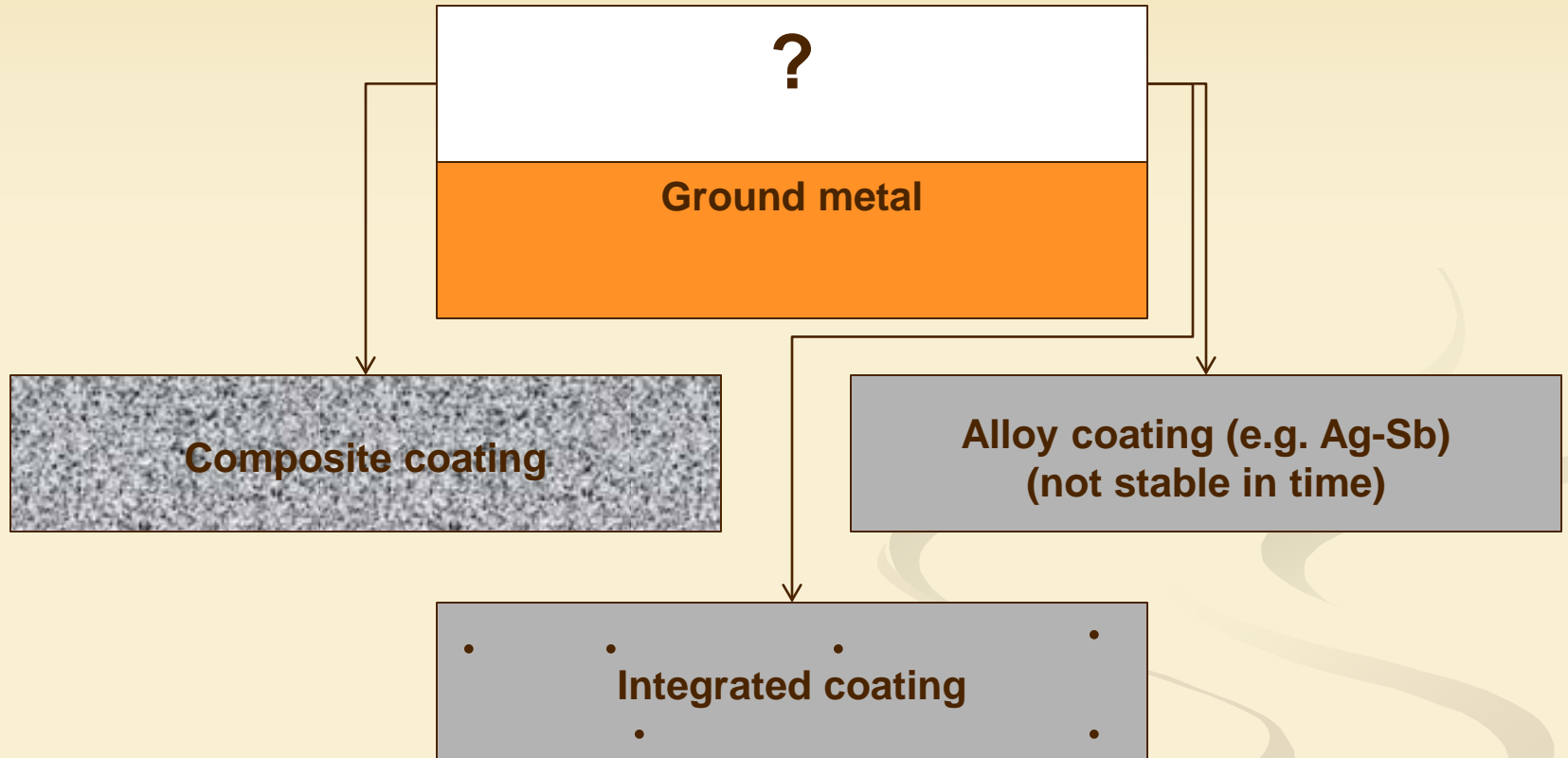
but ...

they have very poor mechanical properties





# Nanoparticles for co-Plating with Ag and Au



# What to choose?

**WO<sub>3</sub>**

**MoS<sub>2</sub>**

**PTFE**

**SiC**

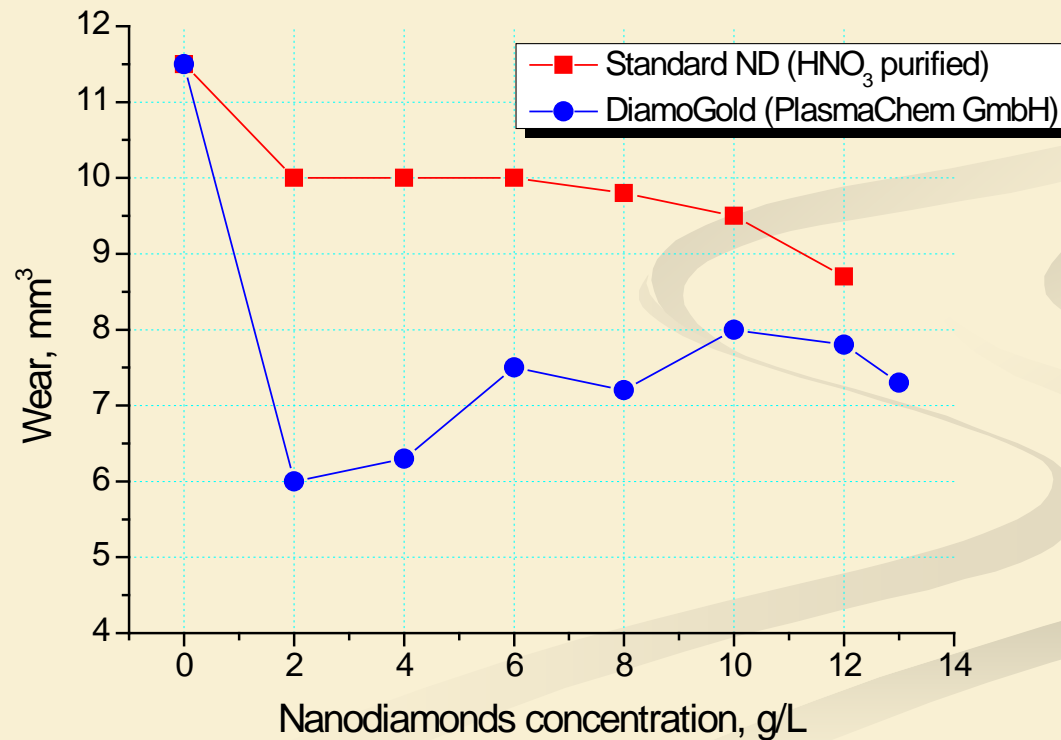
**Graphite**

**NanoDiamonds**

**Al<sub>2</sub>O<sub>3</sub>**



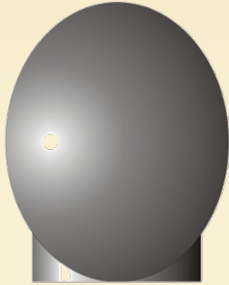
**Not all nanoparticles are the same.  
Here is one example:  
Gold plated with NanoDiamonds of two types**





# Method of synthesis is important

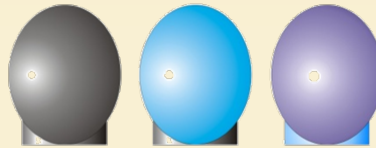
Dry explosion  
in big volume



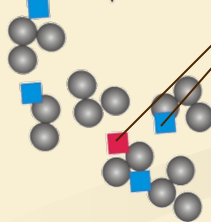
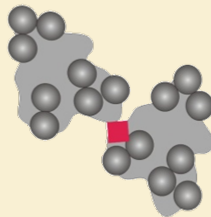
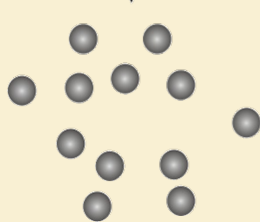
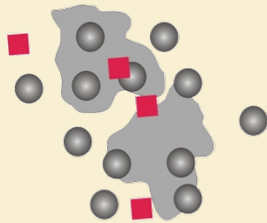
Dry explosion  
in small volume

Explosion in water

Explosion in ice



**Production of raw material**

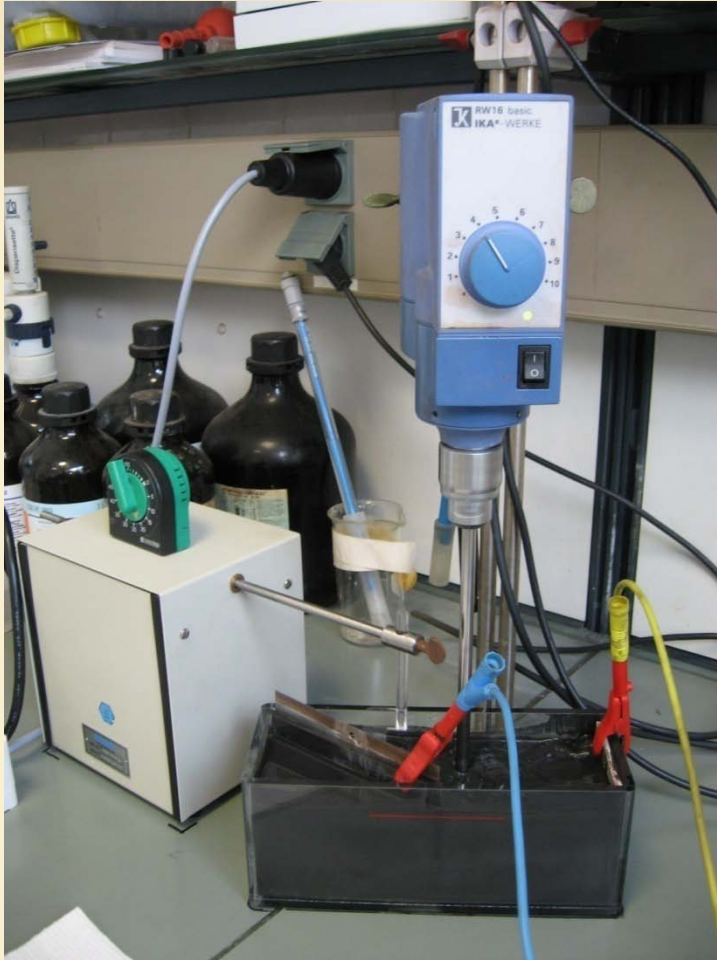


*impurities*

**Isolation and purification  
of nanoparticles**



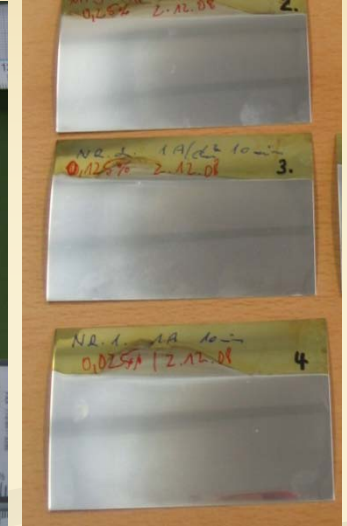
# Hull-Cell Tests



**Hull-Cell Tests (estimation of current density conditions)**



**Industrial Plating**



**Decorative Plating**

**Hull-cell experiments deliver perfect coatings with both ND and  $Al_2O_3$  with both industrial and decorative platings.**



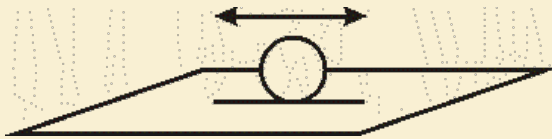
# Tribological Investigation and Wear Calculation

## Tribometer (Wazau GmbH, Germany)

Indenter – ball of 100Cr6 d=10mm

Normal Force: 8 N

Frequency: 8 Hz    Amplitude: 4 mm

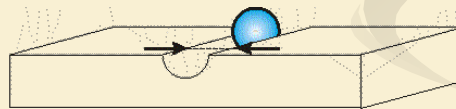


Wear track



## X-ray Fluorimeter (Fisher AG, Germany)

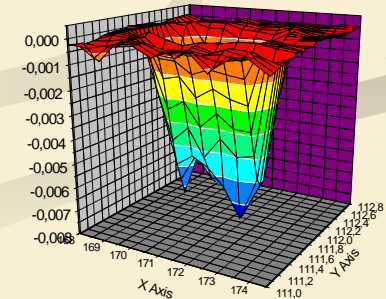
Wear calculation by 360-points  
calculation of layer thickness



Conventional wear calculation  
from the width of a track  
(semi-quantative)

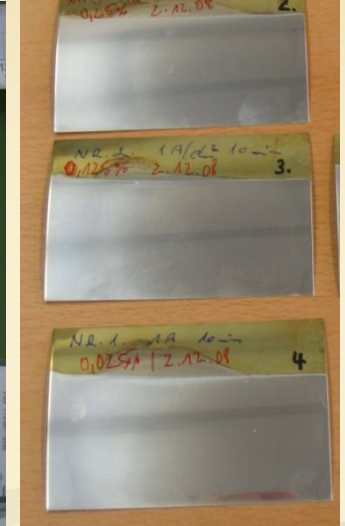


Precise wear calculation from the  
real 3-D profile of a track





**Hull-Cell Tests (estimation of current density conditions)**



**Industrial Plating**

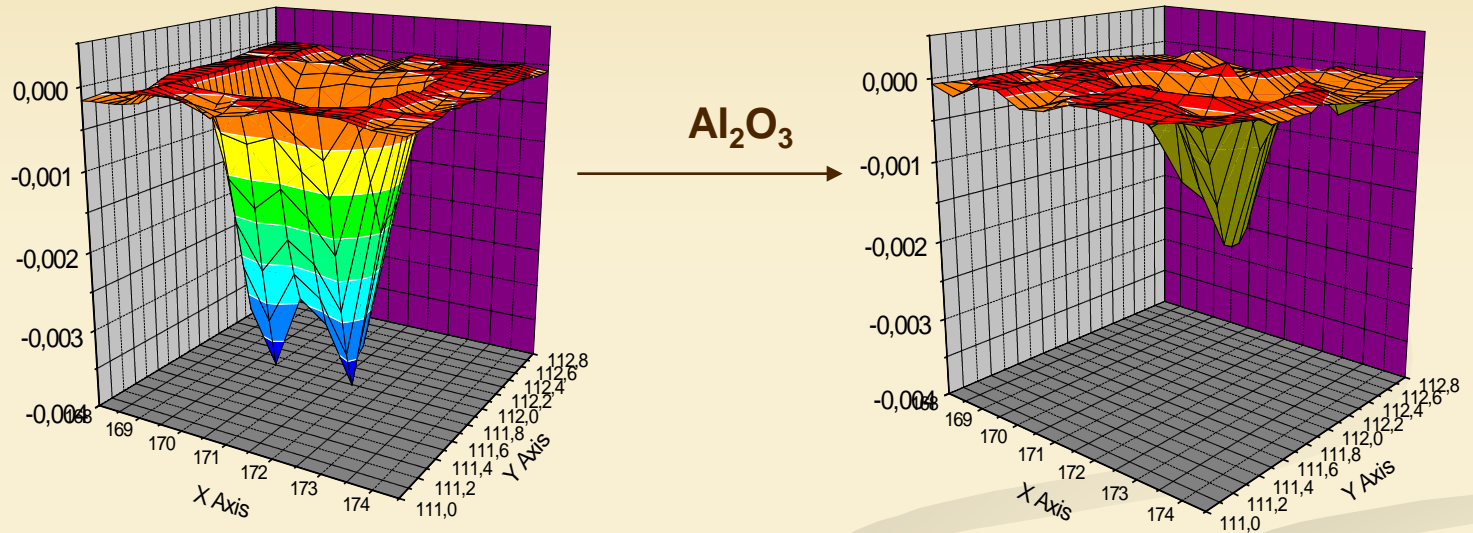
**Decorative Plating**

	0,65	1,08	1,65	A/dm <sup>2</sup>
Z =	22,9 μm	34,8 μm	54,4 μm	
V =	0,00338 mm <sup>3</sup>	0,0049 mm <sup>3</sup>	0,0145 mm <sup>3</sup>	
Z =	26,5 μm	38,5 μm	-	
V =	0,0011 mm <sup>3</sup>	0,0106 mm <sup>3</sup>	-	





# Results on Ag/Al<sub>2</sub>O<sub>3</sub>



**Improvement of tribological properties in comparison with normal Ag:**

**Friction coefficient decrease**

**up to 50%**

**Wear decrease**

**up to 70%**

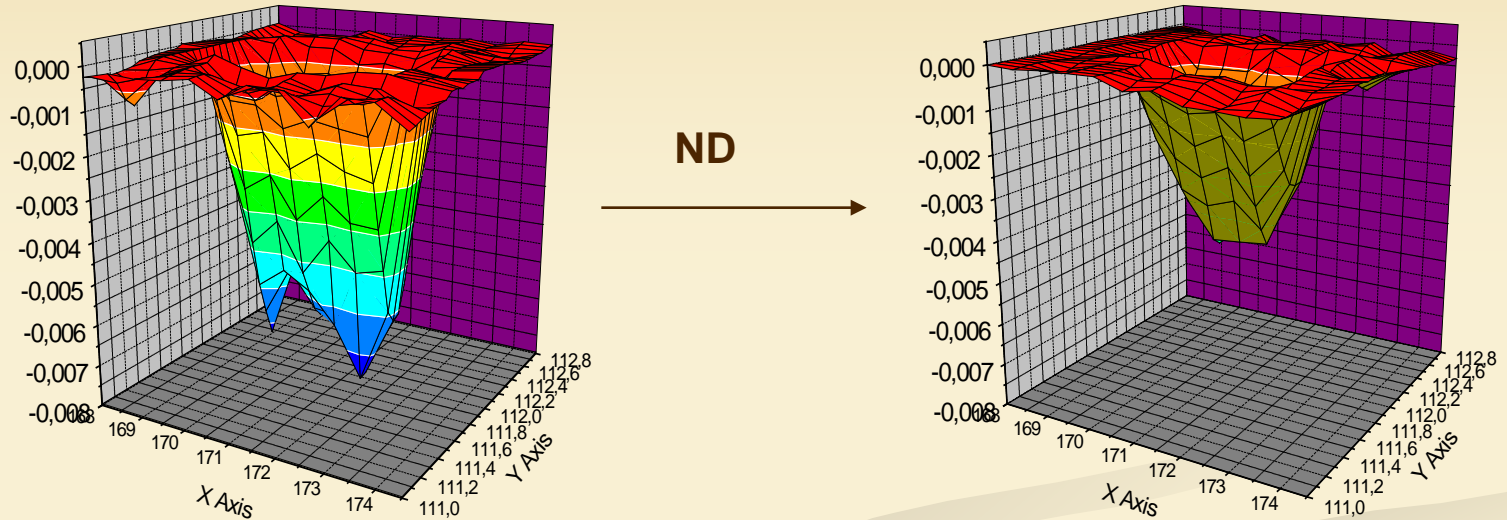
**Microhardness increase**

**ca. 20%**





# Results on Ag/ND



**Improvement of tribological properties in comparison with normal Ag:**

**Friction coefficient decrease**

**up to 50%**

**Wear decrease**

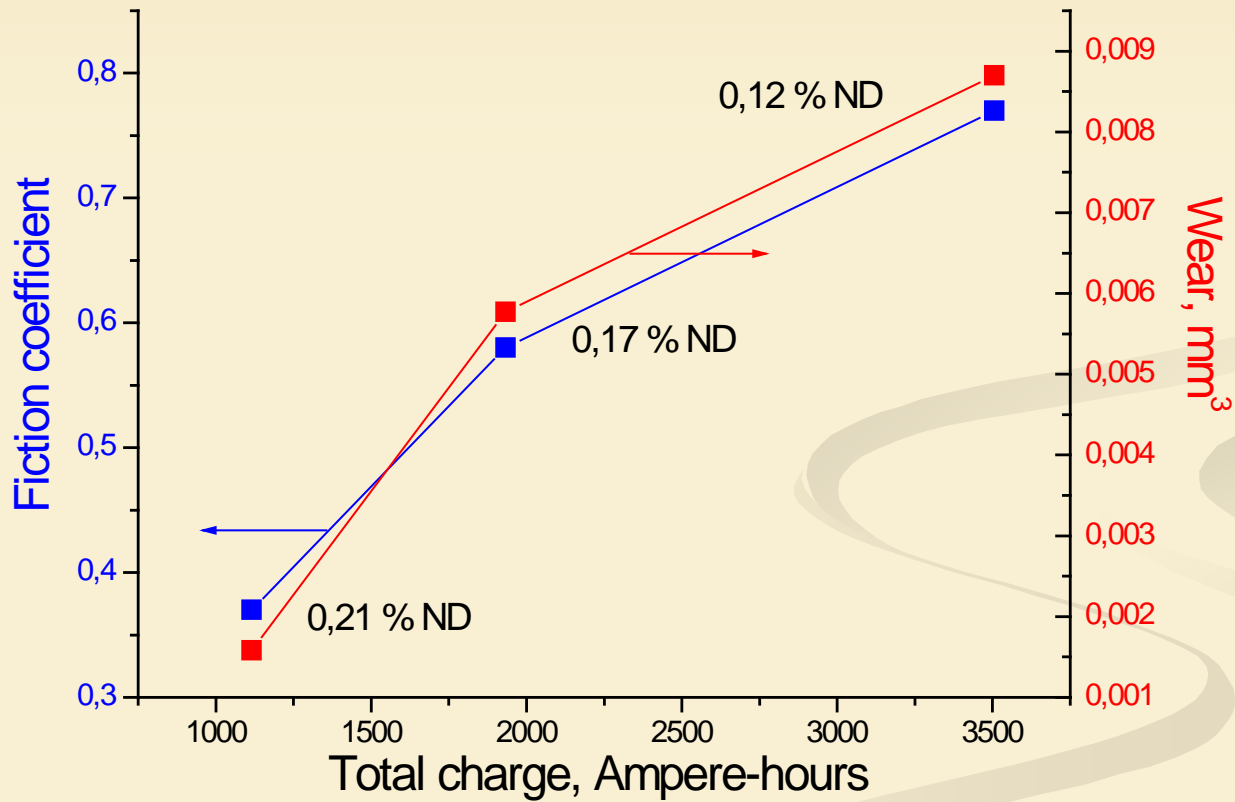
**up to 50%**

**Microhardness increase**

**ca. 35%**



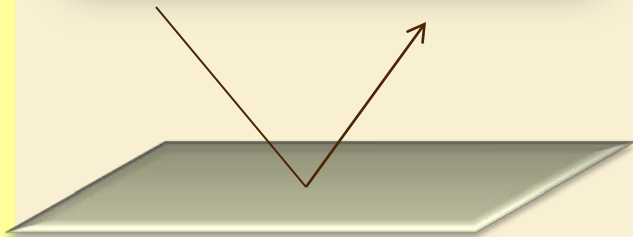
# Tribo-Properties vs. Concentration



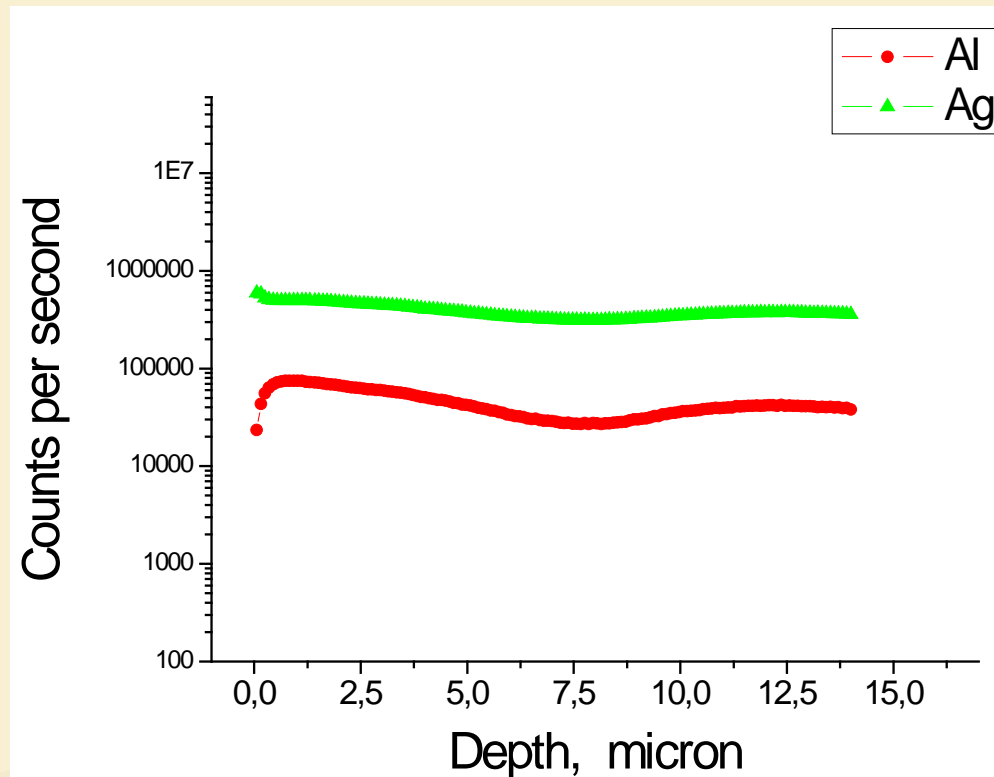
# Nanoparticles Distribution in Layer

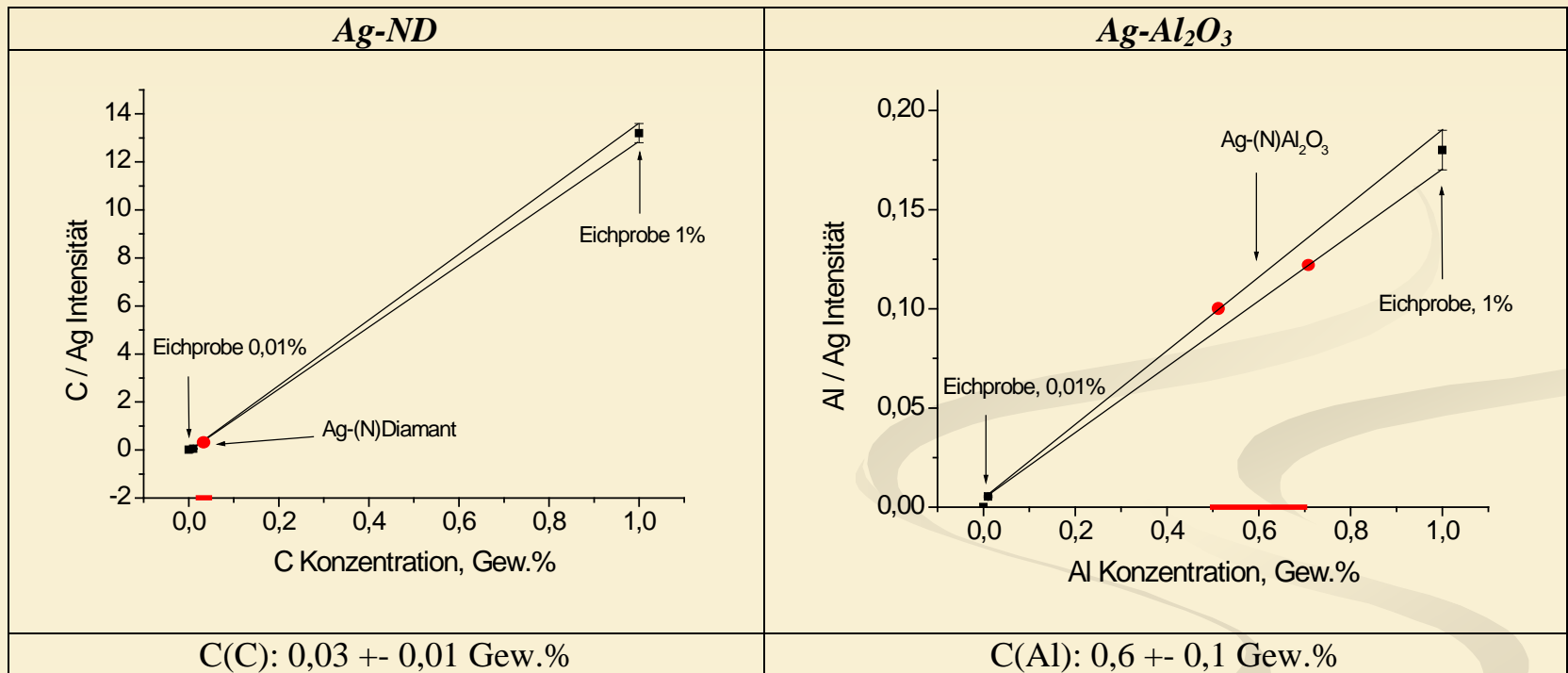


Secondary ion mass spectrometry (SIMS) was employed to analyze the distribution and content of nanoparticles in the layer.



Nanoparticles are incorporated uniformly through the plated layer in both lateral and normal directions.

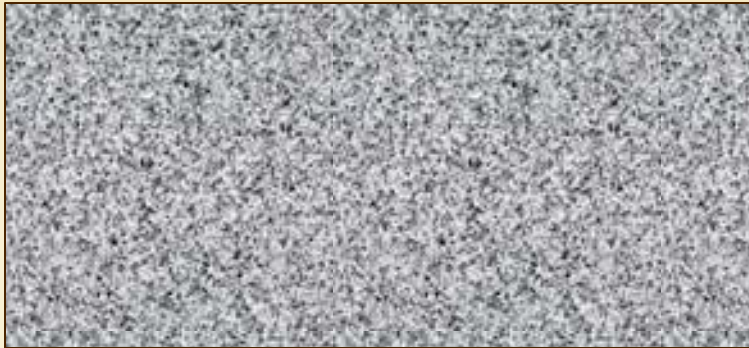




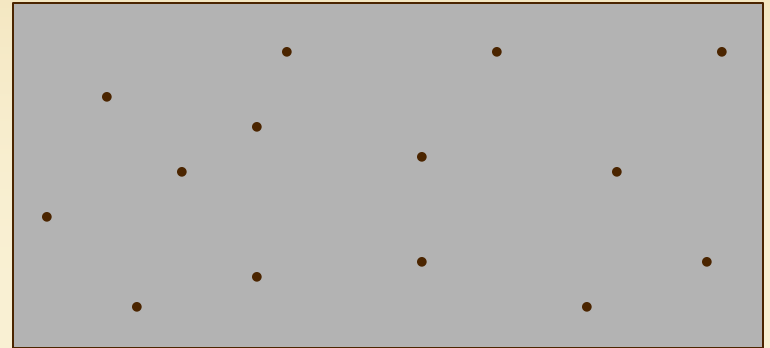
**The amount of nanoparticles in the plated metal is tiny**



# Not the Composite Materials



**Composite material contains a large amount of reinforcing materials, which having different properties from those of matrix, alter its properties.**



**In our case amount of nanoparticles is tiny. They influence the structure of a metal directly, reducing the crystal size of the metal.**







Silver / NanoDiamond



Silver/Al<sub>2</sub>O<sub>3</sub>

- Optimization of nanoparticles synthesis
- Optimization of nanodiamonds purification
- Development of additives package
- Development of technological parameters including electrolyte on-line control
- Final quality control of plated parts



Flute parts coated with Silver-DiamoSilb



# Conclusions

- **Optimization of Nanoparticles synthesis and purification was performed**
- **Reduction of wear and friction by over 50%**
- **Increase of hardness by ca. 30%**
- **Successful transfer into industrial-scale plating baths**
- **Nanoparticles change the metal matrix strongly, but the resulting plated layer is not a classical composite material.**
- **Content of nanoparticles (and their consumption) is negligible making the whole process very economical**



**Big thanks to Siemens AG and Heyday's OHG for fruitful cooperation**

**Thank you for your attention!**

