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

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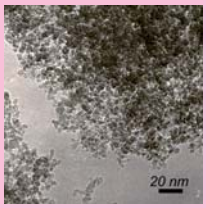
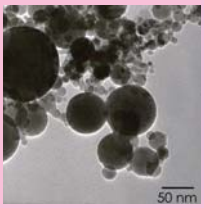
INTRODUCTION

The market of industrial application of gold and silver is huge. Noble metals' plating is often used in electronics, to provide a corrosion-resistant electrically conductive layer on copper, typically in electrical connectors and printed circuit boards. They are also used in the telecom, automotive, jewelry and dinnerware industries. The major drawback of these metals is the poor mechanical properties: low abrasion resistance and high friction coefficients. The main aim of this work was to improve mechanical properties of the metal coatings by addition of nanocomposites into the plating baths.



Nanodiamonds particles:
- Produced by detonation synthesis
- Purified by acidic oxidation
- BET ca. 350 m^2/g
- Primary particle size 4-6 nm
- Zeta-potential ca. -50 mV

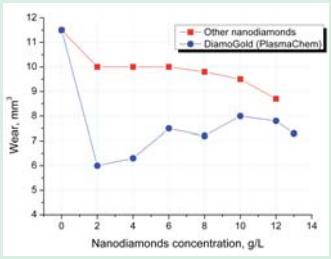


Aluminium oxide nanoparticles:
- Produced by plasma-jet synthesis
- Phase: alpha
- BET > 10 m^2/g
- Primary particle size 5-150 nm
- Zeta-potential ca. +20 mV

- The additive is filled into the electroplating bath. No extra equipment besides of ultraturrax is needed for a fully operational process.
- Both technical and decorative plating processes can be performed.
- Analytical techniques for bath maintenance: analytical balances, table-top centrifuge and small glassware.
- Recommended period of bath analysis: 1000-1500 Ah
- Refill-cycle (addition of nanoparticles without bath-stop): 2500-5000 Ah
- Bath lifetime: min. 50000-75000 Ah (ca. 3 years)

Hull-cell experiments (left) show no difference in the appearance of the coatings (1 - original silver coating, 2-4 - Silver-Nanodiamond composite coating), which allows the use of nanoparticles-additives in the decorative plating processes. The perfect appearance is shown on an example of the coated music instruments parts (right).

Not any nanodiamond is effective!



There are several sources of nanoparticles on the market. Not any nanoparticles show good properties in metal plating applications. Not only the size, but also purity, chemistry of the surface groups, aggregative and other properties of the particles play an extremely important role on the resulting anti-wear effect. Graph above illustrates influence of DiamoGold and nanodiamonds of another manufacturer (closest analogue to nanodiamonds of PlasmaChem) on the wear of gold coatings. DiamoGold allows to reduce wear by 50% at the working concentration.

Wear and friction investigations (Fig. 1) are performed on the reciprocating sliding contact tribometer (Wazau, Berlin). Measuring Parameters:
- Indenter: 10mm 100C6 steel ball
- Frequency: 8 Hz
- Load: 9 N
- Amplitude: 4 mm
- Time: 22.5 minutes

A 3-D imaging of a groove is performed by means of X-ray fluorescence (Fig. 2).

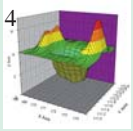
The groove appearance and a 3-D image are presented on Fig. 3 and Fig 4 respectively.

1

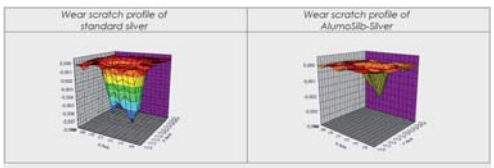
2

3

4



	Standard Silver	DiamoSilb-Silver
Friction coefficient	100 %	Max. 60%
Wear	100 %	Max. 60%



	Standard Silver	AlumoSilb-Silver
Friction coefficient	100 %	Max. 60%
Wear	100 %	Max. 60%

CONCLUSIONS

Novel additives on the base of nanodiamonds (DiamoSilb®) and nano-Al_2O_3 (AlumoSilb®) have been invented and successfully implemented in industrial plating processes. Reduction of wear and friction coefficients by over 50% for silver and gold could be achieved. Industrial application of our additives is verified by over 5-year practice.

This work was performed in cooperation with Siemens AG and Heyday's