

Electrodeposited nickel- and nickel-tungsten-CNT composite coatings

S. Hartwig, C.-P. Klages
 Institut für Oberflächentechnik (IOT)
 Technische Universität Braunschweig
 Bienroder Weg 54E, Braunschweig, Germany

Electrodeposited nickel is commonly used as a decorative or corrosion protection layer for many applications [1]. Tribological characteristics of Ni layers can be improved by codeposition with other metals such as tungsten or cobalt (NiW, NiCo). Chemically (“electroless”) deposited NiP layers have unique properties like high hardness and high corrosion resistance. Another possibility to improve metal layer performance is the incorporation of dispersed particles to build a composite layer. In recent publications such as ref. [2] the application of carbon nanotubes (CNT) as dispersoids in polymer, ceramic or metal matrix composites has been reported, in which the extraordinary structural and mechanical properties of single-wall or multi-wall CNTs (SWCNTs, MWCNTs) are utilized.

This presentation gives a short overview of recent research work at IOT on the deposition of nickel and nickel tungsten alloy layers, resp., with incorporated CNTs.

One of the most challenging tasks to accomplish for successful electrodeposition of Ni-CNT composite layers is the creation and stabilization of CNT dispersions in the plating electrolyte. The generation of CNT dispersions in liquids is normally done by sonication or shearing forces. The hydrophobic character of CNTs, their special shape and high specific surface normally lead to rapid back-formation of agglomerates. Therefore a suitable stabilization of the dispersions is generally required by electrostatically or sterically working additives or by utilization of properly chemical modified CNTs.

For the reported experiments MWCNTs from different manufacturers were used and dispersed in different nickel plating baths. The experiments showed that a quite energetic ultrasound treatment is required to create a homogenous dispersion with well separated MWCNTs. In many experiment a steric stabilization of CNT dispersions in the electrolyte, using an optimized brush copolymer featuring polyethylene glycol side chains at a relatively hydrophobic backbone, has proven superior compared to electrostatic stabilization.

The electrodeposition was done from acidic nickel sulfamate electrolytes. Standard DC plating processes frequently result in Ni-CNT layers with a cauliflower-like structure. Arai et al. established a layer growth mechanism based on conductive CNTs to explain this phenomenon [3].

In order to deposit homogeneously growing dense Ni-CNT layers, pulse plating was therefore applied by the authors to control the layer growth mechanism. Pulsed plating showed better dispersion stability during layer deposition, improved process control and higher quality of layers in terms of density, smoothness and abrasive wear resistance. In the present study the composite deposition parameters were optimized with regard to wear protection and corrosion resistance. Also

parameters like morphology, matrix alloy composition and amount of incorporated MWCNTs were considered.

GDOES, XRD and SEM were applied for elemental analysis and morphological layer characterization. The wear resistance was measured with Taber™ and Calo™ test, corrosion resistance was characterized by potentiostatic, potentiodynamic and electrochemical impedance measurements.

Figure 1 shows the top view of an optimized layer with a homogeneous incorporation of CNT in the nickel matrix. Due to the dense layer growth a layer thickness up to 80 µm can be achieved. The incorporation of CNTs in a nickel matrix increases hardness up to 800 HV_{0.1} and causes an appreciable enhancement in abrasive wear resistance. The addition of CNTs in nickel-tungsten layers results in an order-of-magnitude improvement of wear resistance.

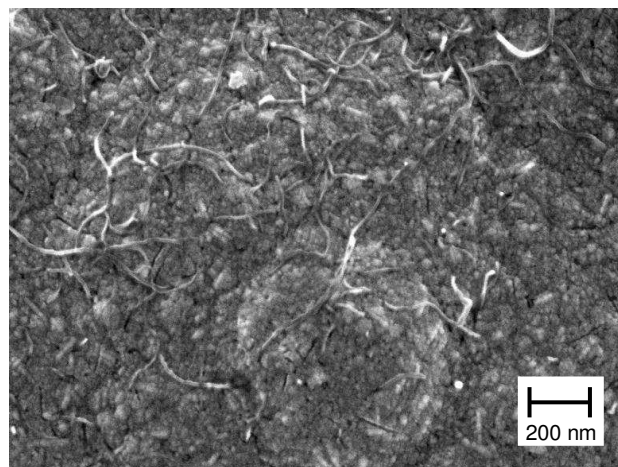


Figure 1: Top view of NiW-CNT layer, SEM picture

- [1] G. A. DiBari, *Metal Finishing*, April 2002, 34-49
- [2] S. R. Bakshi, D. Lahiri, A. Agarwal, *International Materials Reviews* 55 (2010) 41-64
- [3] S. Arai, M. Endo, N. Kaneko, *Carbon* 42 (2004) 641-644