UDC 621.983

Karaguiozova Z.K.
Assistant professor at Bulgarian Academy of Sciences, Space Research and Technology Institute, Sofia, Bulgaria, e-mail: karazuzi@yahoo.com

ELECTROLESS NICKEL COMPOSITE COATINGS WITH NANODIAMOND ADDITIVES

Investigation of the technological parameters' influence on the properties of electroless nickel coatings with nanodiamond additives, analysis and determination the best process terms to obtain coatings with improved properties and development of production technology.

EFTTOM-NICKEL Method is applied for deposition of nickel coatings by electroless process. Nanodiamond powder, produced by detonation synthesis is used as strengthening material to obtain composite coatings. The microhardness and wear resistance of the coatings are measured. An improvement of the mentioned properties is achieved in the presence of nanodiamond in the plated solution. The technological parameters of the process are defined on the base of the experimental results analysis.

Dependences of the coatings properties from nanodiamond concentration are found. The results show a priority of bilayer coating deposition and use of nanodiamond into a suspension. The optimum concentration value is found for ensuring the desire coatings' microhardness and wear resistance in order to achieve higher efficiency.

The production technology for manufacturing of composite coatings with improved properties is developed.

Keywords: *composite coating, electroless nickel, nanodiamond, wear resistance, microhardness.*

Introduction

The metal deposition on the material surfaces is well known method for improvement their properties. The possibility to produce hard, wear and corrosion resistant coating, uniform over the whole substrate surface is achieved by electroless plating process. Electroless nickel coatings are of great importance [1, 2]. They are expected to replace the toxic chrome containing coatings because of that it is one preferred method for plating due to increasing environment and working people protection [3].

Nickel coatings are widely used as a matrix for composite coatings. Composite coating is a unique coating with dispersed co-deposited ultra-fine hard reinforcing particles (as ceramics, diamond, fluoropolymers etc.) within hard matrix. The size of the dispersed particles (micro- or nano-) also influences on the surface properties [4].

Nanodiamonds are used as a strengthening additive in the research work of many authors to improve mechanical and tribological characteristics of the coatings [6-9].

Development of electroless Ni-P composite coatings to maximize the coating performance to meet the demanding needs of engineering application is in focus of scientific community [5].

The purpose of this study is to investigate the influence of strengthening diamond nanoparticles on some physical and mechanical properties (microhardness and wear resistance) of electroless nickel composite coatings.

Methodology

Samples material and coatings composition

Composite nickel coatings are deposited on steel 45 samples. EFTTOM-NICKEL Method for electroless nickel plating is applied for coating deposition [10]. Nanodiamond powder (DND) with particle size 2-6 nm is used as a strengthening material. Nanosized diamond powder is produced by detonation synthesis developed in SRIT – BAS [11]. Two types of coatings are investigated: nickel coating Ni and composite nickel coating with nanodiamond Ni - DND. Nanodiamond is added to the plated solution in two conditions: as a suspension and in dry condition. The investigation of coatings' microhardness and wear resistance is carried out on monolayer composite coating and on bilayer coating consists of Ni/Ni – DND.

Test Methods

The microhardness of the coatings is determined by Hardness Method using 20 g loading.

The coatings wear tests are carried out by comparative experimental study on TABER – ABRASER test machine.

The samples thickness is examined by means of the optic metallographic microscope GX41 OLIMPUS. The samples are treated with 3 % HNO_3 - C_2H_5OH solution.

Results and discussion

The results of coatings' thickness dependence on the plating time are presented on Table 1.

Coating thickness increase is observed with the plating time duration. It is found out that dependence is not directly proportional in the beginning of the process. The specified dependence could be explained with the existence of an incubation period in the initial stage of the process (fig. 1).

Table 1

Dependence of coating thickness on the plating time

Sample	Time of preliminary plating, min.	Time of composite coating plating, min.	Total plating time, min.	Coating thickness, μm
1	2	2	4	4
2	2	3	5	4
3	3	6	9	4
4	5	5	10	5
5	-	10	10	7
6	5	10	15	11

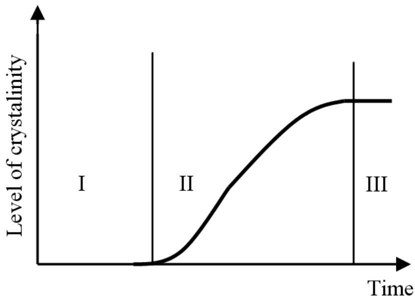

Fig.1. Stages of crystallization: I – incubation, II – initial crystallization, III – secondary crystallization

The experimental results of the influence of nanodiamond concentration on the microhardness and wear resistance of the coatings are presented on fig. 2 – 9. The dependences of these properties on the nanodiamond conditions (fig. 2-5) and plating of monolayer or bilayer coating are specified (fig. 4-7).

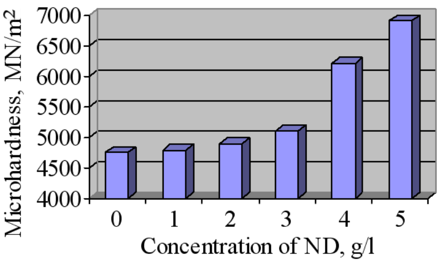

Fig. 2. Influence of DND concentration (DND is added in dry condition) on the coating microhardness

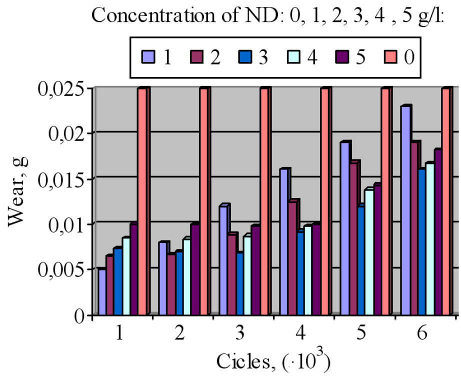

Fig. 3. Influence of DND concentration (DND is added in dry condition) on the wear of the coatings (Taber Abraser test)

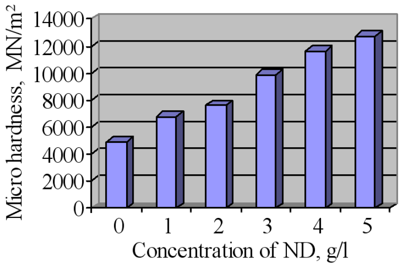

Fig. 4. Influence of DND concentration (DND is added in suspension) on the coating microhardness

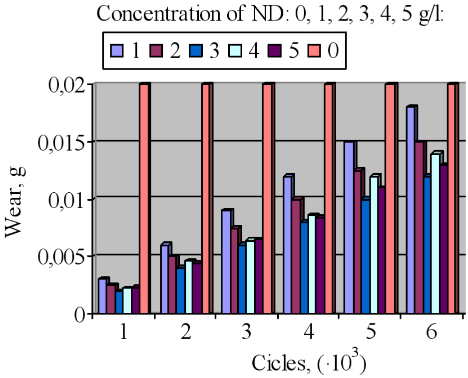

Fig. 5. Influence of DND concentration (DND is added in suspension) on the wear of the coatings (Taber Abraser test)

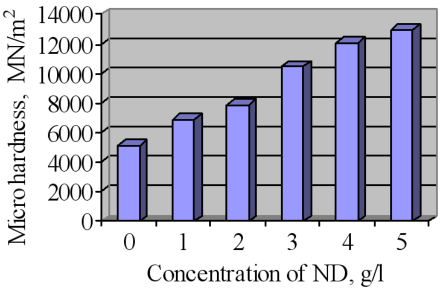

Fig. 6. Influence of DND concentration on the coating microhardness (bilayer coating)

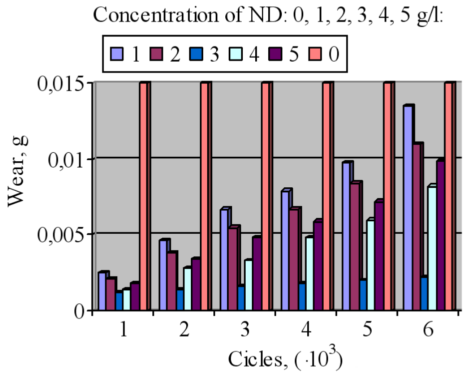

Fig. 7. Influence of DND concentration on the wear of the coatings (bilayer coating, Taber Abraser test)

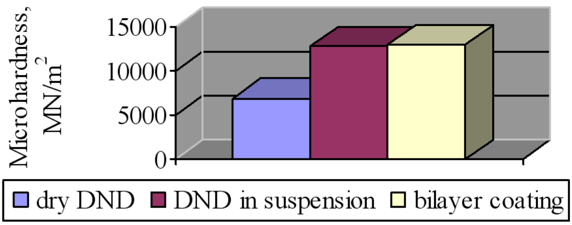

Fig. 8. Microhardness of the coatings in addition of nanodiamond in a dry condition, in suspension and plating of bilayer coating

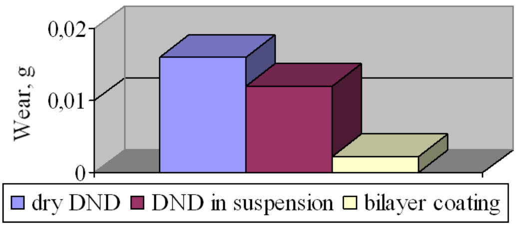

Fig. 9. Wear of the coating in addition of nanodiamond in a dry condition, in suspension and plating of bilayer coating

The higher microhardness of the coatings is achieved with the nanodiamond concentration increase. For the wear of the same coatings the maximum value is obtained at nanodiamond concentration of 3g/l.

A possibility of using nanodiamond additives to electroless nickel solution leads to producing of harder coatings with increased wear resistance.

The analysis of the results allows to propose a technology for producing of electroless composite nickel coatings with strengthening nanodiamond particles with improved microhardness and increased wear resistance: the advantage of the using of nanodiamond in a suspension and plating of bilayer coating is proved (fig. 8); the optimum of nanodiamond concentration, ensuring the best wear resistance is defined (fig. 9).

Conclusions

1. Electroless nickel coatings composition nickel (Ni); nickel and nanodiamond (Ni – DND) are deposited on steel 45 samples. The coatings thickness is defined: 4-11 μm.
2. It is found the coatings obtain higher microhardnes with nanodiamond concentration increase.
3. It is concluded the wear resistance of nickel coatings with nanosized diamond achieve optimum at nanodiamond concentration 3 g/l.

REFERENCES

1. http://www.artisticplating.net/Plating-Underplate-Selection.php/
2. http://www.epson-plaing.com.sg/sepplating/our_services_and_capabilities/ plating_solutions/plating_types/nickel_plating.page/
3. Michael D. Feldstein, 2002. The Environmental Benefits of Composite Electroless Nickel Coatings. Product Finishing, 8/1.
4. Feldstein, N., Lancsek, T., Lindsay, D. and Salerno, L. 1983. Electroless Composite Plating. Met. Finish. Vol. 81, no. 8 pp. 35-41.
5. Balaraju J.N., Narayanan, T.S. and Seshadri, S.K., 2003. Journal of Applied Electrochemistry 33, pp. 807-816.
6. Xu, H., Yang, Z., Li, M.K., Shi, Y.L., Huang, Y., Li, H.L., 2005. Synthesis and properties of electroless Ni–P–Nanometer Diamond composite coatings. Surf. Coat. Technol., 191, pp. 161-165.
7. Doi, T., Furusawa, H., Mizumoto, K., Saitou, I., Yakita, K. and Watanabe Y., 1995. Bull. Tokyo Metro. Ind. Tech. Res. Inst., 24/69.
8. Xiang, Y., Zhang, J., Jin, C., 2001. Study of electroless Ni-P-Nanometer diamond composite coatings. Plat. Surf. Finish., 88(2), pp. 64-67.
9. H. Matsubara, Kobayashi, M., Nishiyama, H., Saito, N., Inoue, Y., Mayuzumi, M., 2004. Co-deposition Characteristics of Nanodiamond Particles in Electrolessly Plated Nickel Films. Electrochemistry, 72, pp. 446-448.
10. Gavrilov, G., Nicolov, C. 1985. Electroless Nickel and Composite Coatings, Tehnika, Sofia.
11. Stavrev, S. et al., 1994. US Patent No. 5353708.