ABSTRACT AND REFERENCES
MATERIALS SCIENCE

DOI: 10.15587/1729-4061.2017.112037

MODELING AND QUANTITATIVE ANALYSIS OF CONNECTIVITY AND CONDUCTIVITY IN RANDOM NETWORKS OF NANOTUBES (p. 4-12)

Andriy Stelmashchuk
Ivan Franko National University of Lviv, Lviv, Ukraine
ORCID: http://orcid.org/0000-0003-1898-8646

Ivan Karbovnyk
Ivan Franko National University of Lviv, Lviv, Ukraine
ORCID: http://orcid.org/0000-0002-3697-4902

Halyna Klym
Lviv Polytechnic National University, Lviv, Ukraine
ORCID: http://orcid.org/0000-0001-9927-0649

Oleksandr Berezko
Lviv Polytechnic National University, Lviv, Ukraine
ORCID: http://orcid.org/0000-0002-0664-4339

Yuriy Kostiv
Lviv Polytechnic National University, Lviv, Ukraine
ORCID: http://orcid.org/0000-0002-1821-6542

Roman Lys
Ivan Franko National University of Lviv, Lviv, Ukraine
ORCID: http://orcid.org/0000-0002-2459-4152

The work describes the framework that allows performing a computer simulation of complex random networks of conducting nanotubes embedded in the dielectric medium. The representative volume element filled with a large number of interconnected nanotubes is modeled and the tunneling conduction mechanism between adjacent tubes is considered. The principal goal is to develop a computational approach for the three-dimensional multielement structure simulation, which will be relatively simple, yet capable of producing realistic results.

The connectivity formation processes among nanotubes in random nanotube networks are studied using the elements of graph theory. All stages of the modeling process are discussed in details. The system conductivity model with taking into account the tunnel effect and intrinsic nanotube conductivities is formulated. The random resistor model is used to calculate the total equivalent conductivity of the network.

The results of the computer experiments on electrical conductivity simulations for different systems are presented. The dependencies of the electrical conductivity of nanotube networks in the insulating medium on the concentration of nanotubes, geometric parameters and properties of tunneling conductivity between individual tubes are investigated. It is found that the percolation threshold corresponds to the nanotube loading of 0.5 % when the aspect ratio of nanotubes is 160. Non-linear dependence between the aspect ratio and the percolation threshold was established. The analysis of computational complexity and calculation time is performed for quad-core computing systems.

Computer experiments carried out in a systematic fashion within the proposed framework can be useful when designing novel CNT-polymer composites for state of the art electronic applications. By following the predictions of the proposed model, tailoring of electrical properties of such composites can be made easier when adjusting the parameters of nanotubes and their concentration during the fabrication of the nanocomposite samples.

Keywords: statistical modeling, random resistor networks, percolation, tunneling conductance, nanotubes, nanocomposites.

References

1. Davis, W. R., Slawson, R. J., Rigby, G. R. (1953). An Unusual Form of Carbon. Nature, 171 (4356), 756–756. doi: 10.1038/171756a0
2. Iijima, S. (1991). Helical microtubules of graphitic carbon. Nature, 354 (6348), 56–58. doi: 10.1038/354056a0
3. Prolongo, S. G., Gude, M. R., Ureña, A. (2009). Synthesis and Characterisation of Epoxy Resins Reinforced with Carbon Nanotubes and Nanofibers. Journal of Nanoscience and Nanotechnology, 9 (10), 6181–6187. doi: 10.1166/jnn.2009.1554
4. Zhang, Y., Li, H., Liu, P., Peng, Z. (2016). Study on electrical properties and thermal conductivity of carbon nanotube/epoxy resin nanocomposites with different filler aspect ratios. 2016 IEEE International Conference on High Voltage Engineering and Application (ICHVE). doi: 10.1109/ichve.2016.7800771
5. Zhou, Y. X., Wu, P. X., Cheng, Z.-Y., Ingram, J., Jeelani, S. (2008). Improvement in electrical, thermal and mechanical properties of epoxy by filling carbon nanotube. Express Polymer Letters, 2 (1), 40–48. doi: 10.3144/expresspolymlett.2008.6
6. Karbovnyk, I., Olenych, I., Aksimentyeva, O., Klym, H., Dzendzelyuk, O., Olenych, Y., Hrushetska, O. (2016). Effect of Radiation on the Electrical Properties of PEDOT-Based Nanocomposites. Nanoscale Research Letters, 11 (1). doi: 10.1186/s11671-016-1293-0
7. Zaumseil, J. (2015). Single-walled carbon nanotube networks for flexible and printed electronics. Semiconductor Science and Technology, 30 (7), 074001. doi: 10.1088/0268-1242/30/7/074001
8. Park, S., Vosguerichian, M., Bao, Z. (2013). A review of fabrication and applications of carbon nanotube film-based flexible electronics. Nanoscale, 5 (5), 1727–1752. doi: 10.1039/c3nr33560g
9. Mendoza, M. O., Acosta, E. M. V., Prokhorov, E., Barcenas, G. L., Krishnan, S. K. (2016). Percolation Phenomena In Polymer Nanocomposites. Advanced Materials Letters, 7 (5), 353–359. doi: 10.5185/amlett.2016.6091
10. Stelmashchuk, A., Karbovnyk, I., Bolesta, I. (2012). Percolation in a random network of conducting nanotubes: a computer simulation study. Proceedings of the 11-th International Conference «Modern Problems of Radio Engineering, Telecommunications and Computer Science». Lviv-Slavske, 240.
11. Karbovnyk, I., Stelmashchuk, A., Bolesta, I., Klym, H. (2013). Percolating array of bent nanotubes studied by computer simulations. Proceedings of the 6-th International Conference «Advanced Computer Systems and Networks: Design and Application» (ACSN-2013). Lviv, 108–109.
12. Stelmashchuk, A., Karbovnyk, I., Klym, H. (2016). Computer simulations of nanotube networks in dielectric matrix. 2016 13th International Conference on Modern Problems of Radio Engineering, Telecommunications and Computer Science (TCSET). doi: 10.1109/tcset.2016.7452074
13. Wang, Y., Shan, J. W., Weng, G. J. (2015). Percolation threshold and electrical conductivity of graphene-based nanocomposites with filler agglomeration and interfacial tunneling. Journal of Applied Physics, 118 (6), 065101. doi: 10.1063/1.4928293
14. Colasanti, S., Bhatt, V. D., Lugli, P. (2014). 3D modeling of CNT networks for sensing applications. 2014 10th Conference on Ph.D. Research in Microelectronics and Electronics (PRIME). doi: 10.1109/prime.2014.6872679

15. Vakiv, M., Hadzaman, I., Klym, H., Shpotyuk, O., Brunner, M. (2011). Multifunctional thick-film structures based on spinel ceramics for environment sensors. Journal of Physics: Conference Series, 289, 012011. doi: 10.1088/1742-6596/289/1/012011
16. Klym, H., Hadzaman, I., Ingram, A., Shpotyuk, O. (2014). Multilayer thick-film structures based on spinel ceramics1. Canadian Journal of Physics, 92 (7/8), 822–826. doi: 10.1139/cjp-2013-0597
17. Klym, H., Hadzaman, I., Shpotyuk, O., Brunner, M. (2014). Integrated thick-film nanostructures based on spinel ceramics. Nanoscale Research Letters, 9 (1), 149. doi: 10.1186/1556-276x-9-149
18. Shpotyuk, O., Balitska, V., Brunner, M., Hadzaman, I., Klym, H. (2015). Thermally-induced electronic relaxation in structurally-modified Cu0.1Ni0.8Co0.2Mn1.9O4 spinel ceramics. Physica B: Condensed Matter, 459, 116–121. doi: 10.1016/j.physb.2014.11.023
19. Klym, H., Balitska, V., Shpotyuk, O., Hadzaman, I. (2014). Degradation transformation in spinel-type functional thick-film ceramic materials. Microelectronics Reliability, 54 (12), 2843–2848. doi: 10.1016/j.microrel.2014.07.137
20. Hadzaman, I., Klym, H., Shpotyuk, O. (2014). Nanostructured oxyspinel multilayers for novel high-efficient conversion and control. International Journal of Nanotechnology, 11 (9/10/11), 843. doi: 10.1504/ijnt.2014.063793
21. Klym, H., Shpotyuk, O., Ingram, A., Calvez, L., Hadzaman, I., Kostiv, Y. et. al. (2017). Influence of Free Volumes on Functional Properties of Modified Chalcogenide Glasses and Oxide Ceramics. Nanophysics, Nanomaterials, Interface Studies, and Applications, 479–493. doi: 10.1007/978-3-319-56422-7_36
22. Pal, G., Kumar, S. (2016). Modeling of carbon nanotubes and carbon nanotube–polymer composites. Progress in Aerospace Sciences, 80, 33–58. doi: 10.1016/j.paerosci.2015.12.001
23. Fakhim, B., Hassani, A., Rashidi, A., Ghodousi, P. (2013). Predicting the Impact of Multiwalled Carbon Nanotubes on the Cement Hydration Products and Durability of Cementitious Matrix Using Artificial Neural Network Modeling Technique. The Scientific World Journal, 2013, 1–8. doi: 10.1155/2013/103713
24. Gong, S., Zhu, Z. H., Li, J., Meguid, S. A. (2014). Modeling and characterization of carbon nanotube agglomeration effect on electrical conductivity of carbon nanotube polymer composites. Journal of Applied Physics, 116 (19), 194306. doi: 10.1063/1.4902175
25. Perumal, L., Leng, L. T., Tso, C. P. (2016). Nanoscale Continuum Modelling of Carbon Nanotubes by Polyhedral Finite Elements. Journal of Nanomaterials, 2016, 1–9. doi: 10.1155/2016/6374092
26. Araújo, F. C., d'Azevedo, E. F., Gray, L. J. (2010). Boundary-element parallel-computing algorithm for the microstructural analysis of general composites. Computers & Structures, 88 (11-12), 773–784. doi: 10.1016/j.compstruc.2010.03.001
27. Yu, Y., Song, G., Sun, L. (2010). Determinant role of tunneling resistance in electrical conductivity of polymer composites reinforced by well dispersed carbon nanotubes. Journal of Applied Physics, 108 (8), 084319. doi: 10.1063/1.3499628
28. Bao, W. S., Meguid, S. A., Zhu, Z. H., Weng, G. J. (2012). Tunneling resistance and its effect on the electrical conductivity of carbon nanotube nanocomposites. Journal of Applied Physics, 111 (9), 093726. doi: 10.1063/1.4716010
29. Hu, N., Masuda, Z., Yan, C., Yamamoto, G., Fukunaga, H., Hashida, T. (2008). The electrical properties of polymer nanocomposites with carbon nanotube fillers. Nanotechnology, 19 (21), 215701. doi: 10.1088/0957-4484/19/21/215701
30. Büttiker, M., Imry, Y., Landauer, R., Pinhas, S. (1985). Generalized many-channel conductance formula with application to small rings. Physical Review B, 31 (10), 6207–6215. doi: 10.1103/physrevb.31.6207
31. Tamura, R., Tsukada, M. (1997). Electronic transport in carbon nanotube junctions. Solid State Communications, 101 (8), 601–605. doi: 10.1016/s0038-1098(96)00761-2
32. Physical properties of carbon nanotubes. Volume 3 [Text] / R. Saito, G. Dresselhaus, M. S. Dresselhaus – London: Imperial College Press, 1998.
33. Imry, Y., Landauer, R. (1999). Conductance viewed as transmission. Reviews of Modern Physics, 71 (2), S306–S312. doi: 10.1103/revmodphys.71.s306
34. Buldum, A., Lu, J. P. (2001). Contact resistance between carbon nanotubes. Physical Review B, 63 (16). doi: 10.1103/physrevb.63.161403
35. Naeemi, A., Meindl, J. D. (2008). Performance Modeling for Carbon Nanotube Interconnects. Carbon Nanotube Electronics, 163–190. doi: 10.1007/978-0-387-69285-2_7
36. Hertel, T., Walkup, R. E., Avouris, P. (1998). Deformation of carbon nanotubes by surface van der Waals forces. Physical Review B, 58 (20), 13870–13873. doi: 10.1103/physrevb.58.13870
37. Girifalco, L. A., Hodak, M., Lee, R. S. (2000). Carbon nanotubes, buckyballs, ropes, and a universal graphitic potential. Physical Review B, 62 (19), 13104–13110. doi: 10.1103/physrevb.62.13104
38. Simmons, J. G. (1963). Generalized Formula for the Electric Tunnel Effect between Similar Electrodes Separated by a Thin Insulating Film. Journal of Applied Physics, 34 (6), 1793–1803. doi: 10.1063/1.1702682
39. Li, X. S. (2005). An overview of SuperLU. ACM Transactions on Mathematical Software, 31 (3), 302–325. doi: 10.1145/1089014.1089017
40. Demmel, J. W., Gilbert, J. R., Li, X. S. (1999). SuperLU users guide. Lawrence Berkeley National Laboratory. doi: 10.2172/751785
41. Demmel, J. W., Eisenstat, S. C., Gilbert, J. R., Li, X. S., Liu, J. W. H. (1999). A Supernodal Approach to Sparse Partial Pivoting. SIAM Journal on Matrix Analysis and Applications, 20 (3), 720–755. doi: 10.1137/s0895479895291765

DOI: 10.15587/1729-4061.2017.109770

COMPARISON OF OXYGEN EVOLUTION PARAMETERS ON DIFFERENT TYPES OF NICKEL HYDROXIDE (p. 12-19)

Valerii Kotok
Ukrainian State University of Chemical Technology, Dnipro, Ukraine
Vyatka State University, Kirov, Russian Federation
ORCID: http://orcid.org/0000-0001-8879-7189

Vadym Kovalenko
Ukrainian State University of Chemical Technology, Dnipro, Ukraine
Vyatka State University, Kirov, Russian Federation
ORCID: http://orcid.org/0000-0002-8012-6732

Valerii Malyshev
Ukrainian State University of Chemical Technology, Dnipro, Ukraine
ORCID: http://orcid.org/0000-0001-6236-1053

A simple method for determining the oxygen evolution parameters; that uses step-wise potentiostatic regime was proposed. The proposed method was used to study the oxygen evolution on the nickel hydroxide samples that were prepared using different methods and had different grain size. The samples used in the research were studied using Scanning Electron Microscopy, X-ray diffraction, IR-spectroscopy, and Energy Dispersive X-ray analysis. It was demonstrated that the used $Ni(OH)_2$ samples have different morphology, structure and composition. The industrial β-$Ni(OH)_2$ sample has a shard-like structure, high degree of crystallinity and no intercalated anions. The electrochemically prepared sample has a low degree of crystallinity and has a structure that is composed of α and β-forms that contain carbonate and sulfate ions. It had been demonstrated that polarization of oxygen evolution depends on the methods of nickel (II) hydroxide synthesis and its grain size. The effective constants of the Tafel equation had been determined, which for industrial $Ni(OH)_2$ samples are a_{eff}=0.383 b_{eff}=0.055 (0–70 μm grain size) and a_{eff}=0.414, b_{eff}=0.067 (0–40 μm grain size), for the electrochemically prepared sample – a_{eff}=0.451, b_{eff}=0.089 (0–70 μm grain size). It was also demonstrated that polarization of oxygen evolution is affected differently by high current densities for different powders.

Keywords: oxygen evolution, side-process, nickel hydroxide, $Ni(OH)_2$, cyclic voltamperometry curve.

References

1. Kovalenko, V., Kotok, V., Bolotin, O. (2016). Definition of factors influencing on $Ni(OH)_2$ electrochemical characteristics for supercapacitors. Eastern-European Journal of Enterprise Technologies, 5 (6 (83)), 17–22. doi: 10.15587/1729-4061.2016.79406
2. Kovalenko, V. L., Kotok, V. A., Sykchin, A. A., Mudryi, I. A., Ananchenko, B. A., Burkov, A. A. et. al. (2016). Nickel hydroxide obtained by high-temperature two-step synthesis as an effective material for supercapacitor applications. Journal of Solid State Electrochemistry, 21 (3), 683–691. doi: 10.1007/s10008-016-3405-2
3. Kovalenko, V., Kotok, V. (2017). Study of the influence of the template concentration under homogeneous precepitation on the properties of Ni(OH)2 for supercapacitors. Eastern-European Journal of Enterprise Technologies, 4 (6 (88)), 17–22. doi: 10.15587/1729-4061.2017.106813
4. Kotok, V., Kovalenko, V. (2017). The properties investigation of the faradaic supercapacitor electrode formed on foamed nickel substrate with polyvinyl alcohol using. EasternEuropean Journal of Enterprise Technologies, 4 (12 (88)), 31–37. doi: 10.15587/1729-4061.2017.108839
5. Solovov, V., Kovalenko, V., Nikolenko, N., Kotok, V., Vlasova, E. (2017). Influence of temperature on the characteristics of Ni(II), Ti(IV) layered double hydroxides synthesised by different methods. Eastern-European Journal of Enterprise Technologies, 1 (6 (85)), 16–22. doi: 10.15587/1729-4061.2017.90873
6. Miao, F., Tao, B., Chu, P. K. (2015). Ordered-standing nickel hydroxide microchannel arrays: Synthesis and application for highly sensitive non-enzymatic glucose sensors. Microelectronic Engineering, 133, 11–15. doi: 10.1016/j.mee.2014.11.005
7. Kotok, V. A., Kovalenko, V. L., Kovalenko, P. V., Solovov, V. A., Deabate, S., Mehdi, A. et. al. (2017). Advanced electrochromic $Ni(OH)_2$/PVA films formed by electrochemical template synthesis. ARPN Journal of Engineering and Applied Sciences, 12 (13), 3962–3977.
8. Kotok, V., Kovalenko, V. (2017). The electrochemical cathodic template synthesis of nickel hydroxide thin films for electrochromic devices: role of temperature. Eastern-European Journal of Enterprise Technologies, 2 (11 (86)), 28–34. doi: 10.15587/1729-4061.2017.97371
9. Huang, W., Wang, H., Zhou, J., Wang, J., Duchesne, P. N., Muir, D. et. al. (2015). Highly active and durable methanol oxidation electrocatalyst based on the synergy of platinum–nickel hydroxide–graphene. Nature Communications, 6, 10035. doi: 10.1038/ncomms10035
10. Ranganathan, P., Sasikumar, R., Chen, S.-M., Rwei, S.-P., Sireesha, P. (2017). Enhanced photovoltaic performance of dye-sensitized solar cells based on nickel oxide supported on nitrogen-doped graphene nanocomposite as a photoanode. Journal of Colloid and Interface Science, 504, 570–578. doi: 10.1016/j.jcis.2017.06.012
11. Huo, J., Tu, Y., Zheng, M., Wu, J. (2017). Fabrication a thin nickel oxide layer on photoanodes for control of charge recombination in dye-sensitized solar cells. Journal of Solid State Electrochemistry, 21 (6), 1523–1531. doi: 10.1007/s10008-017-3515-5
12. Malara, F., Carallo, S., Rotunno, E., Lazzarini, L., Piperopoulos, E., Milone, C., Naldoni, A. (2017). A Flexible Electrode Based on Al-Doped Nickel Hydroxide Wrapped around a Carbon Nanotube Forest for Efficient Oxygen Evolution. ACS Catalysis, 7 (7), 4786–4795. doi: 10.1021/acscatal.7b01188
13. Qiu, C., Liu, D., Jin, K., Fang, L., Sha, T. (2017). Corrosion resistance and micro-tribological properties of nickel hydroxide-graphene oxide composite coating. Diamond and Related Materials, 76, 150–156. doi: 10.1016/j.diamond.2017.04.015
14. Hall, D. S., Lockwood, D. J., Bock, C., MacDougall, B. R. (2014). Nickel hydroxides and related materials: a review of their structures, synthesis and properties. Proceedings of the Royal Society A: Mathematical, Physical and Engineering Sciences, 471 (2174), 20140792–20140792. doi: 10.1098/rspa.2014.0792
15. Vidotti, M., Torresi, R., Torresi, S. I. C. de. (2010). Eletrodos modificados por hidróxido de níquel: um estudo de revisão sobre suas propriedades estruturais e eletroquímicas visando suas aplicações em eletrocatálise, eletrocromismo e baterias secundárias. Química Nova, 33 (10), 2176–2186. doi: 10.1590/s0100-40422010001000030
16. Yan-wei, L., Chang-jiu, L., Jin-huan, Y. (2010). Progress in research on amorphous nickel hydroxide electrode materials. Xiandai Huagong/Modern Chemical Industry, 30 (2), 25–27.
17. Feng, L., Zhu, Y., Ding, H., Ni, C. (2014). Recent progress in nickel based materials for high performance pseudocapacitor electrodes. Journal of Power Sources, 267, 430–444. doi: 10.1016/j.jpowsour.2014.05.092
18. Snook, G. A., Duffy, N. W., Pandolfo, A. G. (2008). Detection of Oxygen Evolution from Nickel Hydroxide Electrodes Using Scanning Electrochemical Microscopy. Journal of The Electrochemical Society, 155 (3), A262. doi: 10.1149/1.2830837
19. Kotok, V., Kovalenko, V. (2017). Optimization of nickel hydroxide electrode of the hybrid supercapacitor. Eastern-European Journal of Enterprise Technologies, 1 (6 (85)), 4–9. doi: 10.15587/1729-4061.2017.90810
20. Bronoel, G., Reby, J. (1980). Mechanism of oxygen evolution in basic medium at a nickel electrode. Electrochimica Acta, 25 (7), 973–976. doi: 10.1016/0013-4686(80)87102-7
21. Nadesan, J. C. B. (1985). Oxygen Evolution on Nickel Oxide Electrodes. Journal of The Electrochemical Society, 132 (12), 2957. doi: 10.1149/1.2113700
22. Motupally, S. (1998). The Role of Oxygen at the Second Discharge Plateau of Nickel Hydroxide. Journal of The Electrochemical Society, 145 (1), 34. doi: 10.1149/1.1838206
23. Wang, X. (2004). Oxygen catalytic evolution reaction on nickel hydroxide electrode modified by electroless cobalt coating. International Journal of Hydrogen Energy, 29 (9), 967–972. doi: 10.1016/j.ijhydene.2003.05.001
24. Snook, G. A., Duffy, N. W., Pandolfo, A. G. (2007). Evaluation of the effects of oxygen evolution on the capacity and cycle life of nickel hydroxide electrode materials. Journal of Power Sources, 168 (2), 513–521. doi: 10.1016/j.jpowsour.2007.02.060
25. Lyons, M. E. G., Russell, L., O'Brien, M., Doyle, R. L., Godwin, I., Brandon, M. P. (2012). Redox Switching and Oxygen Evolution at Hydrous Oxyhydroxide Modified Nickel Electrodes in Aqueous Alkaline Solution: Effect of Hydrous Oxide Thickness and Base Concentration. Int. J. Electrochem. Sci., 7, 2710–2763.

26. Lyons, M. E. G., Doyle, R. L., Godwin, I., O'Brien, M., Russell, L. (2012). Hydrous Nickel Oxide: Redox Switching and the Oxygen Evolution Reaction in Aqueous Alkaline Solution. Journal of the Electrochemical Society, 159 (12), H932–H944. doi: 10.1149/2.078212jes
27. Mellsop, S. R., Gardiner, A., Marshall, A. T. (2015). Electrocatalytic oxygen evolution on nickel oxy-hydroxide anodes: Improvement through rejuvenation. Electrochimica Acta, 180, 501–506. doi: 10.1016/j.electacta.2015.08.061
28. Bau, J. A., Luber, E. J., Buriak, J. M. (2015). Oxygen Evolution Catalyzed by Nickel–Iron Oxide Nanocrystals with a Nonequilibrium Phase. ACS Applied Materials & Interfaces, 7 (35), 19755–19763. doi: 10.1021/acsami.5b05594
29. Kovalenko, V., Kotok, V. (2017). Obtaining of Ni–Al layered double hydroxide by slit diaphragm electrolyzer. Eastern-European Journal of Enterprise Technologies, 2 (6 (86)), 11–17. doi: 10.15587/1729-4061.2017.95699
30. Kotok, V., Kovalenko, V. (2017). Electrochromism of $Ni(OH)_2$ films obtained by cathode template method with addition of Al, Zn, Co ions. Eastern-European Journal of Enterprise Technologies, 3 (12 (87)), 38–43. doi: 10.15587/1729-4061.2017.103010
31. Oliva, P., Leonardi, J., Laurent, J. F., Delmas, C., Braconnier, J. J., Figlarz, M. et. al. (1982). Review of the structure and the electrochemistry of nickel hydroxides and oxy-hydroxides. Journal of Power Sources, 8 (2), 229–255. doi: 10.1016/0378-7753(82)80057-8
32. Genin, P., Delahaye-Vidal, A., Portemer, F., Tekaia-Elhsissen, K., Figlarz, M. (1991). Preparation and characterization of α-type nickel hydroxides obtained by chemical precipitation: study of the anionic species. Eur. J. Solid State Inorg. Chem., 28, 505.
33. Faure, C., Delmas, C., Fouassier, M. (1991). Characterization of a turbostratic α-nickel hydroxide quantitatively obtained from an $NiSO_4$ solution. Journal of Power Sources, 35 (3), 279–290. doi: 10.1016/0378-7753(91)80112-b
34. Delahaye-Vidal, A. (1996). Structural and textural investigations of the nickel hydroxide electrode. Solid State Ionics, 84 (3-4), 239–248. doi: 10.1016/0167-2738(96)00030-6
35. Srinivasan, V., Weidner, J. W., White, R. E. (2000). Mathematical models of the nickel hydroxide active material. Journal of Solid State Electrochemistry, 4 (7), 367–382. doi: 10.1007/s100080000107

DOI: 10.15587/1729-4061.2017.111350

RESEARCH INTO SURFACE PROPERTIES OF DISPERSE FILLERS BASED ON PLANT RAW MATERIALS (p. 20-26)

Yuliya Danchenko
Kharkiv National University of Civil Engineering and Architecture, Kharkiv, Ukraine
ORCID: http://orcid.org/0000-0003-3865-2496

Vladimir Andronov
National University of Civil Protection of Ukraine, Kharkiv, Ukraine
ORCID: http://orcid.org/0000-0001-7486-482X

Artem Kariev
Kharkiv National University of Civil Engineering and Architecture, Kharkiv, Ukraine
ORCID: http://orcid.org/0000-0002-7726-0359

Vladimir Lebedev
National Technical University "Kharkiv Polytechnic Institute", Kharkiv, Ukraine
ORCID: http://orcid.org/0000-0001-6934-2349

Evgeniy Rybka
National University of Civil Protection of Ukraine, Kharkiv, Ukraine
ORCID: http://orcid.org/0000-0002-5396-5151

Ruslan Meleshchenko
National University of Civil Protection of Ukraine, Kharkiv, Ukraine
ORCID: http://orcid.org/0000-0001-5411-2030

Dayana Yavorska
V. N. Karazin Kharkiv National University, Kharkiv, Ukraine
ORCID: http://orcid.org/0000-0003-0670-4052

The properties of the dispersed fillers are investigated based on the agricultural and wood industry wastes: buckwheat and oats husk, wood and pine-needle flour. We experimentally determined structural-rheological characteristics, morphology and acid-base properties of the surface. By applying a potentiometric determining of hydrogen indicator of aqueous suspensions $pH_{susp.}$, we studied the qualitative and quantitative characteristics of acid-base active centers on the surface of the particles of fillers. It was revealed that the surface of buckwheat husk is dominated by two types of active centers: weakly-acidic (pK_a≈5.53–5.83) and close to neutral (pK_a≈6.16–6.30). The surfaces of wood flour and pine-needle flour are characterized as the weakly-acidic with centers pK_a≈5.29–5.52 and pK_a≈5.02–5.36, respectively. Based on sources from the scientific literature, we compiled a comparative characteristic of the chemical composition of the examined fillers. A correlation is established between chemical composition, physical-chemical and surface properties. It is shown that the total mass content of cellulose and lignin can be one of the criteria for evaluating resistance of the fillers to high temperatures and acidic-base properties. A decrease in the sum of mass content of cellulose and lignin in the composition of fillers results in the improved thermal resistance while the surface acidity decreases. The results obtained allow us to predict behaviour of the fillers in compositions and control performance characteristics of composite materials.

Keywords: disperse filler, plant raw materials, composite material, surface active centre, acid-base properties.

References

1. Klesov, A. A. (2010). Drevesno-polimernye kompozity. Sankt-Peterburg: Nauchnye osnovy i tekhnologi, 736.
2. Dikobe, D. G., Luyt, A. S. (2006). Effect of filler content and size on the properties of ethylene vinyl acetate copolymer–wood fiber composites. Journal of Applied Polymer Science, 103 (6), 3645–3654. doi: 10.1002/app.25513
3. Nwabunma, D., Kyu, T. (Eds.) (2007). Polyolefin composites. John Wiley & Sons, Inc., 603. doi: 10.1002/9780470199039
4. Shkuro, A. E., Gluhih, V. V., Muhin, N. M. (2016). Poluchenie i izuchenie drevesno-polimernyh kompozitov s napolnitelyami iz othodov rastitel'nogo proiskhozhdeniya. Lesnoy vestnik, 3, 101–105.
5. Kariev, A. I., Danchenko, Yu. M. (2016). Perspektyvy vykorystannia roslynnykh vidkhodiv u vyrobnytstvi polimernykh kompozytiv. Materialy IX Mizhnarodnoi naukovo-tekhnichnoi WEB-konferentsii «Kompozytsiini materialy». Kyiv, 81–82.
6. Kariev, A. I., Yu. M. Danchenko (2016). Vplyv pryrody dyspersnykh orhanichnykh napovniuvachiv na fizyko-mekhanichni vlastyvosti kompozytiv z vtorynnoho polipropilenu. Materialy II Mizhnarodnoi naukovo-tekhnichnoi Internet-konferentsyi «Resursozberezhennia ta enerhoefektyvnist inzhenernoi infrastruktury urbanizovanykh

terytoryi ta promyslovykh pidpryiemstv». Kharkiv: KhNUHKh im. A. N. Beketova, 104–107.
7. Zini, E., Scandola, M. (2011). Green composites: An overview. Polymer Composites, 32 (12), 1905–1915. doi: 10.1002/pc.21224
8. Petchwattana, N., Covavisaruch, S. (2013). Effects of Rice Hull Particle Size and Content on the Mechanical Properties and Visual Appearance of Wood Plastic Composites Prepared from Poly(vinyl chloride). Journal of Bionic Engineering, 10 (1), 110–117. doi: 10.1016/s1672-6529(13)60205-x
9. Lim, L. A., Makeich, D. A., Prishchenko, N. A., Zabolotnaya, A. M., Reutov, V. A., Kovaleva, E. V. (2015). Poluchenie lignocellyuloznyh polimernyh kompozitov na osnove grechnevoy sheluhi i poliehtilena. Mezhdunarodnyy zhurnal prikladnyh i ehksperimental'nyh issledovaniy, 6, 514–514.
10. Reutov, V. A., Lim, L. A., Zabolotnaya, A. M., Prishchenko, N. A., Anufriev, A. V., Pustovalov, E. V. (2016). Vliyanie sostava napolnitelya na svoystva lignocellyuloznogo polimernogo kompozicionnogo materiala. Sb. materialov Vtorogo mezhdisciplinarnogo molodezhnogo nauchnogo foruma s mezhdunarodnym uchastiem «Novye materialy». Moscow: Interkontaktnauka, 69–71.
11. Yan, L., Chouw, N., Jayaraman, K. (2014). Flax fibre and its composites – A review. Composites Part B: Engineering, 56, 296–317. doi: 10.1016/j.compositesb.2013.08.014
12. Bajwa, S. G., Bajwa, D. S., Holt, G., Coffelt, T., Nakayama, F. (2011). Properties of thermoplastic composites with cotton and guayule biomass residues as fiber fillers. Industrial Crops and Products, 33 (3), 747–755. doi: 10.1016/j.indcrop.2011.01.017
13. Binhussain, M. A., El-Tonsy, M. M. (2013). Palm leave and plastic waste wood composite for out-door structures. Construction and Building Materials, 47, 1431–1435. doi: 10.1016/j.conbuildmat.2013.06.031
14. Kengkhetkit, N., Amornsakchai, T. (2014). A new approach to "Greening" plastic composites using pineapple leaf waste for performance and cost effectiveness. Materials & Design, 55, 292–299. doi: 10.1016/j.matdes.2013.10.005
15. Mattos, B. D., Misso, A. L., de Cademartori, P. H. G., de Lima, E. A., Magalhães, W. L. E., Gatto, D. A. (2014). Properties of polypropylene composites filled with a mixture of household waste of mate-tea and wood particles. Construction and Building Materials, 61, 60–68. doi: 10.1016/j.conbuildmat.2014.02.022
16. Zemnuhova, L. A., V. V. Budaeva, G. A. Fedorishcheva, T. A. Kaydalova, L. N. Kurilenko, E. D. Shkorina, S. G. Il'yasov (2009). Neorganicheskie komponenty solomy i sheluhi ovsa. Himiya rastitel'nogo syr'ya, 1, 147–152.
17. Zemnuhova, L. A., Makarenko, N. V., Tishchenko, L. Ya., Kovaleva, E. V. (2009). Issledovanie aminokislotnogo sostava v othodah proizvodstva risa, grechihi i podsolnechnika. Himiya rastitel'nogo syr'ya, 3, 147–149.
18. Yamansarova, E. T., Gromyko, N. V., Abdullin, M. I., Kukovinec, O. S., Zvorygina, O. B. (2016). Issledovanie sorbcionnyh svoystv materialov na osnove rastitel'nogo syr'ya po otnosheniyu k organicheskim i neorganicheskim primesyam. Vestnik Bashkirskogo universiteta, 21 (1), 73–77.
19. Li, F.-Z., Lu, Z.-L., Yang, Z.-H., Qi, K. (2015). Surface interaction energy simulation of ceramic materials with epoxy resin. Polimery, 60 (07/08), 468–471. doi: 10.14314/polimery.2015.468
20. Danchenko, Yu. M. (2017). Regulation of free surface energy of epoxy polymer materials using mineral fillers. Polymer materials and technologies, 3 (2), 56–63.
21. Glazkov, S. S., Kozlov, V. A., Pozhidaeva, A. E., Rudakov, O. B. (2009). Poverhnostnye ehnergeticheskie harakteristiki kompozitov na osnove prirodnyh polimerov. Sorbcionnye i hromatograficheskie processy, 1 (1), 58–66.
22. Starostina, I. A., Stoyanov, O. V. (2010). Kislotno-osnovnye vzaimodeystviya i adgeziya v metall-polimernyh sistemah. Kazan': Izd-vo Kazan. gos. Tekhnol. un-ta, 200.
23. Barabash, E. S., Popov, Yu. V., Danchenko, Yu. M. (2015). Vliyanie modificiruyushchih dobavok na adgezionnuyu sposobnost' ehpoksiaminnyh svyazuyushchih k alyumoborsilikatnomu steklu i stali. Naukovyi visnyk budivnytstva, 4 (82), 122–128.
24. Danchenko, Yu. M., Popov, Yu. V., Barabash, O. S. (2016). Vplyv kyslotno-osnovnykh vlastyvostei poverkhni poli mineralnykh napovniuvachiv na strukturu ta kharakterystyky epoksykompozytiv. Voprosy himii i himicheskoy tekhnologii, 3 (107), 53–60.
25. Andronov, V. A., Danchenko, Yu. M., Skripinets, A. V., Bukchman, O. M. (2013). Efficiency of utilization of vibration-absorbing polimer coating for reducing local vibration. Scientific Bulletin of National Mining University, 6, 85–91.
26. Osipchik, V. S., Yakovleva, R. A., Danchenko, Yu. M., Kachomanova, M. P., Bykov, R. A., Posohova, I. A. (2007). Issledovanie vliyaniya poverhnostnyh svoystv bentonita na processy otverzhdeniya ehpoksiaminnyh kompoziciy. Uspekhi v himii i himicheskoy tekhnologii, XXI (6 (74)), 40–43.
27. Yamansarova, E. T., Gromyko, N. V., Abdullin, M. I., Kukovinec, O. S., Zvorygina, O. B. (2015). Issledovanie sorbcionnyh svoystv materialov na osnove rastitel'nogo syr'ya po otnosheniyu k neftyanym zagryazneniyam vody. Vestnik Bashkirskogo universiteta, 20 (4), 1209–1212.
28. Lysak, I. A., Lysak, G. V., Malinovskaya, T. D., Skvorcova, L. N., Potekaev, A. I. (2013). Issledovanie kislotno-osnovnyh svoystv poverhnosti polimernyh voloknistyh materialov. Pis'ma o materialah, 3 (4), 300–303.
29. Baranova, N. V., Pashina, L. A., Osipova, E. G. (2013). Vzaimosvyaz' himicheskoy struktury poverhnosti polimerov vinilovogo ryada s poverhnostnymi kislotno-osnovnymi harakteristikami. Vestnik Kazanskogo tekhnologicheskogo universiteta, 16 (21), 171–175.
30. Zenkiewicz, M. (2007). Methods for the calculation of surface free energy of solids. Journal of Achievements in Materials and Manufacturing Engineering, 24 (1), 137–145.
31. Hejda, F., Solar, P., Kousal, J. (2010). Surface free energy determination by contact angle measurements – a comparison of various approaches. WDS'10 Proceeding of Contributed Papers. Prague, 25–30.
32. Ikonnikova, K. V., Ikonnikova, L. F., Minakova, T. S., Sarkisov, Yu. S. (2011). Teoriya i praktika rN-metricheskogo opredeleniya kislotno-osnovnyh svoystv poverhnosti tverdyh tel. Tomsk: Izd-vo Tomsk. politekhn. un-ta, 85.
33. Kariev, A. I., Danchenko, Yu. M., Yavorska, D. H. (2016). Vlastyvosti orhanichnykh napovniuvachiv derevno-polimernykh kompozytiv budivelnoho pryznachennia. Naukovyi visnyk budivnytstva, 86 (4), 160–164.
34. Osadchuk, L. S. (2015). Vmist terpenovykh vuhlevodniv u khvoi sosny zvychainoi riznoi katehoryi smoloproduktyvnosti. Naukovyi visnyk NLHU Ukrainy, 25.3, 16–21.
35. Mitrofanov, L. Yu., Zolotuhin, V. N., Budaeva, V. V. (2010). Izuchenie himicheskogo sostava vodnogo ehkstrakta solomy ovsa (AVENA SATIVA L.) i issledovanie ego rostoreguliruyushchih svoystv. Polzunovskiy Vestnik, 4-1,. 174–179.
36. Tarasevich, Yu. I. (2011). Poverhnostnye yavleniya na dispersnyh materialah. Kyiv: Naukova dumka, 390.
37. Danchenko, Yu., Andronov, V., Rybka, E., Skliarov, S. (2017). Investigation into acid-basic equilibrium on the surface of oxides with various chemical nature. Eastern-European Journal of Enterprise Technologies, 4 (12 (88)), 17–25. doi: 10.15587/1729-4061.2017.108946

DOI: 10.15587/1729-4061.2017.109814
SYNTHESIS AND CHARACTERISATION OF DYE-INTERCALATED NICKEL-ALUMINIUM LAYERED-DOUBLE HYDROXIDE AS A COSMETIC PIGMENT
(p. 27-33)

Vadym Kovalenko
Ukrainian State University of Chemical Technology, Dnipro, Ukraine
Vyatka State University, Kirov, Russian Federation
ORCID: http://orcid.org/0000-0002-8012-6732

Valerii Kotok
Ukrainian State University of Chemical Technology, Dnipro, Ukraine
Vyatka State University, Kirov, Russian Federation
ORCID: http://orcid.org/0000-0001-8879-7189

Anastasiya Yeroshkina
Ukrainian State University of Chemical Technology, Dnipro, Ukraine
ORCID: http://orcid.org/0000-0002-6293-3557

Alexander Zaychuk
Ukrainian State University of Chemical Technology, Dnipro, Ukraine
ORCID: http://orcid.org/0000-0001-5209-7498

Dye-intercalated layered double hydroxides (LDH) are modern promising pigments for paint and cosmetics industry. For the preparation of high-quality cosmetic pigments, particularly for nail polish, it was proposed to use not only intercalation but also chemisorption. For the pigment synthesis, Ni-AL LDH was chosen, along with murexide (Ammonium (purpurate) 2,6-dioxo-5-[(2,4,6-trioxo-5-hexahydropyrimidinylidene)amino]-3H-pyrimidin-4-olate), in which colored purpurate anion is able to form complex compounds with Ni^{2+}. The murexide-intercalated (murexide amount for intercalation only) and murexide-intercalated-chemisorbed (murexide amount for Ni^{2+}) Ni-Al LDH pigments were synthesized and used for the preparation of nail polish samples. The crystallographic composition was studied by means of XRD analysis. The color parameters (coordinates of color and chromaticity, dominant wavelength and color purity) of pigment powders and nail polish samples with these pigments have been studied using a color comparator. Organoleptic characteristics of pigment and nail polish samples were studied. The positive influence of chemisorption was shown: murexide-intercalated-chemisorbed pigment is easily ground, with the formation of highly dispersed powder, which during the preparation of nail polish was easily dispersed with the formation of stable yellow samples (dominant wavelength 583 nm) with high color purity of 43 %. Also, high covering ability of the murexide-intercalated-chemisorbed pigment was shown: high-quality, opaque, colored nail polish coat was formed at the pigment content of 45 %, 30 % and 15 % (wt.). For the synthesis of such pigments, it was recommended to choose anionic dyes that can form coordination bonds with LDH cations.

Keywords: cosmetic pigment, murexide, Ni-Al LDH, chemisorption, intercalation, nail polish.

References

1. Drahl, C. (2008). Nail polish. Chemical & Engineering News, 86 (32), 42. doi: 10.1021/cen-v086n032.p042
2. Mariani, F. Q., Borth, K. W., Müller, M., Dalpasquale, M., Anaissi, F. J. (2017). Sustainable innovative method to synthesize different shades of iron oxide pigments. Dyes and Pigments, 137, 403–409. doi: 10.1016/j.dyepig.2016.10.024
3. Zaichuk, A. V., Belyi, Y. I. (2012). Brown ceramic pigments based on open-hearth slag. Russian Journal of Applied Chemistry, 85 (10), 1531–1535. doi: 10.1134/s1070427212100072
4. Zaichuk, A. V., Belyi, Y. I. (2012). Black ceramic pigments based on open-hearth slag. Glass and Ceramics, 69 (3-4), 99–103. doi: 10.1007/s10717-012-9423-3
5. Zaychuk, A., Iovleva, J. (2013). The study of ceramic pigments of spinel type with the use of slage of aluminothermal production of ferrotitanium. Chemistry & Chemical Technology, 7 (2), 217–225.
6. Zaichuk, A. V., Belyi, Y. I. (2013). Improvement of the Compositions and Properties of Gray Ceramic Pigments. Glass and Ceramics, 70 (5-6), 229–233. doi: 10.1007/s10717-013-9550-5
7. Zaichuk, A. V., Amelina, A. A. (2017). Production of Uvarovite Ceramic Pigments Using Granulated Blast-Furnace Slag. Glass and Ceramics, 74 (3-4), 99–103. doi: 10.1007/s10717-017-9937-9
8. Khan, A. I., Ragavan, A., Fong, B., Markland, C., O'Brien, M., Dunbar, T. G. et. al. (2009). Recent Developments in the Use of Layered Double Hydroxides as Host Materials for the Storage and Triggered Release of Functional Anions. Industrial & Engineering Chemistry Research, 48 (23), 10196–10205. doi: 10.1021/ie9012612
9. Mandal, S., Tichit, D., Lerner, D. A., Marcotte, N. (2009). Azoic Dye Hosted in Layered Double Hydroxide: Physicochemical Characterization of the Intercalated Materials. Langmuir, 25 (18), 10980–10986. doi: 10.1021/la901201s
10. Mandal, S., Lerner, D. A., Marcotte, N., Tichit, D. (2009). Structural characterization of azoic dye hosted layered double hydroxides. Zeitschrift Für Kristallographie, 224 (5-6). doi: 10.1524/zkri.2009.1150
11. Wang, Q., Feng, Y., Feng, J., Li, D. (2011). Enhanced thermal- and photo-stability of acid yellow 17 by incorporation into layered double hydroxides. Journal of Solid State Chemistry, 184 (6), 1551–1555. doi: 10.1016/j.jssc.2011.04.020
12. Liu, J. Q., Zhang, X. C., Hou, W. G., Dai, Y. Y., Xiao, H., Yan, S. S. (2009). Synthesis and Characterization of Methyl-Red/Layered Double Hydroxide (LDH) Nanocomposite. Advanced Materials Research, 79-82, 493–496. doi: 10.4028/www.scientific.net/amr.79-82.493
13. Tian, Y., Wang, G., Li, F., Evans, D. G. (2007). Synthesis and thermo-optical stability of o-methyl red-intercalated Ni–Fe layered double hydroxide material. Materials Letters, 61 (8-9), 1662–1666. doi: 10.1016/j.matlet.2006.07.094
14. Hwang, S.-H., Jung, S.-C., Yoon, S.-M., Kim, D.-K. (2008). Preparation and characterization of dye-intercalated Zn–Al-layered double hydroxide and its surface modification by silica coating. Journal of Physics and Chemistry of Solids, 69 (5-6), 1061–1065. doi: 10.1016/j.jpcs.2007.11.002
15. Tang, P., Deng, F., Feng, Y., Li, D. (2012). Mordant Yellow 3 Anions Intercalated Layered Double Hydroxides: Preparation, Thermo- and Photostability. Industrial & Engineering Chemistry Research, 51 (32), 10542–10545. doi: 10.1021/ie300645b
16. Tang, P., Feng, Y., Li, D. (2011). Fabrication and properties of Acid Yellow 49 dye-intercalated layered double hydroxides film on an alumina-coated aluminum substrate. Dyes and Pigments, 91 (2), 120–125. doi: 10.1016/j.dyepig.2011.03.012
17. Tang, P., Feng, Y., Li, D. (2011). Improved thermal and photostability of an anthraquinone dye by intercalation in a zinc–aluminum layered double hydroxides host. Dyes and Pigments, 90 (3), 253–258. doi: 10.1016/j.dyepig.2011.01.007
18. Burmistr, M. V., Boiko, V. S., Lipko, E. O., Gerasimenko, K. O., Gomza, Y. P., Vesnin, R. L. et. al. (2014). Antifriction and Construction Materials Based on Modified Phenol-Formaldehyde Resins Reinforced with Mineral and Synthetic Fibrous Fillers. Mechanics

of Composite Materials, 50 (2), 213–222. doi: 10.1007/s11029-014-9408-0

19. Kovalenko, V., Kotok, V. (2017). Selective anodic treatment of W(WC)-based superalloy scrap. Eastern-European Journal of Enterprise Technologies, 1 (5 (85)), 53–58. doi: 10.15587/1729-4061.2017.91205
20. Shamim, M., Dana, K. (2017). Efficient removal of Evans blue dye by Zn–Al–NO_3 layered double hydroxide. International Journal of Environmental Science and Technology. doi: 10.1007/s13762-017-1478-9
21. Mahjoubi, F. Z., Khalidi, A., Abdennouri, M., Barka, N. (2017). Zn–Al layered double hydroxides intercalated with carbonate, nitrate, chloride and sulphate ions: Synthesis, characterisation and dye removal properties. Journal of Taibah University for Science, 11 (1), 90–100. doi: 10.1016/j.jtusci.2015.10.007
22. Chakraborty, C., Dana, K., Malik, S. (2011). Intercalation of Perylenediimide Dye into LDH Clays: Enhancement of Photostability. The Journal of Physical Chemistry C, 115 (5), 1996–2004. doi: 10.1021/jp110486r
23. Pahalagedara, M. N., Samaraweera, M., Dharmarathna, S., Kuo, C.-H., Pahalagedara, L. R., Gascón, J. A., Suib, S. L. (2014). Removal of Azo Dyes: Intercalation into Sonochemically Synthesized NiAl Layered Double Hydroxide. The Journal of Physical Chemistry C, 118 (31), 17801–17809. doi: 10.1021/jp505260a
24. Darmograi, G., Prelot, B., Layrac, G., Tichit, D., Martin-Gassin, G., Salles, F., Zajac, J. (2015). Study of Adsorption and Intercalation of Orange-Type Dyes into Mg–Al Layered Double Hydroxide. The Journal of Physical Chemistry C, 119 (41), 23388–23397. doi: 10.1021/acs.jpcc.5b05510
25. Marangoni, R., Bouhent, M., Taviot-Guého, C., Wypych, F., Leroux, F. (2009). Zn2Al layered double hydroxides intercalated and adsorbed with anionic blue dyes: A physico-chemical characterization. Journal of Colloid and Interface Science, 333 (1), 120–127. doi: 10.1016/j.jcis.2009.02.001
26. El Hassani, K., Beakou, B. H., Kalnina, D., Oukani, E., Anouar, A. (2017). Effect of morphological properties of layered double hydroxides on adsorption of azo dye Methyl Orange: A comparative study. Applied Clay Science, 140, 124–131. doi: 10.1016/j.clay.2017.02.010
27. Abdellaoui, K., Pavlovic, I., Bouhent, M., Benhamou, A., Barriga, C. (2017). A comparative study of the amaranth azo dye adsorption/desorption from aqueous solutions by layered double hydroxides. Applied Clay Science, 143, 142–150. doi: 10.1016/j.clay.2017.03.019
28. Santos, R. M. M. dos, Gonçalves, R. G. L., Constantino, V. R. L., Santilli, C. V., Borges, P. D., Tronto, J., Pinto, F. G. (2017). Adsorption of Acid Yellow 42 dye on calcined layered double hydroxide: Effect of time, concentration, pH and temperature. Applied Clay Science, 140, 132–139. doi: 10.1016/j.clay.2017.02.005
29. Bharali, D., Deka, R. C. (2017). Adsorptive removal of congo red from aqueous solution by sonochemically synthesized NiAl layered double hydroxide. Journal of Environmental Chemical Engineering, 5 (2), 2056–2067. doi: 10.1016/j.jece.2017.04.012
30. Ahmed, M. A., brick, A. A., Mohamed, A. A. (2017). An efficient adsorption of indigo carmine dye from aqueous solution on mesoporous Mg/Fe layered double hydroxide nanoparticles prepared by controlled sol-gel route. Chemosphere, 174, 280–288. doi: 10.1016/j.chemosphere.2017.01.147
31. Solovov, V., Kovalenko, V., Nikolenko, N., Kotok, V., Vlasova, E. (2017). Influence of temperature on the characteristics of Ni(II), Ti(IV) layered double hydroxides synthesised by different methods. Eastern-European Journal of Enterprise Technologies, 1 (6 (85)), 16–22. doi: 10.15587/1729-4061.2017.90873
32. Hu, M., Lei, L. (2006). Effects of particle size on the electrochemical performances of a layered double hydroxide, [Ni4Al(OH)10] NO_3. Journal of Solid State Electrochemistry, 11 (6), 847–852. doi: 10.1007/s10008-006-0231-y
33. Kovalenko, V., Kotok, V., Bolotin, O. (2016). Definition of factors influencing on Ni(OH)2 electrochemical characteristics for supercapacitors. Eastern-European Journal of Enterprise Technologies, 5 (6 (83)), 17–22. doi: 10.15587/1729-4061.2016.79406
34. Kovalenko, V. L., Kotok, V. A., Sykchin, A. A., Mudryi, I. A., Ananchenko, B. A., Burkov, A. A. et. al. (2016). Nickel hydroxide obtained by high-temperature two-step synthesis as an effective material for supercapacitor applications. Journal of Solid State Electrochemistry, 21 (3), 683–691. doi: 10.1007/s10008-016-3405-2
35. Xiao-yan, G., Jian-cheng, D. (2007). Preparation and electrochemical performance of nano-scale nickel hydroxide with different shapes. Materials Letters, 61 (3), 621–625. doi: 10.1016/j.matlet.2006.05.026
36. Kovalenko, V., Kotok, V. (2017). Study of the influence of the template concentration on the properties of nickel hydroxide, obtained by homogeneous precepitation, for supercapacitor application. Eastern-European Journal of Enterprise Technologies, 4 (6 (88)), 17–22. doi: 10.15587/1729-4061.2017.106813
37. Saikia, H., Ganguli, J. N. (2012). Intercalation of Azo Dyes in Ni-Al Layered Double Hydroxides. Asian Journal of Chemistry, 24 (12), 5909–5913.
38. Kotok, V., Kovalenko, V. (2017). Electrochromism of $Ni(OH)_2$ films obtained by cathode template method with addition of Al, Zn, Co ions. Eastern-European Journal of Enterprise Technologies, 3 (12 (87)), 38–43. doi: 10.15587/1729-4061.2017.103010
39. Kotok, V., Kovalenko, V. (2017). The properties investigation of the faradaic supercapacitor electrode formed on foamed nickel substrate with polyvinyl alcohol using. Eastern-European Journal of Enterprise Technologies, 4 (12 (88)), 31–37. doi: 10.15587/1729-4061.2017.108839
40. Kovalenko, V., Kotok, V. (2017). Obtaining of Ni–Al layered double hydroxide by slit diaphragm electrolyzer. Eastern-European Journal of Enterprise Technologies, 2 (6 (86)), 11–17. doi: 10.15587/1729-4061.2017.95699

DOI: 10.15587/1729-4061.2017.109738

RESEARCH INTO SPECIFICS OF RECYCLING THE SCALE OF NICKEL-MOLYBDENUM CONTAINING PRECISION ALLOYS BY THE METHOD OF HYDROGEN REDUCTION (p. 34-38)

Stanislav Hryhoriev
Zaporizhzhya National University, Zaporizhzhya, Ukraine
ORCID: http://orcid.org/0000-0002-1170-6856

Artem Petryshchev
Zaporizhzhya National Technical University, Zaporizhzhya, Ukraine
ORCID: http://orcid.org/0000-0003-2631-1723

Andriy Kovalyov
ORCID: http://orcid.org/0000-0002-3580-7889

Ganna Shyshkanova
Zaporizhzhya National Technical University, Zaporizhzhya, Ukraine
ORCID: http://orcid.org/0000-0002-0336-2803

Mykhail Yamshinskij
National Technical University of Ukraine
"Igor Sikorsky Kyiv Polytechnic Institute", Kyiv, Ukraine
ORCID: http://orcid.org/0000-0002-2293-2939

Grigoriy Fedorov
National Technical University of Ukraine
"Igor Sikorsky Kyiv Polytechnic Institute", Kyiv, Ukraine
ORCID: http://orcid.org/0000-0001-8254-9643

Yaroslav Chumachenko
Ivano-Frankivsk National Technical University of Oil and Gas, Ivano-Frankivsk, Ukraine
ORCID: http://orcid.org/0000-0002-0447-4874

Olena Mizerna
Zaporizhzhya National Technical University, Zaporizhzhya, Ukraine
ORCID: http://orcid.org/0000-0003-1867-4700

Yevgen Goliev
Zaporizhzhya state engineer academy, Zaporizhzhya, Ukraine
ORCID: http://orcid.org/0000-0002-4166-5338

Oksana Shcherbyna
Zaporizhzhya National Technical University, Zaporizhzhya, Ukraine
ORCID: http://orcid.org/0000-0002-0376-5258

We explored kinetic patterns of hydrogen reduction of the scale of a nickel-molybdenum containing precision alloy at a temperature of 673–1573 K over the interval from 0 to 360 min. The largest degree of reduction is achieved after thermal treatment at 1273 K – 99 %. This is due to the intensification of reduction processes and a sufficient level of porosity, which enables a satisfactory gas exchange. It was discovered that the starting scale consists mainly of Fe_2O_3 and Fe_3O_4 with the atoms substituting their alloying elements, as well as MoO_3. The target product of metallization had a sponge microstructure and consisted of γ-Fe, FeNi, the phase of Mo, and the remaining non-reduced Fe_3O_4 and FeO.

The resulting phases do not demonstrate a noticeable inclination to sublimation. This ensures a reduction in the losses of alloying elements when obtaining and using the highly-alloyed metallized scale, which was confirmed by the experimental- industrial tests. At the same time, disposal of industrial wastes provides a reduction in the technogenic load on industrial regions and improves ecological situation.

Keywords: scale, precision alloy, hydrogen reduction, phase analysis, microstructure, resource saving, alloying.

References

1. Yuzov, O. V., Sedyh, A. M. (2017). Tendencii razvitiya mirovogo rynka stali. Stal', 2, 60–67.
2. Ryabchikov, I. V., Belov, B. F., Mizin, V. G. (2014). Reactions of metal oxides with carbon. Steel in Translation, 44 (5), 368–373. doi: 10.3103/s0967091214050118
3. Mechachti, S, Benchiheub, O., Serrai, S., Shalabi, M. (2013). Preparation of iron Powders by Reduction of Rolling Mill Scale. International Journal of Scientific & Engineering Research, 4, 5, 1467–1472.
4. Zhu, H., Li, Z., Yang, H., Luo, L. (2013). Carbothermic Reduction of MoO3 for Direct Alloying Process. Journal of Iron and Steel Research, International, 20 (10), 51–56. doi: 10.1016/s1006-706x(13)60176-4
5. Molotilov, B. V., Galkin, M. P., Kornienkov, B. A. (2016). Design of new precision alloys. Steel in Translation, 46 (9), 675–678. doi: 10.3103/s0967091216090060
6. Saunin, V. N., Telegin, S. V. (2014). Issledovaniya ferromagnitnyh poroshkov i pokrytiy na ih osnove. Vestnik Sibirskogo gosudarstvennogo aerokosmicheskogo universiteta imeni akademika M. F. Reshetneva, 1, 72–75.
7. Dang, J., Zhang, G.-H., Chou, K.-C., Reddy, R. G., He, Y., Sun, Y. (2013). Kinetics and mechanism of hydrogen reduction of MoO3 to MoO_2. International Journal of Refractory Metals and Hard Materials, 41, 216–223. doi: 10.1016/j.ijrmhm.2013.04.002
8. Wang, L., Zhang, G.-H., Chou, K.-C. (2016). Synthesis of nanocrystalline molybdenum powder by hydrogen reduction of industrial grade MoO3. International Journal of Refractory Metals and Hard Materials, 59, 100–104. doi: 10.1016/j.ijrmhm.2016.06.001
9. Badenikov, A. V., Badenikov, V. Ya., Bal'chugov, A. V. (2015). Kinetika plazmennogo vosstanovleniya trekhokisi molibdena. Vestnik Angarskogo gosudarstvennogo tekhnicheskogo universiteta, 9, 8–10.
10. Manukyan, K. V., Avetisyan, A. G., Shuck, C. E., Chatilyan, H. A., Rouvimov, S., Kharatyan, S. L., Mukasyan, A. S. (2015). Nickel Oxide Reduction by Hydrogen: Kinetics and Structural Transformations. The Journal of Physical Chemistry C, 119 (28), 16131–16138. doi: 10.1021/acs.jpcc.5b04313
11. Vnukov, A. A., Golovachev, A. N., Belaya, A. V. (2016). Influence of rolling scale processing parameters on morphology of reduced iron powder particles. Technology audit and production reserves, 6 (1 (32)), 4–8. doi: 10.15587/2312-8372.2016.85866

DOI: 10.15587/1729-4061.2017.109710

RESEARCH INTO CORROSION AND ELECTROCATALYTIC PROPERTIES OF THE MODIFIED OXIDE FILMS ON TIN (p. 39-44)

Kateryna Plyasovskaya
Oles Honchar Dnipropetrovsk National University, Dnipro, Ukraine
ORCID: http://orcid.org/0000-0001-9100-8064

Victor Vargalyuk
Oles Honchar Dnipropetrovsk National University, Dnipro, Ukraine
ORCID: http://orcid.org/0000-0001-8160-3222

Irina Sknar
Ukrainian State University of Chemical Technology, Dnipro, Ukraine
ORCID: http://orcid.org/0000-0001-8433-1285

Anna Cheremysinova
Ukrainian State University of Chemical Technology, Dnipro, Ukraine
ORCID: http://orcid.org/0000-0002-7877-1257

Oleksii Sigunov
Ukrainian State University of Chemical Technology, Dnipro, Ukraine
ORCID: http://orcid.org/0000-0001-7413-355X

Ann Karakurkchi
National Technical University "Kharkiv Polytechnic Institute", Kharkiv, Ukraine
ORCID: http://orcid.org/0000-0002-1287-3859

Oxide films on tin, modified by titanium compounds, are non-toxic and serve as anticorrosion protection, material for gas sensors, photo- and electrocatalysts. We investigated the process of anodic tin treatment in the presence of potassium metatitanate. It is shown that the two-stage technique for the formation of an oxide film at the electrode potentials of –0.3 V and 3.0 V makes it possible to substantially increase the content of titanium oxide compounds in the oxide mixture. The content of Ti(IV) reaches values of 14–15 % (mol). Films with a maximum content of titanium compounds and the largest corrosion resistance are formed at a concentration of potassium metatitanate above $1\cdot10^{-3}$ mol/l. The time of self-activation of such films is 10 times longer than that of the unmodified films.

We explored catalytic properties of the obtained films with mixed composition $SnO_x(TiO_y)$. It is shown that an increase in the content of titanium oxide compounds in the film contributes to the acceleration of anodic oxidation of MTBE. It was established that

this process takes place directly on the surface of the oxide film rather than during interaction with oxygen formed on the anode. The modified oxide films $SnO_x(TiO_y)$ on tin with maximal corrosion resistance and electrocatalytic activity are formed from the solutions that contain 0.5M KOH.

Keywords: modified oxide films, titanium oxide compounds, tin, corrosion resistance, electrocatalyctic activity.

References

1. El-Sherif, R. M., Badawy, W. A. (2011). Mechanism of Corrosion and Corrosion Inhibition of Tin in Aqueous Solutions Containing Tartaric Acid. Int. J. Electrochem. Sci., 6, 6469–6482.
2. Zhong, X., Zhang, G., Qiu, Y., Chen, Z., Guo, X., Fu, C. (2013). The corrosion of tin under thin electrolyte layers containing chloride. Corrosion Science, 66, 14–25. doi: 10.1016/j.corsci.2012.08.040
3. Gervasi, C. A., Palacios, P. A., Fiori Bimbi, M. V., Alvarez, P. E. (2010). Electrochemical studies on the anodic behavior of tin in citrate buffer solutions. Journal of Electroanalytical Chemistry, 639 (1-2), 141–146. doi: 10.1016/j.jelechem.2009.12.002
4. Gervasi, C. A., Palacios, P. A., Alvarez, P. E., Fiori-Bimbi, M. V., Brandan, S. A. (2013). Electronic Structure of Tin Passive Films and Its Influence on the Corrosion of the Base Metal. Industrial & Engineering Chemistry Research, 52 (26), 9115–9120. doi: 10.1021/ie4008216
5. Gervasi, C. A., Alvarez, P. E., Fiori Bimbi, M. V., Folquer, M. E. (2007). Comparative cyclic voltammetry and SEM analysis of tin electrodes in citrate buffer solutions. Journal of Electroanalytical Chemistry, 601 (1-2), 194–204. doi: 10.1016/j.jelechem.2006.11.019
6. Gervasi, C. A., Fiori Bimbi, M. V., Alvarez, P. E. (2009). Characterization of anodic tin passive films formed in citrate buffer solutions. Journal of Electroanalytical Chemistry, 625 (1), 60–68. doi: 10.1016/j.jelechem.2008.10.013
7. Tselesh, A. S. (2008). Anodic behaviour of tin in citrate solutions: The IR and XPS study on the composition of the passive layer. Thin Solid Films, 516 (18), 6253–6260. doi: 10.1016/j.tsf.2007.11.118
8. Palacios-Padrós, A., Caballero-Briones, F., Díez-Pérez, I., Sanz, F. (2013). Tin passivation in alkaline media: Formation of SnO microcrystals as hydroxyl etching product. Electrochimica Acta, 111, 837–845. doi: 10.1016/j.electacta.2013.07.200
9. Kwaśniewski, D., Grdeń, M. (2015). Electrochemical behaviour of tin in alkaline electrolyte. Electrochemistry Communications, 61, 125–128. doi: 10.1016/j.elecom.2015.10.019
10. Wang, M., Liu, Y., Xue, D., Zhang, D., Yang, H. (2011). Preparation of nanoporous tin oxide by electrochemical anodization in alkaline electrolytes. Electrochimica Acta, 56 (24), 8797–8801. doi: 10.1016/j.electacta.2011.07.085
11. Lu, C., Wang, J., Meng, D., Wang, A., Wang, Y., Zhu, Z. (2016). Tunable synthesis of nanoporous tin oxide structures on metallic tin by one-step electrochemical anodization. Journal of Alloys and Compounds, 685, 670–679. doi: 10.1016/j.jallcom.2016.05.316
12. Kaizra, S., Louafi, Y., Bellal, B., Trari, M., Rekhila, G. (2015). Electrochemical growth of tin(II) oxide films: Application in photocatalytic degradation of methylene blue. Materials Science in Semiconductor Processing, 30, 554–560. doi: 10.1016/j.mssp.2014.10.045
13. Vargalyuk, V. F., Plyasovskaya, E. A., Nester, E. I. (2016). Electrodeposition of tin in presence of K_2TiO_3. Visn. Dnipropetr. un-tu. Ser.: Khim., 24 (1), 7–12.
14. Sknar, Y. E., Amirulloeva, N. V., Sknar, I. V., Danylov, F. I. (2016). Electrodeposition of Ni–ZrO2 Nanocomposites from Methanesulfonate Electrolytes. Materials Science, 51 (6), 877–884. doi: 10.1007/s11003-016-9916-2
15. Danilov, F. I., Sknar, Y. E., Tkach, I. G., Sknar, I. V. (2015). Electrodeposition of nickel-based nanocomposite coatings from cerium(III)-ion-containing methanesulfonate electrolytes. Russian Journal of Electrochemistry, 51 (4), 294–298. doi: 10.1134/s1023193515040023
16. Danilov, F. I., Sknar, Y. E., Amirulloeva, N. V., Sknar, I. V. (2016). Kinetics of electrodeposition of Ni–ZrO_2 nanocomposite coatings from methanesulfonate electrolytes. Russian Journal of Electrochemistry, 52 (5), 494–499. doi: 10.1134/s1023193516050037
17. Yu, Y., Wang, T., Fu, Y., Su, W., Hu, J. (2014). Platinum nanoparticles ion-implanted-modified indium tin oxide electrode for electrocatalytic oxidation of formaldehyde. International Journal of Hydrogen Energy, 39 (31), 17617–17621. doi: 10.1016/j.ijhydene.2014.08.149
18. Geiger, S., Kasian, O., Mingers, A. M., Mayrhofer, K. J. J., Cherevko, S. (2017). Stability limits of tin-based electrocatalyst supports. Scientific Reports, 7 (1). doi: 10.1038/s41598-017-04079-9
19. Vargalyuk, V. F., Plyasovska, K. A. (2009). Electrochemical formation of SnxTi(1-x)O_2 oxide film on tin. Visn. Dnipropetr. un-tu. Ser.: Khim., 17 (15), 42–45.
20. Vargalyuk, V. F., Plyasovskaya, E. A., Zamyatina, A. S. (2015). Peculiarities of the electrooxidation of tin in alkaline medium. Ukrainian Chemistry Journal, 81 (1/2), 40–43.

DOI: 10.15587/1729-4061.2017.111977

A STUDY OF THE INFLUENCE OF ADDITIVES ON THE PROCESS OF FORMATION AND CORROSIVE PROPERTIES OF TRIPOLYPHOSPHATE COATINGS ON STEEL (p. 45-51)

Olena Vlasova
SHEI «National Metallurgical Academy of Ukraine», Dnipro, Ukraine
ORCID: http:// orcid.org//0000-0002-6814-409X

Vadym Kovalenko
Ukrainian State University of Chemical Technology, Dnipro, Ukraine
Vyatka State University, Kirov, Russian Federation
ORCID: http://orcid.org/0000-0002-8012-6732

Valerii Kotok
Ukrainian State University of Chemical Technology, Dnipro, Ukraine
Vyatka State University, Kirov, Russian Federation
ORCID: http://orcid.org/0000-0001-8879-7189

Sergey Vlasov
SHEI «National Mining University», Dnipro, Ukraine
Vyatka State University, Kirov, Russian Federation
ORCID: http:// orcid.org/0000-0002-5537-6342

Kostiantyn Sukhyy
Ukrainian State University of Chemical Technology, Dnipro, Ukraine
ORCID: http://orcid.org/0000-0002-4585-8268

The anodic behavior of cold-rolled low-carbon steel in the aqueous STPP solution with aluminum hydroxide, borax, and glycerin additives at room temperature has been studied.

It was revealed that the potentiodynamic curves that characterize the anodic behavior of steel st05kp samples shows up to three passivation plateaus. Additionally, the anodic curve ends with the complete passivation plateau with an anodic current density equal to zero. The obtained results demonstrate realization of the step-wise formation mechanism of tripolyphosphate coat in the 12 % aqueous STPP solution with additives.

It was found that with the addition of 2 % $Al(OH)_3$, a narrowing of the first passivation plateaus is observed. The addition of glycerin shifts the potential of passivation plateau formation toward negative

values by about 150 mV. When borax was added, only the complete passivation plateau is present on the anodic curve.

It was established that in the STPP solution with the addition of aluminum hydroxide, glycerin, and especially borax, steel passivation occurs earlier than in the solution without additives. This indicated the acceleration of tripolyphosphate coat formation when additives are used. The absence of the first two passivation plateaus on the anodic curve that describes the coat formation in the STPP solution with the borax additive indicated that formation occurs at the highest rate.

In the process of studying the anodic behavior of steel st05kp with the formed coats, in 0.1 N Na_2SO_4, it was found that the coats formed in the aqueous sodium tripolyphosphate solution with additives possess protective properties. The greatest positive effect on protective properties of the coats is provided by aluminum hydroxide.

Based on the results of combined studies, it was established that aluminum hydroxide can be recommended as the most effective additive for improving protective properties of tripolyphosphate coats. Borax can be recommended as an additive that accelerates coat formation.

Keywords: steel, corrosion, tripolyphosphate coat, additives, anodic behavior, potentiodynamic curves, passivation, acceleration, composite structure, protective properties.

References

1. Tamilselvi, M., Kamaraj, P., Arthanareeswari, M., Devikala, S., Selvi, J. A. (2015). Progress in Zinc Phosphate Conversion Coatings: A Review. International Journal of Advanced Chemical Science and Applications (IJACSA), 3 (1), 25–41.
2. Zeng, R. C., Lan, Z. D., Chen, J., Mo, X. H., Han, E. H. (2009). Progress of Chemical Conversion Coatings on Magnesium Alloys. Transactions of Nonferrous Metal Society of China, 19, 397–404.
3. Lin, B., Lu, J., Kong, G., Liu, J. (2007). Growth and corrosion resistance of molybdate modified zinc phosphate conversion coatings on hot-dip galvanized steel. Transactions of Nonferrous Metals Society of China, 17 (4), 755–761. doi: 10.1016/s1003-6326(07)60169-1
4. Weng, D., Jokiel, P., Uebleis, A., Boehni, H. (1997). Corrosion and protection characteristics of zinc and manganese phosphate coatings. Surface and Coatings Technology, 88 (1-3), 147–156. doi: 10.1016/s0257-8972(96)02860-5
5. Sankara Narayanan, T. S. N. (2005). Surfuce pretreament by phosphate conversion coatings. Rev. Adv. Mater. Sci., 9, 130–177.
6. Amini, R., Sarabi, A. A. (2011). The corrosion properties of phosphate coating on AZ31 magnesium alloy: The effect of sodium dodecyl sulfate (SDS) as an eco-friendly accelerating agent. Applied Surface Science, 257 (16), 7134–7139. doi: 10.1016/j.apsusc.2011.03.072
7. Banczek, E. P., Rodrigues, P. R. P., Costa, I. (2006). Investigation on the effect of benzotriazole on the phosphating of carbon steel. Surface and Coatings Technology, 201 (6), 3701–3708. doi: 10.1016/j.surfcoat.2006.09.003
8. Gomelya, N. D., Radovenchik, V. M., Shut'ko, G. L. (1996). Issledovanie processov korrozii stali v vode. Ekotekhnologii i resusosberezhenie, 1, 36–40.
9. Kuznecov, Yu. I. (2001). Ingibitory korrozii v konversionnyh pokrytiyah III. Zashchita metallov ot korrozii, 37 (2), 119–125.
10. Lipkin, Ya. N., V. M. Shtan'ko (1974). Himicheskaya i elektrohimicheskaya obrabotka stal'nyh trub. Moscow: Metallurgiya, 216.
11. Burokas, V., Martušienė, A., Bikulčius, G. (1998). The influence of hexametaphosphate on formation of zinc phosphate coatings for deep drawing of steel tubes. Surface and Coatings Technology, 102 (3), 233–236. doi: 10.1016/s0257-8972(98)00359-4
12. Lee, S.-J., Toan, D. L. H., Chen, Y.-H., Peng, H.-C. (2016). Performance Improvement of Phosphate Coating on Carbon Steel by Cathodic Electrochemical Method. International Journal of Electrochemical Science, 11, 2306–2316.
13. Tumbaleva, Y., Ivanova, D., Fachikov, L. (2011). Effect of the P2O5:NO_3 – retio on the zink phosphate coating formation. Journal of the University of Chemical Technology and Metallurgy, 46 (4), 357–362.
14. Fahim, I., Kheireddine, A., Belaaouad, S. (2013). Sodium tripolyphosphate (STPP) as a novel corrosion inhibitor for mild steel in 1M HCL. Journal of optoelectronics and advanced materials, 15 (5-6), 451–456.
15. Vlasova, E., Kovalenko, V., Kotok, V., Vlasov, S. (2016). Research of the mechanism of formation and properties of tripolyphosphate coating on the steel basis. Eastern-European Journal of Enterprise Technologies, 5 (5 (83)), 33–39. doi: 10.15587/1729-4061.2016.79559
16. Vlasova, E. V., Karasik, T. L. (2010). Issledovanie pokrytiy, poluchennyh iz vodnyh rastvorov fosfatov. Metallurgicheskaya i gornorudnaya promyshlennost', 5, 89–91.
17. Vlasova, E. V. (2015). Osobennosti struktury mezhoperacionnyh tripolifosfatnyh pokrytiy metalloprokata. Metallurgicheskaya i gornorudnaya promyshlennost', 3, 59–62.
18. Vlasova, E., Kovalenko, V., Kotok, V., Vlasov, S., Sknar, I., Cheremysinova, A. (2017). Investigation of composition and structure of tripoliphosphate coating on low carbon steel. Eastern-European Journal of Enterprise Technologies, 2 (6 (86)), 4–10. doi: 10.15587/1729-4061.2017.96572
19. Grigoryan, N. S., Akimova, E. F., Vagramyan, T. A. (2008). Fosfatirovanie. Moscow: Globus, 144.
20. Hain, I. I. (1973). Teoriya i praktika fosfatirovaniya metallov. Leningrad: Himiya, 312.
21. Kouisni, L., Azzi, M., Dalard, F., Maximovitch, S. (2005). Phosphate coatings on magnesium alloy AM60Part 2: Electrochemical behaviour in borate buffer solution. Surface and Coatings Technology, 192 (2-3), 239–246. doi: 10.1016/s0257-8972(04)00432-3
22. Li, Q., Xu, S., Hu, J., Zhang, S., Zhong, X., Yang, X. (2010). The effects to the structure and electrochemical behavior of zinc phosphate conversion coatings with ethanolamine on magnesium alloy AZ91D. Electrochimica Acta, 55 (3), 887–894. doi: 10.1016/j.electacta.2009.06.048
23. Thomas, R., Umapathy, M. J. (2017). Environment Friendly Nano Silicon Dioxide Accelerated Zinc Phosphate Coating on Mild Steel Using a Series of Surfactants as Additives. Silicon, 9 (5), 675–688. doi: 10.1007/s12633-016-9460-6
24. Sheng, M., Wang, Y., Zhong, Q., Wu, H., Zhou, Q., Lin, H. (2011). The effects of nano-SiO_2 additive on the zinc phosphating of carbon steel. Surface and Coatings Technology, 205 (11), 3455–3460. doi: 10.1016/j.surfcoat.2010.12.011
25. Jiang, C., Cao, Y., Xiao, G., Zhu, R., Lu, Y. (2017). A review on the application of inorganic nanoparticles in chemical surface coatings on metallic substrates. RSC Adv., 7 (13), 7531–7539. doi: 10.1039/c6ra25841g
26. Kotok, V., Kovalenko, V. (2017). The electrochemical cathodic template synthesis of nickel hydroxide thin films for electrochromic devices: role of temperature. Eastern-European Journal of Enterprise Technologies, 2 (11 (86)), 28–34. doi: 10.15587/1729-4061.2017.97371
27. Kotok, V. A., Kovalenko, V. L., Kovalenko, P. V., Solovov, V. A., Deabate, S., Mehdi, A., Bantignies, J. L., Henn, F. (2017). Advanced electrochromic Ni(OH)2/PVA films formed by electrochemical template synthesis. ARPN Journal of Engineering and Applied Sciences, 12 (13), 3962–3977.

28. Kotok, V., Kovalenko, V. (2017). The properties investigation of the faradaic supercapacitor electrode formed on foamed nickel substrate with polyvinyl alcohol using. Eastern-European Journal of Enterprise Technologies, 4 (12 (88)), 31–37. doi: 10.15587/1729-4061.2017.108839
29. Kotok, V., Kovalenko, V. (2017). Electrochromism of Ni(OH)2 films obtained by cathode template method with addition of Al, Zn, Co ions. Eastern-European Journal of Enterprise Technologies, 3 (12 (87)), 38–43. doi: 10.15587/1729-4061.2017.103010
30. Vlasova, E. V., Levko, E. N., Kovalenko, V. L., Kotok, V. A. (2015). Vliyanie dobavok na svoystva mezhoperacionnyh tripolifosfatnyh pokrytiy. Zbirnyk naukovykh prats Natsionalnoho hirnychoho universytetu, 49, 200–207.

DOI: 10.15587/1729-4061.2017.112065

THE INFLUENCE OF THE CONDITIONS OF MICROPLASMA PROCESSING (MICROARC OXIDATION IN ANODE-CATHODE REGIME) OF ALUMINUM ALLOYS ON THEIR PHASE COMPOSITION (p. 52-57)

Valery Belozerov
National Technical University
“Kharkiv Polytechnic Institute”, Kharkiv, Ukraine
ORCID: http://orcid.org/0000-0002-7623-3658

Oleg Sobol
National Technical University
“Kharkiv Polytechnic Institute”, Kharkiv, Ukraine
ORCID: http://orcid.org/0000-0002-4497-4419

Anna Mahatilova
National Technical University
“Kharkiv Polytechnic Institute”, Kharkiv, Ukraine
ORCID: http://orcid.org/0000-0001-7146-7087

Valeria Subbotina
National Technical University
“Kharkiv Polytechnic Institute”, Kharkiv, Ukraine
ORCID: http://orcid.org/0000-0002-3882-0368

Taha A. Tabaza
Al-Zaytoonah University, Amman, Jordan

Ubeidulla F. Al-Qawabeha
Tafila Technical University, Tafila, Jordan

Safwan M. Al-Qawabah
Al-Zaytoonah University, Amman, Jordan

Investigations have been performed on the effect of microplasma oxidation regimes in electrolytes with activating additives on the phase-structural state of coatings formed on the basis of aluminum. In microarc oxidation (MAO), the surface layer of the processed aluminum-based alloy was converted to a coating consisting of aluminum oxides with increased hardness. Such a modification of the surface layers makes it possible to use the properties of base materials and modified layers most rationally, sparing expensive and rare metals and alloys.

The study has revealed the formation of intermediate phases (multistage) during the formation of coatings on aluminum alloys in the alkali-silicate electrolyte and the anode-cathode mode of microplasma oxidation. The main intermediate phases are γ-Al_2O_3 and $3Al_2O_3 \cdot 2SiO_2$.

The composition of the electrolyte has a significant effect on the initial stages of the process during which strong passivating layers are formed on the metallic surface. These layers determine the possibility of spark explosions of sufficient intensity and, thus, the implementation of the MAO process. The obtained results indicate that during the oxidation process, the γ-Al_2O_3 phase is alloyed with the base components and the electrolyte components to form solid substitutional solutions. The change in the lattice period in this case will be determined, on the one hand, by the difference in the ionic radii of atoms in the lattice and, on the other hand, by the difference in valence.

The paper discloses the influence of the crystal-chemical characteristics of the cations of the processed alloy and the cations that make up the electrolyte on the γ-Al_2O_3→α-Al_2O_3. The absence of the hardest phase of α-Al_2O_3 (corundum) in the coating is explained by the low power of microdischarges, at which the temperature of the polymorphic γ→α transformation is not ensured. Pilot-industrial tests were performed on friction pair parts, and recommendations have been given on the change in the composition of the electrolyte and the parameters of electrolysis that ensure an increase in the content of the α-Al_2O_3 phase in the coating composition.

Keywords: structural engineering, microplasma treatment, anode-cathode regime, phase composition.

References

1. Belozerov, V., Mahatilova, A., Sobol’, O., Subbotina, V., Subbotin, A. (2017). Investigation of the influence of technological conditions of microarc oxidation of magnesium alloys on their structural state and mechanical properties. Eastern-European Journal of Enterprise Technologies, 2 (5 (86)), 39–43. doi: 10.15587/1729-4061.2017.96721
2. Barmin, A. E., Zubkov, A. I., Il’inskii, A. I. (2012). Structural features of the vacuum condensates of iron alloyed with tungsten. Functional Materials, 19 (2), 256–259.
3. Shim, D.-S., Baek, G.-Y., Lee, S.-B., Yu, J.-H., Choi, Y.-S., Park, S.-H. (2017). Influence of heat treatment on wear behavior and impact toughness of AISI M4 coated by laser melting deposition. Surface and Coatings Technology, 328, 219–230. doi: 10.1016/j.surfcoat.2017.08.059
4. Sapegina, I. V., Dorofeev, G. A., Mokrushina, M. I., Pushkarev, B. E., Lad’yanov, V. I. (2017). High-nitrogen 23Cr9Mn1N steel manufactured by aluminothermy under nitrogen pressure: structure and mechanical properties. Letters on Materials, 7 (2), 137–140. doi: 10.22226/2410-3535-2017-2-137-140
5. Barmin, A. E., Sobol’, O. V., Zubkov, A. I., Mal’tseva, L. A. (2015). Modifying effect of tungsten on vacuum condensates of iron. The Physics of Metals and Metallography, 116 (7), 706–710. doi: 10.1134/s0031918x15070017
6. Ivashchenko, V. I., Dub, S. N., Scrynskii, P. L., Pogrebnjak, A. D., Sobol’, O. V., Tolmacheva, G. N. et. al. (2016). Nb–Al–N thin films: Structural transition from nanocrystalline solid solution nc-(Nb,Al)N into nanocomposite nc-(Nb, Al)N/a–AlN. Journal of Superhard Materials, 38 (2), 103–113. doi: 10.3103/s1063457616020040
7. Grigoriev, S. N., Sobol, O. V., Beresnev, V. M., Serdyuk, I. V., Pogrebnyak, A. D., Kolesnikov, D. A., Nemchenko, U. S. (2014). Tribological characteristics of (TiZrHfVNbTa)N coatings applied using the vacuum arc deposition method. Journal of Friction and Wear, 35 (5), 359–364. doi: 10.3103/s1068366614050067
8. Bourebia, M., Laouar, L., Hamadache, H., Dominiak, S. (2016). Improvement of surface finish by ball burnishing: approach by fractal dimension. Surface Engineering, 33 (4), 255–262. doi: 10.1080/02670844.2016.1232778
9. Sobol’, O. V. (2016). The influence of nonstoichiometry on elastic characteristics of metastable β-WC1–x phase in ion plasma condensates. Technical Physics Letters, 42 (9), 909–911. doi: 10.1134/s1063785016090108
10. Sobol’, O. V. (2011). Control of the structure and stress state of thin films and coatings in the process of their preparation by ion-

plasma methods. Physics of the Solid State, 53 (7), 1464–1473. doi: 10.1134/s1063783411070274
11. Sobol', O. V., Andreev, A. A., Grigoriev, S. N., Volosova, M. A., Gorban', V. F. (2012). Vacuum-arc multilayer nanostructured TiN/Ti coatings: structure, stress state, properties. Metal Science and Heat Treatment, 54 (1-2), 28–33. doi: 10.1007/s11041-012-9451-1
12. Sobol', O. V. (2016). Structural Engineering Vacuum-plasma Coatings Interstitial Phases. Journal of Nano- and Electronic Physics, 8 (2), 02024–1–02024–7. doi: 10.21272/jnep.8(2).02024
13. Pogrebnjak, A. D., Bondar, O. V., Abadias, G., Ivashchenko, V., Sobol, O. V., Jurga, S., Coy, E. (2016). Structural and mechanical properties of NbN and Nb-Si-N films: Experiment and molecular dynamics simulations. Ceramics International, 42 (10), 11743–11756. doi: 10.1016/j.ceramint.2016.04.095
14. Chen, C.-M., Chu, H.-J., He, J.-L. (2017). Anodic dyeing of micro-arc oxidized aluminum with a cathodic pretreatment. Surface and Coatings Technology, 324, 92–98. doi: 10.1016/j.surfcoat.2017.05.062
15. Krivonosova, E. A., Ponomarev, I. S. (2016). Features of Aluminum Alloy Microplasma Oxidation During Operation in a Polar Pulsating Current Regime. Metallurgist, 60 (5-6), 641–645. doi: 10.1007/s11015-016-0344-1
16. Banakh, O., Journot, T., Gay, P.-A., Matthey, J., Csefalvay, C., Kalinichenko, O. et. al. (2016). Synthesis by anodic-spark deposition of Ca- and P-containing films on pure titanium and their biological response. Applied Surface Science, 378, 207–215. doi: 10.1016/j.apsusc.2016.03.161
17. Yerokhin, A. L., Nie, X., Leyland, A., Matthews, A., Dowey, S. J. (1999). Plasma electrolysis for surface engineering. Surface and Coatings Technology, 122 (2-3), 73–93. doi: 10.1016/s0257-8972(99)00441-7
18. Asadi, S., Kazeminezhad, M. (2016). Multi Directional Forging of 2024 Al Alloy After Different Heat Treatments: Microstructural and Mechanical Behavior. Transactions of the Indian Institute of Metals, 70 (7), 1707–1719. doi: 10.1007/s12666-016-0967-8
19. Martin, J., Melhem, A., Shchedrina, I., Duchanoy, T., Nominé, A., Henrion, G. et. al. (2013). Effects of electrical parameters on plasma electrolytic oxidation of aluminium. Surface and Coatings Technology, 221, 70–76. doi: 10.1016/j.surfcoat.2013.01.029
20. Lv, G., Gu, W., Chen, H., Feng, W., Khosa, M. L., Li, L. et. al. (2006). Characteristic of ceramic coatings on aluminum by plasma electrolytic oxidation in silicate and phosphate electrolyte. Applied Surface Science, 253 (5), 2947–2952. doi: 10.1016/j.apsusc.2006.06.036
21. Veys-Renaux, D., Chahboun, N., Rocca, E. (2016). Anodizing of multiphase aluminium alloys in sulfuric acid: in-situ electrochemical behaviour and oxide properties. Electrochimica Acta, 211, 1056–1065. doi: 10.1016/j.electacta.2016.06.131
22. Wang, P., Wu, T., Xiao, Y. T., Zhang, L., Pu, J., Cao, W. J., Zhong, X. M. (2017). Characterization of micro-arc oxidation coatings on aluminum drillpipes at different current density. Vacuum, 142, 21–28. doi: 10.1016/j.vacuum.2017.04.038
23. Shen, Y., Sahoo, P. K., Pan, Y. (2017). A Study of Micro-Arc Oxidation Coatings on Aluminum Alloy Drill Pipe for Offshore Platform. Marine Technology Society Journal, 51 (3), 16–22. doi: 10.1115/omae2016-54685
24. Tran, Q.-P., Kuo, Y.-C., Sun, J.-K., He, J.-L., Chin, T.-S. (2016). High quality oxide-layers on Al-alloy by micro-arc oxidation using hybrid voltages. Surface and Coatings Technology, 303, 61–67. doi: 10.1016/j.surfcoat.2016.03.049
25. Ayday, A. (2017). Effect of Two-Step Oxidation on Performance of Micro-Arc Oxidation on 6063 Aluminum Alloy. Acta Physica Polonica A, 131 (1), 96–98. doi: 10.12693/aphyspola.131.96
26. Tran, Q.-P., Sun, J.-K., Kuo, Y.-C., Tseng, C.-Y., He, J.-L., Chin, T.-S. (2017). Anomalous layer-thickening during micro-arc oxidation of 6061 Al alloy. Journal of Alloys and Compounds, 697, 326–332. doi: 10.1016/j.jallcom.2016.11.372
27. Pawlik, A., Hnida, K., Socha, R. P., Wiercigroch, E., Małek, K., Sulka, G. D. (2017). Effects of anodizing conditions and annealing temperature on the morphology and crystalline structure of anodic oxide layers grown on iron. Applied Surface Science, 426, 1084–1093. doi: 10.1016/j.apsusc.2017.07.156
28. Lv, P. X., Chi, G. X., Wei, D. B., Di, S. C. (2011). Design of Scanning Micro-Arc Oxidation Forming Ceramic Coatings on 2024 Aluminium Alloy. Advanced Materials Research, 189-193, 1296–1300. doi: 10.4028/www.scientific.net/amr.189-193.1296
29. Choi, J. W., Heo, S. J., Koak, J. Y., Kim, S. K., Lim, Y. J., Kim, S. H., Lee, J. B. (2006). Biological responses of anodized titanium implants under different current voltages. Journal of Oral Rehabilitation, 33 (12), 889–897. doi: 10.1111/j.1365-2842.2006.01669.x
30. Klopotov, A. A., Abzaev, Yu. A., Potekaev, A. I., Volokitin, O. G. (2012). Osnovy rentgenostrukturnogo analiza v materialovedenii. Tomsk: Izd-vo Tom. gos. arhit.-stroit. Un-ta, 276.
31. Sabaghi Joni, M., Fattah-alhosseini, A. (2016). Effect of KOH concentration on the electrochemical behavior of coatings formed by pulsed DC micro-arc oxidation (MAO) on AZ31B Mg alloy. Journal of Alloys and Compounds, 661, 237–244. doi: 10.1016/j.jallcom.2015.11.169

DOI: 10.15587/1729-4061.2017.111996

DESIGN OF THE THERMAL INSULATION POROUS MATERIALS BASED ON TECHNOGENIC MINERAL FILLERS (p. 58-64)

Anatoliy Pavlenko
Kielce University of Technology, Kielce, Poland
ORCID: http://orcid.org/0000-0002-8103-2578

Hanna Koshlak
Ivano Frankivsk National Technical University of Oil and Gas, Ivano-Frankivsk, Ukraine
ORCID: http://orcid.org/0000-0001-8940-5925

We report results of research into processes of formation of porous structure by the method of thermal bloating of the gel-like mixture of raw materials. Regularities of the course of physical-chemical transformations are considered in the material when it is heated; as a result, we established the initial water content in the raw mixture, optimal for the formation of xerogel, and the residual water content in gel, sufficient for effective bloating. We proposed the optimized composition of the raw mixture that employs maximally permissible amount of ash as a mineral filler; the thermal modes of bloating are studied. Based on the data obtained, a new technology for the production of porous thermal insulation materials is created. New porous thermal insulation materials were obtained using soluble glass as a binding component; foaming agent; regulator of hardening rate of the mixture. The basic thermophysical properties were determined.

A study of physicochemical phenomena occurring during thermal bloating of analogous compositions allowed us to predict the course of the processes in the case of using additional chemical elements and techniques. It was established that ash can be effectively utilized when creating an efficient raw material mixture. The results obtained could be useful for the production of effective porous thermal insulation materials for various purposes. In addition, the task is resolved on the disposal of ash from coal-based thermal power plants.

Keywords: fly ash, soluble glass, alkaline silicate composite thermal insulation materials, thermal bloating.

References

1. Pavlenko, A., Koshlak, H., Usenko, B. (2014). Peculiarities of controlled forming of porous structure. Metallurgical and Mining Industry, 6, 50–55.
2. Malyavsky, N. I. (2003). Shchelochno-silikatnyie utepliteli. Svoistva i khimicheskiye osnovy proizvodstva [Alkaline silicate heat insulants. Properties and chemical bases of production]. Rossiyskiy khimicheskiy zhurnal, XLVII (4), 39–45.
3. Leonovich, S. N., Shulkin, G. L., Belanovich, A. L. (2012). Osobennosti polucheniya shchelochno-silikatnyh teploizolyacionnyh materialov. Nauka i tekhnika, 6, 45–50.
4. Figovskiy, O. L., Kudryavcev, P. G. (2014). Zhidkoe steklo i vodnye rastvory silikatov kak perspektivnaya osnova tekhnologicheskih processov polucheniya novyh nanokompozitnyh materialov. Elektronnyy nauchnyy zhurnal: Inzhenerniy vestnik Dona, 29 (2), 55–97.
5. Fei, S., Wang, L., Liu, J., Zeng, M. (2007). Effect of heat treatment on silica aerogels prepared via ambient drying. Journal of Materials Science and Technology, 23 (3), 402–406.
6. Knunyanc, I. L. (Ed.) (1990). Himicheskaya enciklopediya. Vol. 2. Moscow: Soveckaya enciklopediya, 671.
7. Pavlenko, A., Koshlak, H. (2015). Design of processes of thermal bloating of silicates. Metallurgical and Mining Industry, 1, 118–122.
8. Pavlenko, A., Koshlak, H. (2015). Production of porous material with projected thermophysical characteristics. Metallurgical and Mining Industry, 1, 123–127.
9. Okuyama, K., Kim, J.-H., Mori, S., Iida, Y. (2006). Boiling propagation of water on a smooth film heater surface. International Journal of Heat and Mass Transfer, 49 (13-14), 2207–2214. doi: 10.1016/j.ijheatmasstransfer.2006.01.001
10. Pariy, V. I., Nikonova, N. S., Bazhanov, E. A. (2000). Pat. No. 2161142 RF. Sposob polucheniya teploizolyacionno-konstrukcionnogo materiala na osnove vspuchennogo vermikulita. C04B28/24, C04B111:20. No. 2000114219/03; declareted: 06.06.2000; published: 27.12.2000.
11. Artemenko, N. F., Golubev, V. I., Bondar', S. D., Valeev, R. F., Malofeev, S. V., Shevelev, V. N., Mubarakshin, M. M., Mardamshin, G. K. (1995). Pat. No. 2097362 RF. Syr'evaya smes' dlya polucheniya penosilikatnogo teploizolyacionnogo materiala. MKI S04V 38/00. No. 95108038/03; declareted: 17.05.1995; published: 27.11.1997.
12. Radina, T. N., Bormotina, E. A. (2000). Pat. No. 2177921 RF. Sposob polucheniya granulirovannogo teploizolyacionnogo materiala. MPK S04V28/26. No. 2000108899/03; declareted: 10.04.2000; published: 10.01.2002, Bul. No. 29, 6.
13. Radina, T. N., Ivanov, M. Yu. (2004). Pat. No. 2220928 RF. Syr'evaya smes' i sposob polucheniya granulirovannogo teploizolyacionnogo materiala. MPK S 04 V 28 / 26. No. 2004128504/03; declareted: 27.09.2004; published: 20.04.2006, Bul. No. 11, 5.
14. Kudyakov, A. I., Radina, T. N., Ivanov, M. Yu. (2003). Pat. No. 2246462 RF. Syr'evaya smes' i sposob polucheniya granulirovannogo teploizolyacionnogo materiala. MPK S 04V28 / 26. No. 2003124577/03; declareted: 06.08.2003; published: 20.02.2005, Bul. No. 5, 5.
15. Brykov, S. I., Busygin, V. M., Valeev, R. G., Gaysin, L. G., Galimov, K. S., Zakirov, F. A. et. al. (1998). Pat. No. 2134668 RF. Sposob izgotovleniya poristyh silikatnyh materialov. MPK C04B28/26, C04B111:20. No. 98109881/03; declareted: 29.05.1998; published: 20.08.1999, Bul. No. 5, 3.
16. Lotov, V. A., Rudik, K. A. (2004). Pat. No. 2268248 RF. Vspenennyy material i sposob ego izgotovleniya. MPK C04B 38/00. No. 2004120692/03; declareted: 06.07.2004; published: 20.01.2006.
17. Malyavskiy, N. I., Pokid'ko, B. V. (2006). Tekhnologii polucheniya vodostoykogo shchelochno-silikatnogo uteplitelya iz zhidkogo stekla, modificirovannogo alyuminiem. Krovel'nye i izolyacionnye materialy, 4, 60–62.
18. Eom, J.-H., Kim, Y.-W., Raju, S. (2013). Processing and properties of macroporous silicon carbide ceramics: A review. Journal of Asian Ceramic Societies, 1 (3), 220–242. doi: 10.1016/j.jascer.2013.07.003
19. Shaw, S., Henderson, C. M. B., Komanschek, B. U. (2000). Dehydration/recrystallization mechanisms, energetics, and kinetics of hydrated calcium silicate minerals: an in situ TGA/DSC and synchrotron radiation SAXS/WAXS study. Chemical Geology, 167 (1-2), 141–159. doi: 10.1016/s0009-2541(99)00206-5
20. Wang, X., Jin, Y., Wang, Z., Nie, Y., Huang, Q., Wang, Q. (2009). Development of lightweight aggregate from dry sewage sludge and coal ash. Waste Management, 29 (4), 1330–1335. doi: 10.1016/j.wasman.2008.09.006
21. Volland, S., Brötz, J. (2015). Lightweight aggregates produced from sand sludge and zeolitic rocks. Construction and Building Materials, 85, 22–29. doi: 10.1016/j.conbuildmat.2015.03.018
22. Koutný, O., Opravil, T. (2016). The Basics of Low Volume Weight Aerated Autoclaved Concrete Preparation. Materials Science Forum, 851, 69–74. doi: 10.4028/www.scientific.net/msf.851.69
23. Wenger, M. D., DePhillips, P., Bracewell, D. G. (2008). A Microscale Yeast Cell Disruption Technique for Integrated Process Development Strategies. Biotechnology Progress, 24 (3), 606–614. doi: 10.1021/bp070359s
24. Leong, T. S. H., Wooster, T. J., Kentish, S. E., Ashokkumar, M. (2009). Minimising oil droplet size using ultrasonic emulsification. Ultrasonics Sonochemistry, 16 (6), 721–727. doi: 10.1016/j.ultsonch.2009.02.008
25. Malyavskiy, N. I., Zvereva, V. V. (2015). Kal'ciy-silikatnye otverditeli zhidkogo stekla dlya polucheniya vodostoykih shchelochnosilikatnyh utepliteley. Internet-vestnik VolgGASU, 2 (38). Available at: http://vestnik.vgasu.ru/attachments/5MalyavskiiZvereva-2015_2_38_.pdf
26. Behkish, A., Lemoine, R., Oukaci, R., Morsi, B. I. (2006). Novel correlations for gas holdup in large-scale slurry bubble column reactors operating under elevated pressures and temperatures. Chemical Engineering Journal, 115 (3), 157–171. doi: 10.1016/j.cej.2005.10.006

DOI: 10.15587/1729-4061.2017.112003

EFFECT OF FLAME RETARDANT FILLERS ON THE FIRE RESISTANCE AND PHYSICAL-MECHANICAL PROPERTIES OF POLYMERIC COMPOSITIONS (p. 65-70)

Olena Chulieieva
PJSC «YUZHCABLE WORKS», Kharkiv, Ukraine
ORCID: http://orcid.org/0000-0002-7310-0788

An effect of copolymer of ethylene with vinyl acetate of the polymeric matrix and flame retardant fillers on the fire resistance of composite materials was studied. We used of ethylene-vinyl acetate copolymer in the research. The content of vinyl acetate is 18 % and 28 %; melt flow index is 1.8 g/10 min and 2.5 g/10 min, respectively. The flame retardant fillers are aluminum oxide trihydrates with an average diameter of particles of 1.5 μm and 3 μm; magnesium oxide dihydrates – 3.0 μm and 3.7 μm; hydromagnesites – 1.5 μm.

The fire resistance of polymeric compositions was determined using a method of Oxygen Index. It is shown that in order to achieve Oxygen Index larger than 27 %, the degree of filling of the polymeric compositions based on EVA 1 and EVA 2 has to reach 40–60 % depending on the chemical composition and properties of the fire retardants. At the same time, applying EVA 2 makes it possible to achieve this indicator at smaller values of the filling.

We established regularities in the effect of the nature of a polymeric matrix and flame retardant fillers on the physical-mechanical

properties of compositions before and after ageing. An increase in the content of fillers in the polymeric composition results in reduced destructive stress and relative elongation at breaking, while the modulus of elasticity at stretching increases.

The results obtained could be applied when designing the formulations of polymeric compositions, which do not support combustion, for cable products, and which allow control over operational characteristics.

Keywords: fire resistance, ethylene-vinyl acetate copolymer, flame retardants, physical-mechanical properties, Oxygen Index.

References

1. Peshkov, I. B. (2013). Materialy kabel'nogo proizvodstva. Moscow: Mashinostroenie, 456.
2. Tirelli, D. (2013). Antipireny dlya kompozitov. The Chemical Journal, 1-2, 42–45.
3. Obzor mineral'nyh antipirenov-gidroksidov dlya bezgalogennyh kabel'nyh kompoziciy (2009). Kabel'-news, 8, 41–43.
4. Bezgalogennye ogneupornye kabeli. Available at: http://www.amtenergo.ru/statji/ognestoikie-kabeli.html
5. Lujan-Acosta, R., Sánchez-Valdes, S., Ramírez-Vargas, E., Ramos-DeValle, L. F., Espinoza-Martinez, A. B., Rodriguez-Fernandez, O. S. et. al. (2014). Effect of Amino alcohol functionalized polyethylene as compatibilizer for LDPE/EVA/clay/flame-retardant nanocomposites. Materials Chemistry and Physics, 146 (3), 437–445. doi: 10.1016/j.matchemphys.2014.03.050
6. Sonnier, R., Viretto, A., Dumazert, L., Longerey, M., Buonomo, S., Gallard, B. et. al. (2016). Fire retardant benefits of combining aluminum hydroxide and silica in ethylene-vinyl acetate copolymer (EVA). Polymer Degradation and Stability, 128, 228–236. doi: 10.1016/j.polymdegradstab.2016.03.030
7. Jeencham, R., Suppakarn, N., Jarukumjorn, K. (2014). Effect of flame retardants on flame retardant, mechanical, and thermal properties of sisal fiber/polypropylene composites. Composites Part B: Engineering, 56, 249–253. doi: 10.1016/j.compositesb.2013.08.012
8. Yen, Y.-Y., Wang, H.-T., Guo, W.-J. (2012). Synergistic flame retardant effect of metal hydroxide and nanoclay in EVA composites. Polymer Degradation and Stability, 97 (6), 863–869. doi: 10.1016/j.polymdegradstab.2012.03.043
9. Feng, C., Liang, M., Chen, W., Huang, J., Liu, H. (2015). Flame retardancy and thermal degradation of intumescent flame retardant EVA composite with efficient charring agent. Journal of Analytical and Applied Pyrolysis, 113, 266–273. doi: 10.1016/j.jaap.2015.01.021
10. Shevchenko, V. G. (2010). Osnovy fiziki polimernyh kompozicionnyh materialov. Moscow: MGU im. Lomonosova, 98.
11. Makarova, N. V., Trofimec, V. Ya. (2002). Statistika v Excel. Moscow: Finansy i statistika, 368.
12. Muhin, N. M., Buryndin, V. G. (2011). Opredelenie reologicheskih i fiziko-mekhanicheskih svoystv polimernyh materialov. Ekarenburg: UGLTU, 33.
13. Bobovich, B. B. (2009). Nemetallicheskie konstrukcionnye materialy. Moscow: MGIU, 384.