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Two-step electrosynthesis and catalytic activity of CoO−CoO • xH2O-supported Ag, Au, and Pd nanoparticles

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Abstract

© 2020, Springer Science+Business Media LLC. Two-step electrosynthesis of CoO-CoO•xH2--supported metal nanoparticles (MNPs, M = Au, Ag, Pd) was carried out in N,N-dimethylformamide in the absence and in presence of poly(N-vinylpyrrolidone) (PVP) using atmospheric oxygen as both a reagent and a mediator at potentials of its reduction to a superoxide radical anion. In the first step, oxygen reduction in the presence of Co2+ ions added to the solution as a salt or generated by dissolving the Co-anode during electrolysis produces a mixture of cobalt oxide CoO and its hydrated form CoO-CoO • xH2O (CoOxHy). When Ag+, Au+, Pd2+ ions are added to the obtained solution of CoOx H y, a redox reaction between CoO and the metal ion gives the MNPs and CoO+. In the second step, oxygen-mediated electroreduction of CoO+ serving as the second mediator is carried out, and the redox reaction is completely shifted towards the formation of MNPs. In the absence of PVP, AgNPs (18±4 nm) bind and stabilize completely in the CoOxHy matrix, PdNPs (6±1 nm) stabilize only partially, and AuNPs (21±10 nm) do not bind and, therefore, only their agglomerates are obtained (~200 nm). In the presence of PVP, individual AgNPs (5±2 nm), AuNPs (13±5 nm), PdNPs (3±1 nm) are stabilized in the PVP shell and are bound by the matrix. The obtained nanocomposites M/CoOx H y and M@PVP/CoOxHy catalyze the reduction of p-nitrophenol with sodium borohydride in an aqueous medium. Their catalytic activity is due to MNPs; CoOx H y acts as an inert matrix.

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Keywords

cobalt(II) oxide, electrochemical synthesis, nanocomposite, oxygen-mediated electroreduction

References

[1] A. Eremenko, N. Smirnova, I. Gnatiuk, O. Linnik, N. Vityuk, Y. Mukha, A. Korduban, in Nanocomposites and Polymers with Analytical Methods, Ed. J. Cuppoletti, InTech, Rijeka, 2011, p. 51; DOI: 10.5772/18252.

[2] S. M. Majhi, G. K. Naik, H.-J. Lee, H.-G. Song, C.-R. Lee, I.-H. Lee, Y.-T. Yu, Sensors and Actuators, B, 2018, 268, 223.

[3] J. Liu, S. Zou, S. Li, X. Liao, Y. Hong, L. Xiao, J. Fan, J. Mater. Chem. A, 2013, 1, 4038.

[4] R. P. Padbury, J. C. Halbur, P. J. Krommenhoek, J. B. Tracy, J. S. Jur, Langmuir, 2015, 31, 1135.

[5] D. Han, Z. Zhang, Z. Bao, H. Xing, Q. Ren, Front. Chem. Sci. Eng., 2018, 12, 24.

[6] T. Hu, Y. Wang, Q. Liu, L. Zhang, H. Wang, T. Tang, W. Chen, M. Zhao, J. Jia, Int. J. Hydrogen Energy, 2017, 42, 25951.

[7] F.-Z. Song, Q.-L. Zhu, X. Yang, W.-W. Zhan, P. Pachfule, N. Tsumori, Q. Xu, Adv. Energy Mater., 2018, 8, 1701416.

[8] A. B. Kuriganova, I. N. Leontyev, A. S. Alexandrin, O. A. Maslova, A. I. Rakhmatullin, N. V. Smirnova, Mendeleev Commun., 2017, 27, 67.

[9] A. B. Kuriganova, D. V. Leontyeva, S. Ivanov, A. Bund, N. V. Smirnova, J. Appl. Electrochem., 2016, 46, 1245.

[10] A. B. Kuriganova, N. V. Smirnova, Mendeleev Commun., 2014, 24, 351.

[11] D. E. Doronkin, A. B. Kuriganova, I. N. Leontyev, S. Baier, H. Lichtenberg, N. V. Smirnova, J.-D. Grunwaldt, Catal. Lett., 2016, 146, 452.

[12] P. S. Solmanov, N. M. Maximov, N. N. Tomina, A. A. Pimerzin, Mendeleev Commun., 2018, 28, 562.

[13] A. V. Rassolov, G. N. Baeva, I. S. Mashkovsky, A. Yu. Sta-kheev, Mendeleev Commun., 2018, 28, 538.

[14] S. W. Lee, J. T. Song, J. Kim, J. Oh, J. Y. Park, Nanoscale, 2018, 10, 3911.

[15] Z. Zhang, Q. Wu, X. Bu, Z. Hang, Z. Wang, Q. Wang, Y. Ma, Bull. Korean Chem. Soc., 2018, 39, 71.

[16] M. Liu, W. Tang, Y. Xu, H. Yu, H. Yin, S. Zhao, S. Zhou, Appl. Catal. A, 2018, 549, 273.

[17] P. Supriya, B. T. V. Srinivas, K. Chowdeswari, N. V. S. Naidu, B. Sreedhar, Mater. Chem. Phys., 2018, 204, 27.

[18] M. Gilanizadeh, B. Zeynizadeh, Res. Chem. Intermed., 2018, 44, 6053.

[19] F. Aryanasab, RSC Adv., 2016, 6, 32018.

[20] S. Jammi, S. Sakthivel, L. Rout, T. Mukherjee, S. Mandal, R. Mitra, P. Saha, T. Punniyamurthy, J. Org. Chem., 2009, 74, 1971.

[21] V. V. Yanilkin, N. V. Nastapova, G. R. Nasretdinova, R. R. Fazleeva, Yu. N. Osin, Electrochem. Commun., 2016, 69, 36.

[22] V. V. Yanilkin, G. R. Nasretdinova, V. A. Kokorekin, Russ. Chem. Rev., 2018, 87, 1080.

[23] V. V. Yanilkin, N. V. Nastapova, R. R. Fazleeva, G. R. Nasretdinova, E. D. Sultanova, A. Yu. Ziganshina, A. T. Gubaidullin, A. I. Samigullina, V. G. Evtyugin, V. V. Vorob’ev, Yu. N. Osin, Russ. J. Electrochem., 2018, 54, 265.

[24] G. R. Nasretdinova, R. R. Fazleeva, Yu. N. Osin, V. G. Evtugin, A. T. Gubaidullin, A. Yu. Ziganshina, V. V. Yanilkin, Electrochim. Acta, 2018, 285, 149.

[25] V. V. Yanilkin, N. V. Nastapova, E. D. Sultanova, G. R. Nasret dinova, R. K. Mukhitova, A. Yu. Ziganshina, I. R. Nizameev, M. K. Kadirov, Russ. Chem. Bull., 2016, 65, 125.

[26] V. V. Yanilkin, N. V. Nastapova, G. R. Nasretdinova, G. M. Fazleeva, L. N. Islamova, Yu. N. Osin, A. T. Gubaidullin, ECS J. Solid State Sci. Technol., 2017, 6, M143.

[27] L. A. Dykman, V. A. Bogatyrev, S. Yu. Shchegolev, N. G. Khlebtsov, Zolotye nanochastitsy. Sintez, svoystva, biomedit-sinskoye primenenie [Gold Nanoparticles. Synthesis, Properties, Biomedical Application], Nauka, Moscow, 2008, 319 pp. (in Russian).

[28] V. V. Yanilkin, R. R. Fazleeva, G. R. Nasretdinova, N. V. Nas tapova, Yu. N. Osin, Butlerov Commun., 2016, 46, 128.

[29] V. V. Yanilkin, R. R. Fazleeva, G. R. Nasretdinova, N. V. Nastapova, Yu. N. Osin, New Mater., Compd. Appl., 2018, 2, 28.

[30] V. V. Yanilkin, R. R. Fazleeva, G. R. Nasretdinova, N. V. Nastapova, Yu. N. Osin, ECS J. Solid State Sci. Technol., 2018, 7, M55.

[31] V. V. Yanilkin, R. R. Fazleeva, N. V. Nastapova, G. R. Nasretdinova, A. T. Gubaidullin, N. B. Berezin, Yu. N. Osin, Russ. J. Electrochem., 2018, 54, 650.

[32] I. P. Suzdalev, Nanotekhnologiya: fiziko-khimiya nanoklasterov, nanostruktur i nanomaterialov [Nanotechnology: Physical Chemistry of Nanoclusters, Nanostructures, and Nanomaterials], 2nd ed., Librokom, Moscow, 2009, 589 pp. (in Russian).

[33] B. I. Kharisov, O. V. Kharissova, U. Ortiz-Méndez, Handbook of Less-Common Nanostructures, CRC Press, Taylor and Francis Group, Boca Raton, 2012, 836 pp.

[34] A. M. Tafesh, J. Weiguny, Chem. Rev., 1996, 96, 2035.

[35] D. Astruc, Nanoparticles and Catalysis, Wiley-VCH, Weinheim, 2008, 663 pp.

[36] P. Lara, K. Philippot, Catal. Sci. Technol., 2014, 4, 2445.

[37] V. V. Yanilkin, N. V. Nastapova, R. R. Fazleeva, G. R. Nasretdinova, E. D. Sultanova, A. Yu. Ziganshina, A. T. Gubaidullin, A. I. Samigullina, V. G. Evtugin, V. V. Vorobev, Yu. N. Osin, Russ. Chem. Bull., 2018, 67, 215.

[38] P. Babji, V. L. Rao, Int. J. Chem. Stud., 2016, 4, 123.

[39] M. Yaseen, Z. Shah, R. C. Veses, S. L. P. Dias, É. C. Lima, G. S. dos Reis, J. C. P. Vaghetti, W. S. D. Alencar, K. Meh-mood, J. Anal. Bioanal. Technol., 2017, 8, 1.

[40] N. Pradhan, A. Pal, T. Pal, Colloids Surf., A, 2002, 196, 247.

[41] P. Hervés, M. Pérez-Lorenzo, L. M. Liz-Marzán, J. Dzubiella, Y. Lu, M. Ballauff, Chem. Soc. Rev., 2012, 41, 5577.