6th International Conference on Nanotechnologies and Biomedical Engineering Proceedings of ICNBME-2023, September 20–23, 2023, Chisinau, Moldova - Volume 1: Nanotechnologies and Nano-biomaterials for Applications in Medicine

ZnO Microtetrapods Covered by Au Nanodots as a Platform for the Preparation of Complex Micro-nano-structures

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https://doi.org/10.1007/978-3-031-42775-6_22

Abstract

We propose to use hybrid networks of ZnO microtetrapods produced by flame transport synthesis and Au nanodots deposited by pulsed electroplating, for the preparation of more complex 3D micro-nano-structures via Au catalyst-assisted vapor-liquid-solid growth of semiconductor nanowires on the surface of ZnO microtetrapod arms. The pulsed electrochemical deposition of Au nanodots with optimized pulse parameters was realized in pressed pellets containing the ZnO tetrapods with the density 1 g cm^{-3}. The mechanical stability was increased by means of thermal treatment of pressed hybrid networks of ZnO microtetrapods at 950 °C for 1 h. The morphology of the ZnO microtetrapod networks and the density of the deposited Au nanodots were investigated by scanning electron microscopy. The deposition of Au nanodots with various densities and of monolayers of self-assembled nanodots was demonstrated on ZnO microtetrapods possessing different conductivities. The optical quality of the ZnO microtetrapods was investigated by photoluminescence (PL) spectroscopy in the temperature interval from 10 to 300 K. PL bands related to neutral donor bound excitons D^0X and donor–acceptor pairs (DAP) recombination were observed at low temperature. We assume that the presence in the spectrum of PL bands related to excitonic radiation is indicative of a high enough quality of the investigated ZnO microtetrapods for various optoelectronic and photonic applications.

Keywords: zinc oxide microtetrapods, aurum nanodots, pulsed electroplating,· semiconductor nanowires, scanning electron microscopy, photoluminescence

References

1. Hahn, Y.B.: Zinc oxide nanostructures and their applications. J. Chem. Eng. **28**, 1797–1813 (2011). https://doi.org/10.1007/s11814-011-0213-3
2. Raha, S., Ahmaruzzaman, M.: ZnO nanostructured materials and their potential applications: progress, challenges and perspectives. Nanoscale Adv. **4**, 1868–1925 (2022). https://doi.org/10.1039/d1na00880c
3. Mishra, Y.K., et al.: Fabrication of macroscopically flexible and highly porous 3D semiconductor networks from interpenetrating nanostructures by a simple flame transport approach. Part. Part. Syst. Charact. **30**, 775–783 (2013). https://doi.org/10.1002/ppsc.201300197
4. Tiginyanu, I., et al.: Self-organized and self-propelled aero-GaN with dual hydrophilic/hydrophobic behavior. Nano Energy **56**, 759–769 (2019). https://doi.org/10.1016/j.nanoen.2018.11.049
5. Plesco, I., et al.: Aero-ZnS architectures with dual hydrophilic-hydrophobic properties for microfluidic applications. APL Mater. **8**, 061105 (2020). https://doi.org/10.1063/5.0010222
6. Plesco, I., et al.: Highly porous and ultra-lightweight aero-Ga2O3: enhancement of photocatalytic activity by noble metals. Materials **14**, 1985 (2021). https://doi.org/10.3390/ma14081985
7. Ciobanu, V., et al.: Aero-TiO2 prepared on the basis of networks of ZnO tetrapods. Crystals **12**, 1753 (2022). https://doi.org/10.3390/cryst12121753
8. Shafi, A.M., et al.: Direct epitaxial growth of InP nanowires on MoS2 with strong nonlinear optical response. Chem. Mater. **34**(20), 9055–9061 (2022). https://doi.org/10.1021/acs.chemmater.2c01602
9. Maliakkal, C.B., et al.: In situ analysis of catalyst composition during gold catalyzed GaAs nanowire growth. Nat. Commun. **10**, 4577 (2019). https://doi.org/10.1038/s41467-019-12437-6
10. Boulanger, J.P., LaPierre, R.R.: Patterned gold-assisted growth of GaP nanowires on Si. Semicond. Sci. Technol. **27**, 035002 (2012). https://doi.org/10.1088/0268-1242/27/3/035002
11. Abdullah, A.,Kulkarni, M.A., Thaalbi,H., Tariq, F., Ryu, S.-W.: Epitaxial growth of 1D GaNbased heterostructures on various substrates for photonic and energy applications. Nanoscale Adv. **5**, 1023–1042 (2023). https://doi.org/10.1039/D2NA00711H
12. Kennedy, O.W., White, E.R., Shaffer, M.S.P., Warburton, P.A.: Vapour-liquid-solid growth of ZnO-ZnMgO core–shell nanowires by gold-catalysed molecular beam epitaxy. Nanotechnology **30**, 194001 (2019). https://doi.org/10.1088/1361-6528/ab011c

13. Kumar, S., Fossard, F., Amiri, G., Chauveau, J.-M., Sallet, V.:MOCVD growth and structural properties of ZnS nanowires: a case study of polytypism. Nanomaterials **12**, 2323 (2022). https://doi.org/10.3390/nano12142323

14. Butanovs, E.,Kuzmin,A., Piskunov, S., Smits,K., Kalinko,A.: Synthesis and characterization of GaN/ReS2, ZnS/ReS2 and ZnO/ReS2 core/shell nanowire heterostructures.Appl. Surf. Sci. **536**, 147841 (2021). https://doi.org/10.1016/j.apsusc.2020.147841

15. Mishra,Y.K., et al.:Versatile fabrication of complex shaped metal oxide nano-microstructures and their interconnected networks for multifunctional applications. KONA Powder Particle J. **31**, 92–110 (2014). https://doi.org/10.14356/kona.2014015

16. Monaico, E.I., Monaico, E.V., Ursaki, V.V., Tiginyanu, I.M.: Controlled electroplating of noble metals on III-V semiconductor nanotemplates fabricated by anodic etching of bulk substrates. Coatings **12**, 1521 (2022). https://doi.org/10.3390/coatings12101521

17. Nishio, K., Isshiki, T., Kitano, M., Shiojiri, M.: Structure and growth mechanism of tetrapodlike ZnO particles. Philos. Mag. A **76**, 889–904 (1997). https://doi.org/10.1080/01418619708214216

18. Ronning, C., Shang, N.G., Gerhards, I., Hofsäss, H.: Nucleation mechanism of the seed of tetrapod ZnO nanostructures. J. Appl. Phys. **98**, 034307 (2005). https://doi.org/10.1063/1.1997290

19. Wang, B.-B., Xie, J.-J., Yuan, Q., Zhao, Y.-P.: Growth mechanism and joint structure of ZnOt etrapods. J. Phys. D: Appl. Phys **41**, 102005 (2008). https://doi.org/10.1088/0022-3727/41/10/102005

20. Yang, D., Gopal, R.A., Lkhagvaa, T., Choi, D.: Oxidizing agent impacting on growth of ZnO tetrapod nanostructures and its characterization. Environ. Res. **197**, 111032 (2021). https://doi.org/10.1016/j.envres.2021.111032

21. Meyer, B.K., et al.: Bound exciton and donor–acceptor pair recombinations in ZnO. Phys. Stat. Sol. (B) **241**, 231–260 (2004). https://doi.org/10.1002/pssb.200301962

22. Ursaki, V.V., et al.: Photoluminescence of ZnO layers grown on opals by chemical deposition from zinc nitrate solution Semicond. Sci. Technol. **19**, 851–854 (2004). https://doi.org/10.1088/0268-1242/19/7/012

23. Ursaki, V.V., et al.: Photoluminescence and resonant Raman scattering from ZnO-opal structures. J. Appl Phys. **96**, 1001–1006 (2004). https://doi.org/10.1063/1.1762997

24. Özgür, Ü., Alivov, Y.I., Liu, C.: A comprehensive review of ZnO materials and devices. J. Appl. Phys. **98**, 041301 (2005). https://doi.org/10.1063/1.1992666

25. Aziz, B., Majid, A., Ghani, L., Aziz I.: Photoluminescence effect on phosphorous irradiated zinc oxide (ZnO) nanotetrapods synthesized by simple thermal oxidation method. J. Phys. Appl. **3**(1), 107–112 (2020). https://doi.org/10.14710/jpa.v3i1.8271

26. Myndrul,V., et al.: MXene nanoflakes decorating ZnO tetrapods for enhanced performance of skin-attachable stretchable enzymatic electrochemical glucose sensor. Biosens. Bioelectron. **207**, 114141 (2022). https://doi.org/10.1016/j.bios.2022.114141

27. Tiginyanu, I.,Monaico, E., Nielsch, K.: Self-assembled monolayer of Au nanodots deposited on porous semiconductor structures. ECS Electrochem. Lett. **4**, D8 (2015). https://doi.org/10.1149/2.0041504eel

28. Monaico, E.V., et al.: Gold electroplating as a tool for assessing the conductivity of InP nanostructures fabricated by anodic etching of crystalline substrates. J. Electrochem. Soc. **164**(4), D179–D183 (2017). https://doi.org/10.1149/2.1071704jes