physica status solidi rrl rapid research letters

2023, Volume 17, number11, pages 2300039

Porous Semiconductor Compounds with Engineered Morphology as a Platform for Various Applications

Monaico Eduard V., Monaico Elena I., Ursaki Veaceslav V., Tiginyanu Ion M.

https://doi.org/10.1002/pssr.202300039

Abstract

Porous semiconductor compounds represent a class of materials which is under an intense research focus over the last years. Herein, morphologies and topologies produced by anodization in binary semiconductor compounds having various bandgaps and crystallographic orientations are demonstrated with a focus on technological procedures applied for generating arrays of pores with a controlled design. The mechanism of pores growth under the photoresist masks is discussed and the connection between the design of the mask and the architecture of the produced porous structure is disclosed. The evolution of physical characteristics of the materials such as luminescence, optical, photonic, vibrational, hydrophilic, and hydrophobic properties as a result of anodization is investigated. Investigations are performed by means of scanning electron microscopy, photoluminescence and cathodoluminescence spectroscopy, and contact angle measurements. Some possible practical applications of the proposed technological approaches and the produced porous structures are briefly discussed.

Keywords: anodization, contact angle, controlled morphology, electroplating, pores by design, semiconductor nanowires

References

1. D. Wu, X. Tang, K. Wang, Z. He, X. Li, *Nanoscale Res. Lett.* 2017, **12**, 604. PubMed Web of Science® Google Scholar
2. M. M. Jansen, P. Perla, M. Kaladzhian, N. von den Driesch, J. Janßen, M. Luysberg, M. I. Lepsa, D. Grützmacher, A. Pawlis, *ACS Appl. Nano Mater.* 2020, **3**, 11037. CAS Web of Science® Google Scholar
3. M. A. Johar, H.-G. Song, A. Waseem, M. A. Hassan, I. V. Bagal, Y.-H. Cho, S.-W. Ryu, *Appl. Mate. Today* 2020, 19, 100541. Web of Science® Google Scholar
4. K. Shugurov, A. Mozharov, G. Sapunov, V. Fedorov, M. Tchernycheva, I. Mukhin, *Phys. Status Solidi RRL* 2021, **15**, 2000590. CAS Web of Science® Google Scholar

physica status solidi rrl rapid research letters

2023, Volume 17, number11, pages 2300039

5. M. Liu, L. Tan, R. T. Rashid, Y. Cen, S. Cheng, G. Botton, Z. Mi, C.-J. Li, *Chem. Sci.* 2020, **11**, 7864.
CAS PubMed Web of Science® Google Scholar
6. K. Peng, P. Parkinson, Q. Gao, J. L. Boland, Z. Li, F. Wang, S. Mokkapati, L. Fu, M. B. Johnston, H. H. Tan, C. Jagadish, *Nanotechnology* 2017, **28**, 125202.
PubMed Web of Science® Google Scholar
7. C. Rodwihok, S. Choopun, P. Ruankham, A. Gardchareon, S. Phadungdhitidhada, D. Wongratanaphisan, *Appl. Surf. Sci.* 2019, **477**, 159.
CAS Web of Science® Google Scholar
8. G. Suo, S. Jiang, J. Zhang, J. Li, M. He, *Adv. Condens. Matter Phys.* 2014, **2014**, e456163.
Web of Science® Google Scholar
9. A. Galdámez-Martinez, G. Santana, F. Güell, P. R. Martínez-Alanis, A. Dutt, *Nanomaterials* 2020, **10**, 857.
CAS PubMed Web of Science® Google Scholar
10. Y. Greenberg, A. Kelrich, S. Cohen, S. Kar-Narayan, D. Ritter, Y. Calahorra, *Nanomaterials* 2019, **9**, 1327.
CAS PubMed Web of Science® Google Scholar
11. L. Balaghi, S. Shan, I. Fotev, F. Moebus, R. Rana, T. Venanzi, R. Hübner, T. Mikolajick, H. Schneider, M. Helm, A. Pashkin, E. Dimakis, *Nat. Commun.* 2021, **12**, 6642.
CAS PubMed Web of Science® Google Scholar
12. V. Neplokh, V. Fedorov, A. Mozharov, F. Kochetkov, K. Shugurov, E. Moiseev, N. Amador-Mendez, T. Statsenko, S. Morozova, D. Krasnikov, A. G. Nasibulin, R. Islamova, G. Cirlin, M. Tchernycheva, I. Mukhin, *Nanomaterials* 2021, **11**, 2549.
CAS PubMed Web of Science® Google Scholar
13. M. Enculescu, A. Costas, A. Evanghelidis, I. Enculescu, *Nanomaterials* 2021, **11**, 1305.
CAS PubMed Web of Science® Google Scholar
14. J. B. Park, M. S. Song, R. Ghosh, R. K. Saroj, Y. Hwang, Y. Tchoe, H. Oh, H. Baek, Y. Lim, B. Kim, S.-W. Kim, G.-C. Yi, *NPG Asia Mater.* 2021, **13**, 1.
Web of Science® Google Scholar
15. P.-M. Coulon, J. R. Pugh, M. Athanasiou, G. Kusch, E. D. L. Boulbar, A. Sarua, R. Smith, R. W. Martin, T. Wang, M. Cryan, D. W. E. Allsopp, P. A. Shields, *Opt. Express* 2017, **25**, 28246.
CAS Web of Science® Google Scholar
16. M. Palit, B. Nag Chowdhury, S. Sikdar, K. Sarkar, P. Banerji, S. Chattopadhyay, *Phys. Lett. A* 2021, **388**, 127056.
CAS Web of Science® Google Scholar
17. J. L. Mohanan, I. U. Arachchige, S. L. Brock, *Science* 2005, **307**, 397.
CAS PubMed Web of Science® Google Scholar
18. C. Ziegler, A. Wolf, W. Liu, A.-K. Herrmann, N. Gaponik, A. Eychmüller, *Angew. Chem., Int. Ed.* 2017, **56**, 13200.
CAS PubMed Web of Science® Google Scholar
19. M. T. Noman, N. Amor, A. Ali, S. Petrik, R. Coufal, K. Adach, M. Fijalkowski, *Gels* 2021, **7**, 264.
CAS PubMed Web of Science® Google Scholar
20. P. Franco, S. Cardea, A. Tabernero, I. De Marco, *Molecules* 2021, **26**, 4440.
CAS PubMed Web of Science® Google Scholar
21. L. Zheng, S. Zhang, Z. Ying, J. Liu, Y. Zhou, F. Chen, *Int. J. Nanomed.* 2020, **15**, 2363.
CAS PubMed Web of Science® Google Scholar

physica status solidi rrl rapid research letters

2023, Volume 17, number11, pages 2300039

22. Q. Liu, K. Yan, J. Chen, M. Xia, M. Li, K. Liu, D. Wang, C. Wu, Y. Xie, *Aggregate* 2021, **2**, 30.
CAS Web of Science® Google Scholar
23. S. Li, X. Hao, X. Dai, T. Tao, *J. Nanomater.* 2018, **2018**, 8752015.
Web of Science® Google Scholar
24. N. H. Mohd Kaus, A. F. Rithwan, R. Adnan, M. L. Ibrahim, S. Thongmee, S. F. Mohd Yusoff, *Catalysts* 2021, **11**, 302.
Web of Science® Google Scholar
25. V. Ciobanu, V. V. Ursaki, S. Lehmann, T. Braniste, S. Raevschi, V. V. Zalamai, E. V. Monaico, P. Colpo, K. Nielsch, I. M. Tiginyanu, *Crystals* 2022, **12**, 1753.
CAS Web of Science® Google Scholar
26. J. Marx, M. R. D. Lewke, D. Smazna, Y. K. Mishra, R. Adelung, K. Schulte, B. Fiedler, *Appl. Surf. Sci.* 2019, **470**, 535.
CAS Web of Science® Google Scholar
27. W. Zhan, L. Sun, X. Han, *Nano-Micro Lett.* 2019, **11**, 1.
CAS PubMed Web of Science® Google Scholar
28. P. H. Griffin, R. A. Oliver, *J. Phys. D: Appl. Phys.* 2020, **53**, 383002.
CAS Web of Science® Google Scholar
29. E. Monaico, I. Tiginyanu, V. Ursaki, *Semicond. Sci. Technol.* 2020, **35**, 103001.
CAS Web of Science® Google Scholar
30. I. Tiginyanu, E. Monaico, E. Monaico, *Electrochem. Commun.* 2008, **10**, 731.
CAS Web of Science® Google Scholar
31. I. M. Tiginyanu, E. Monaico, S. Albu, V. V. Ursaki, *Phys. Status Solidi (RRL)* 2007, **1**, 98.
CAS Web of Science® Google Scholar
32. I. M. Tiginyanu, V. V. Ursaki, E. Monaico, M. Enachi, V. V. Sergentu, G. Colibaba, D. D. Nedeoglo, A. Cojocaru, H. Föll, *J. Nanoelectron. Optoelectron.* 2011, **6**, 463.
CAS Web of Science® Google Scholar
33. Ed. Monaico, E. I. Monaico, V. V. Ursaki, I. M. Tiginyanu, K. Nielsch, *Surf. Engin. Appl. Electrochem.* 2019, **55**, 367.
Web of Science® Google Scholar
34. I. Wloka, K. Mueller, P. Schmuki, *Electrochem. Solid-State Lett.* 2005, **8**, B72.
CAS Web of Science® Google Scholar
35. I. Müller, J. Wloka, P. Schmuki, *J. Solid State Electrochem.* 2009, **13**, 807.
CAS Web of Science® Google Scholar
36. E. V. Monaico, V. Morari, V. V. Ursaki, K. Nielsch, I. M. Tiginyanu, *Nanomaterials* 2022, **12**, 1506.
CAS PubMed Web of Science® Google Scholar
37. C. Zhang, S. H. Park, D. Chen, D.-W. Lin, W. Xiong, H.-C. Kuo, C.-F. Lin, H. Cao, J. Han, *ACS Photon.* 2015, **2**, 980.
CAS Web of Science® Google Scholar
38. C. Yang, L. Liu, S. Zhu, Z. Yu, X. Xi, S. Wu, H. Cao, J. Li, L. Zhao, *J. Phys. Chem. C* 2017, **121**, 7331.
CAS Web of Science® Google Scholar
39. E. I. Monaico, E. V. Monaico, V. V. Ursaki, S. Honnali, V. Postolache, K. Leistner, K. Nielsch, I. M. Tiginyanu, *Beilstein J. Nanotechnol.* 2020, **11**, 966.
CAS PubMed Web of Science® Google Scholar
40. W. Deng, X. Peng, J. Zou, W. Wang, Y. Liu, T. Zhang, Y. Zhang, D. Zhang, *Appl. Opt.* 2017, **56**, 8991.
CAS PubMed Web of Science® Google Scholar

physica status solidi rrl rapid research letters

2023, Volume 17, number11, pages 2300039

41. H. Küpers, R. B. Lewis, A. Tahraoui, M. Matalla, O. Krüger, F. Bastiman, H. Riechert, L. Geelhaar, *Nano Res.* 2018, **11**, 2885.
CAS Web of Science® Google Scholar
42. I. Vukajlovic-Plestina, W. Kim, V. G. Dubrovski, G. Tütüncüoğlu, M. Lagier, H. Potts, M. Friedl, A. Fontcuberta i Morral, *Nano Lett.* 2017, **17**, 4101.
CAS PubMed Web of Science® Google Scholar
43. S. C. Crawford, S. Ermez, G. Haberfehlner, E. J. Jones, S. Gradečak, *Nanotechnology* 2015, **26**, 225604.
PubMed Web of Science® Google Scholar
44. D. Mora-Fonz, T. Lazauskas, M. R. Farrow, C. R. A. Catlow, S. M. Woodley, A. A. Sokol, *Chem. Mater.* 2017, **29**, 5306.
CAS Web of Science® Google Scholar
45. Y. Wang, G. Deng, J. Ji, H. Ma, S. Yang, J. Yu, Y. Niu, Y. Wang, C. Lu, Y. Liu, K. Tang, W. Guo, B. Zhang, Y. Zhang, *AIP Adv.* 2021, **11**, 115301.
CAS Web of Science® Google Scholar
46. Y. Wang, Y. Wang, L. Zhang, Y. Niu, J. Yu, H. Ma, C. Lu, Z. Shi, G. Deng, B. Zhang, Y. Zhang, *Opt. Lett.* 2022, **47**, 3628.
CAS PubMed Web of Science® Google Scholar
47. Y.-G. Lin, Y.-K. Hsu, A. M. Basilio, Y.-T. Chen, K.-H. Chen, L.-C. Chen, *Opt. Express* 2014, **22**, A21.
PubMed Web of Science® Google Scholar
48. I. Nomoto, H. G. Xing, D. Jena, Y. Cho, *Appl. Phys. Express* 2022, **15**, 064004.
Web of Science® Google Scholar
49. V. V. Zalamai, G. V. Colibaba, E. I. Monaico, E. V. Monaico, *Surf. Engin. Appl. Electrochem.* 2021, **57**, 117.
Web of Science® Google Scholar
50. Ü. Özgür, Ya. I. Alivov, C. Liu, A. Teke, M. A. Reshchikov, S. Doğan, V. Avrutin, S.-J. Cho, H. Morkoç, *J. Appl. Phys.* 2005, **98**, 041301.
CAS Web of Science® Google Scholar
51. B. K. Meyer, H. Alves, D. M. Hofmann, W. Kriegseis, D. Forster, F. Bertram, J. Christen, A. Hoffmann, M. Straßburg, M. Dworzak, U. Haboeck, A. V. Rodina, *Phys. Status Solidi (RRL)* 2004, **241**, 231.
CAS Web of Science® Google Scholar
52. S.-C. Han, J.-K. Kim, J. Y. Kim, K.-K. Kim, H. Tampo, S. Niki, J.-M. Lee, *J. Electrochem. Soc.* 2009, **157**, D60.
Web of Science® Google Scholar
53. I. Mehta, C. Meier, *J. Electrochem. Soc.* 2010, **158**, H119.
Web of Science® Google Scholar
54. W. Klich, M. Inada, H. Gao, H. Saito, M. Ohtaki, *Adv. Powder Technol.* 2021, **32**, 4356–4363.
CAS Web of Science® Google Scholar
55. I. T. Noman, N. Amor, M. Petru, *Crit. Rev. Solid State Mater. Sci.* 2022, **47**, 99.
CAS Web of Science® Google Scholar
56. P. K. Aspoukeh, A. A. Barzinjy, S. M. Hamad, *Int. Nano Lett.* 2022, **12**, 153.
CAS Web of Science® Google Scholar
57. H. Rai, Prashant, N. Kondal, *Mater. Today: Proc.* 2022, **48**, 1320.
CAS Google Scholar

physica status solidi rrl rapid research letters

2023, Volume 17, number11, pages 2300039

58. G. S. Pekar, A. F. Singaevsky, M. M. Lokshin, I. A. Vasin, O. V. Dubikovskyi, *J. Crystal. Process Technol.* 2020, **9**, 39.
Google Scholar
59. T. Braniste, E. Monaico, D. Martin, J.-F. Carlin, V. Popa, V. V. Ursaki, N. Grandjean, I. M. Tiginyanu, in Nanotechnology VIII, vol. **10248**, SPIE 2017, p. 83–89.
Google Scholar
60. I. Tiginyanu, M. A. Stevens-Kalceff, A. Sarua, T. Braniste, E. Monaico, V. Popa, H. D. Andrade, J. O. Thomas, S. Raevschi, K. Schulte, R. Adelung, *ECS J. Solid State Sci. Technol.* 2016, **5**, P218.
CAS Web of Science® Google Scholar
61. T. Braniste, J. Ciers, Ed. Monaico, D. Martin, J.-F. Carlin, V. V. Ursaki, V. V. Sergentu, I. M. Tiginyanu, N. Grandjean, *Superlattices Microstruct.* 2017, **102**, 221.
CAS Web of Science® Google Scholar
62. I. Tiginyanu, E. Monaico, V. Sergentu, A. Tiron, V. Ursaki, *ECS J. Solid State Sci. Technol.* 2015, **4**, P57.
CAS Web of Science® Google Scholar
63. V. V. Sergentu, I. M. Tiginyanu, V. V. Ursaki, *J. Opt.* 2012, **14**, 055703.
CAS Web of Science® Google Scholar
64. I. M. Tiginyanu, E. Foca, V. V. Sergentu, V. V. Ursaki, F. Daschner, R. Knöchel, H. Föll, *J. Nanoelectron. Optoelectron.* 2009, **4**, 20.
Web of Science® Google Scholar
65. I. Naddaf, *Bull. Mater. Sci.* 2022, **45**, 89.
CAS Web of Science® Google Scholar
66. Y. Suchikova, S. Kovachov, I. Bohdanov, *Nanomater. Nanotechnol.* 2022, **12**, 18479804221127308.
Web of Science® Google Scholar
67. Y. Milovanov, V. Skryshevsky, I. Gavrilchenko, A. Oksanich, S. Pritchin, M. Kogdas, *J. Electron. Mater.* 2019, **48**, 2587.
CAS Web of Science® Google Scholar
68. E. V. Monaico, S. Busuioc, I. M. Tiginyanu, in *5th Inter. Conf. on Nanotechnologies and Biomedical Engineering, IFMBE Proc.* (Eds: I. Tiginyanu, V. Sontea, and S. Railean) Springer Inter. Publishing, Cham 2022, pp. 62–69.
Google Scholar
69. I. Tiginyanu, E. Monaico, K. Nielsch, *ECS Electrochem. Lett.* 2015, **4**, D8.
CAS Google Scholar
70. E. V. Monaico, E. I. Monaico, V. V. Ursaki, I. M. Tiginyanu, *ECS J. Solid State Sci. Technol.* 2020, **9**, 064010.
CAS Web of Science® Google Scholar
71. I. Matsushita, A. Fujisawa, N. Ando, H. Kobayashi, H. Naganuma, S. Okuyama, K. Okuyama, *J. Electrochem. Soc.* 2001, **148**, G401.
CAS Web of Science® Google Scholar
72. G. V. Colibaba, *Mater. Sci. Semicond. Process.* 2016, **43**, 75.
CAS Web of Science® Google Scholar
73. E. I. Monaico, E. V. Monaico, V. V. Ursaki, I. M. Tiginyanu, *Coatings* 2022, **12**, 1521.
CAS Web of Science® Google Scholar