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Template Assisted Formation of Metal Nanotubes

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Abstract

This chapter provides a review of methods for the production of metal nanotubes and their applications. The importance of nanotemplated growth of nanowires and nanotubes for nanofabrication, and the advantages of nanotubes over nanowires are revealed. Technological approaches for producing various templates, as well as advantages and drawbacks of specific templates, such as ion-track membranes, porous alumina templates, and porous semiconductor templates for nanofabrication are discussed, especially with respect to their suitability for the production of metal nanotubes. Technological methods applied for deposition of metal nanotubes with a focus on electrodepostion and electroless deposition are overviewed for each type of porous templates, and their mechanisms and peculiarities are evidenced. The prospects of application of nanomaterials based on porous nanotemplates in electronics, energy sector, optics, photonics, computers and communications, magnetism and biomedical sciences are explored.

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References:

1. C.R. Martin, Nanomaterials, a membrane—based synthetic approach. Science 266, 1961 (1994)

2. A. Fert, L. Piraux, Magnetic nanowires. J. Magn. Magn. Mater. 200, 338 (1999)

3. I. Enculescu, Z. Siwy, D. Dobrev, C. Trautmann, M.E. Toimil Molares, R. Neumann, K. Hjort, L. Westerberg, R. Spohr. Copper nanowires electrodeposited in etched single-ion track templates. Appl. Phys. A 77, 751 (2003)

4. I. Enculescu, Nanowires and nanotubes prepared using iob track membrane templates. Digest J. Nanomater. Biostruct. 1(1), 15–20 (2006)

5. P. Lehana, S. Khan, S. Arya, Int. J. VLSI Signal. Proc. Appl. 1, 32 (2011)

6. J. Lee, P. Lee, H. Lee, D. Lee, S.S. Lee, S.H. Ko, Nanoscale 4, 6408 (2012)

7. P.-C. Hsu, S. Wang, H. Wu, V.K. Narasimhan, D. Kong, H.R. Lee, Y. Cui, Nat. Commun. 4, 2522 (2013)

8. D.A. Dinh, K.N. Hui, K.S. Hui, P. Kumar, J. Singh. Rev. Adv. Sci. Eng. 2, 324 (2013)

9. Y. Zhang, W. Xu, S. Xu, G. Fei, Y. Xiao, J. Hu, Nanoscale Res. Lett. 7, 569 (2012)

10. G. Hrkac, J. Dean, D.A. Allwood, Phil. Trans. Phil. Trans. R. Soc. A369, 3214 (2011)

11. Y. Bian, Z. Cheng, X. Zhao, L. Liu, Y. Su, J. Xiao, J. Liu, J. Zhu, T. Zhou, J. Lightwave Technol. 31, 1973 (2013)

12. W.L. Barnes, A. Dereux, T.W. Ebbesen, Nature 424, 824 (2003)

13. Ch. Valsecchi, Al. G. Brolo. Langmuir 29, 5638 (2013)

14. D.A. Bussian, S.A. Crooker, M. Yin, M. Brynda, Al. L. Efros, V.I. Klimov. Nat. Mater. 8, 35 (2008)

15. V.A. Vlaskin, R.G. Beaulac, R. Daniel, Nano Lett. 9, 4376 (2009)

16. M.E. Toimil Molares, V. Buschmann, D. Dobrev, R. Neumann, R. Scholz, I.U. Schuchert, J. Vetter. Single-crystalline copper nanowires

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produced by electrochemical deposition in polymeric ion track membranes. Adv. Mater. 13, 62 (2001)

17. T. Ohgai, I. Enculescu, C. Zet, L. Westerberg, K. Hjort, R. Spohr, R. Neumann, J. Appl. Electrochem. 36, 1157 (2006)

18. W. Schwarzacher, O.I. Kasyutich, P.R. Evans, M.G. Darbyshire, G. Yi, V.M. Fedosyuk, F. Rousseaux, E. Cambril, D. Decanini. J. Magn. Magn. Mater. 198–199, 185 (1999)

19. L. Gravier, A. Fabian, A. Rudolf, A. Cachin, K. Hjort, J-Ph Ansermet, Meas. Sci. Tech. 15, 420 (2004)

20. M. Sima, I. Enculescu, T. Visan, R. Spohr, C. Trautmann. Mol. Cryst. Liquid Cryst. 418, 21(749) (2004)

21. M. Sima, I. Enculescu, E. Vasile, J. Optoelectron. Adv. Mater. 8, 825 (2006)

22. T. Ohgai, L. Gravier, X. Hoffer, J-Ph Ansermet, J. Appl. Electrochem. 35, 479 (2005)

23. D. Xu, Y. Xu, D. Chen, G. Guo, L. Gui, Y. Tang, Chem. Phys. Lett. 325, 340 (2000)

24. K. Nielsch, F. Müller, A. Li, U. Gösele, Uniform nickel deposition into ordered alumina pores by pulsed electrodeposition. Adv. Mater. 12, 582 (2000)

25. I.U. Schuchert, M.E. Toimil Molares, D. Dobrev, J. Vetter, R. Neumann, M. Martin. J. Electrochem. Soc. 150, C189 (2003)

26. W. Lee, R. Scholz, K. Nielsch, U. Gosele, Angew. Chem. Int. Ed. 44, 6050 (2005)

27. G. Sharma, M.V. Pishko, C.A. Grimes, Fabrication of metallic nanowire arrays by electrodeposition into nanoporous alumina membranes: effect of barrier layer. J. Mater. Sci. 42, 4738–4744 (2007)

28. M. Motoyama, Y. Fukunaka, T. Sakka, Y.H. Ogata. Electrochim. Acta 53, 205 (20057)

29. E. Ferain, R. Legras. Heavy ion tracks in polycarbonate. Comparison with a heavy ion irradiated model compound (diphenyl carbonate). Nucl. Instrum. Meth. B 82, 539–548 (1993)

30. E. Ferain, R. Legras, Track-etched membrane: dynamics of pore formation. Nucl. Instrum. Meth. B 84, 331–336 (1994)

2016, pag. 473-506

31. B. Bercu, I. Enculescu, R. Spohr, Nucl. Instrum. Meth. Phys. B 225, 497 (2004)

32. I. Enculescu, M. Sima, M. Enculescu, E. Matei, M.E. Toimil Molares, Th. Cornelius. Nickel nanotubes prepared by electroless deposition in ion track templates. Optoelectr. Adv. Mater. Rapid Commun. 2, 133–136 (2008)

33. H. Masuda, K. Fukuda, Ordered metal nanohole arrays made by a two-step replication of honeycomb structures of anodic alumina. Science 268, 1466–1468 (1995)

34. G. Ali, M. Ahmad, J.I. Akhter, M. Maqbool, S.O. Cho, Novel structure formation in porous anodic alumina fabricated by single step anodization process. Micron 41, 560–564 (2010)

35. G. Ali, M. Maqboo, Fabrication of cobalt-nickel binary nanowires in a highly ordered alumina template via AC electrodeposition. Nanoscale Res. Lett. 8, 352 (2013)

36. S. Shamaila, R. Sharif, S. Riaz, M. Khaleeq-ur-Rahman, X.F. Han. Fabrication and magnetic characterization of CoxPt1-X nanowire arrays. Appl. Phys. A. 92, 687–691 (2008)

37. S. Shamaila, R. Sharif, S. Riaz, M. Ma, M. Khaleeq-ur-Rahman, X.F. Han, Magnetic and magnetization properties of electrodeposited fcc CoPt nanowire arrays. J. Magn. Magn. Mater. 320, 1803–1809 (2008)

38. S. Shamaila, R. Sharif, J.Y. Chen, H.R. Liu, X.F. Han, X.F. Magnetic, Field annealing dependent magnetic properties of Co1-xPtx nanowire arrays. J. Magn. Magn. Mater. 321, 3984–3989 (2009)

39. R. Sharif, X.Q. Zhang, S. Shamaila, S. Riaz, L.X. Jiang, X.F. Han. Magnetic and magnetization properties of CoFeB nanowires. J. Magn. Magn. Mater. 310, e830–e832 (2007)

40. H. Masuda, H. Yamada, M. Satoh, H. Asoh, Appl. Phys. Lett. 71, 2770 (1997)

41. C.L. Chen, Y.-Y. Chen, S.-J. Lin, J.C. Ho, P.-C. Lee, C.-D. Chen, S.R. Harutyunyan, Fabrication and characterization of electrodeposited bismuth telluride films and nanowires. J. Phys. Chem. C 114, 3385–3389 (2010)

42. R. Inguanta, M. Butera, C. Sunseri, S. Piazza, Fabrication of metal nano-structures using anodic alumina membranes grown in phosphoric acid

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solution: tailoring template morphology. Appl. Surf. Sci. 253, 5447–5456 (2007)

43. K. Shimizu, K. Kobayashi, G.E. Thompson, G.C. Wood, Philos. Mag. A 66, 643–652 (1992)

44. H. Fujikura, A. Liu, A. Hamamatsu, T. Sato, H. Hasegawa, Jpn. J. Appl. Phys. 39, 4616 (2000)

45. T. Hirano, A. Ito, T. Sato, F. Ishikawa, H. Hasegawa, Jpn. J. Appl. Phys. 41, 977 (2002)

46. H. Föll, S. Langa, J. Carstensen, M. Christophersen, I.M. Tiginyanu, Adv. Mater. 15, 183 (2003)

47. H. Tsuchiya, M. Hueppe, T. Djenizian, P. Schmuki, Surf. Sci. 547, 268 (2003)

48. S. Langa, M. Christophersen, J. Carstensen, I.M. Tiginyanu, H. Föll, Phys. Status Solidi A 197, 77 (2003)

49. I.M. Tiginyanu, E. Monaico, V.V. Ursaki, V.E. Tezlevan, R.W. Boyd, Appl. Phys. Lett. 86, 063115 (2005)

50. I.M. Tiginyanu, E. Monaico, V.V. Ursaki, E. Foca, H. Föll, Electrochem. Solid State Lett. 10, D127 (2007)

51. I. Tiginyanu, E. Monaico, E. Monaico, Ordered arrays of metal nanotubes in semiconductor envelope. Electrochem. Commun. 10, 731 (2008)

52. M.E. Toimil Molares, N. Chtanko, T.W. Cornelius, D. Dobrev, I. Enculescu, R.H. Blick, R. Neumann. Fabrication and contacting of single Bi nanowires. Nanotechnology 15, S 201–S 207 (2004)

53. M. Sima, I. Enculescu, C. Trautmann, R. Neumann, Electrodeposition of CdTe nanorods in ion track membranes. J. Optoelectron. Adv. Mater. 6, 121–125 (2004)

54. G.E. Possin, Forming very small diameter wires. Rev. Sci. Instrum. 41, 772 (1970)

55. G.E. Possin. Superconductivity in nearly one-dimensional tin wires. Physica (Utrecht) 55, 339 (1971)

56. D.T. Mitchell, S.B. Lee, L. Trofin, N. Li, T.K. Nevanen, H. Soderlund, C.R. Martin, J. Am. Chem. Soc. 124, 11864 (2002)

57. D. Routkevitch, J. Chan, J.M. Xu, M. Moskovits, Electrochem. Soc. Proc. Ser. PV 350, 97 (1997)

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58. A.J. Yin, J. Li, W. Jian, A.J. Bennett, J.M. Xu, Fabrication of highly ordered metallic nanowire arrays by electrodeposition. Appl. Phys. Lett. 79, 1039 (2001)

59. H. Cao, L. Wang, Y. Qiu, Q. Wu, G. Wang, L. Zhang, X. Liu, Generation and growth mechanism of metal (Fe Co, Ni) nanotube arrays. ChemPhysChem 7, 1500–1504 (2006)

60. W.-C. You, J.-K. Lee, Field-dependent growth patterns of metals electroplated in nanoporous alumina membranes. Adv. Mater. 16, 1097–1101 (2004)

61. W. Lee, R. Scholz, K. Nielsch, U. Gosele, A template-based electrochemical method for the synthesis of multisegmented metallic nanotubes. Angew. Chem. 117, 6204–6208 (2005)

62. D.D. Sung, M.S. Choo, J.S. Noh, W.B. Chin, W.S. Yang, A new fabrication method of aluminum nanotube using anodic porous alumina film as a template. Bull. Korean Chem. Soc. 27, 1159 (2006)

63. G.N. Ivanova, D.D. Nedeoglo, N.D. Negeoglo, V.P. Sirkeli, I.M. Tiginyanu, V.V. Ursaki, J. Appl. Phys. 101, 063543 (2007)

64. I.M. Tiginyanu, V.V. Ursaki, E. Monaico, M. Enachi, V.V. Sergentu, G. Colibaba, D.D. Nedeoglo, A. Cojocaru, H. Föll, Quasi-ordered networks of metal nanotubes embedded in semiconductor matrices for photonic applications. J. Nanoelectr. Optoelectr. 6, 463–472 (2011)

65. I. Tiginyanu, E. Monaico, V. Sergentu, A. Tiron, V. Ursaki, Metallized porous GaP templates for electronic and photonic applications. ECS J. Solid State Sci. Technol. 4, P57–P62 (2015)

66. D. Vanmaekelbergh, A. Koster, F.I. Marin, Adv. Mater. 9, 575 (1997)

67. M. Scalora, G. D'Aguanno, N. Mattiucci, M.J. Bloemer, D. de Ceglia, M. Centini, A. Mandatori, C. Sibilia, N. Akozbek, M.G. Cappeddu, M. Fowler, J.W. Haus, Opt. Express 15, 508 (2007)

68. M. Bloemer, G. D'Aguanno, M. Scalora, N. Mattiucci, D. de Ceglia, Opt. Express 16, 19342 (2008)

69. J.B. Pendry, Negative refraction makes a perfect lens. Phys. Rev. Lett. 85, 3966 (2000)

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70. D.R. Smith, W.J. Padilla, D.C. Vier, S.C. Nemat-Nasser, S. Schultz, Composite medium with simultaneously negative permeability and permittivity. Phys. Rev. Lett. 84, 4184 (2000)

71. L.-M. Li, Z.-Q. Zhang, Multiple-scattering approach to finite-sized photonic band-gap materials. Phys. Rev. B 58, 9587 (1998)

72. V.V. Sergentu, I.M. Tiginyanu, V.V. Ursaki, M. Enachi, S.P. Albu, P. Schmuki. Negative index material lenses based on metallo-dielectric nanotubes. Phys. Stat. Sol. (RRL) 2, 242 (2008)

73. M. Hofman, G. Scherrer, M. Kadic, X. Melique, W. Smigaj, B. Cluzel, S. Guenneau, D. Lippens, F. de Fornel, B. Gralak, O. Vanbesien, J. Nanomed. Nanotechnol. 4, 1000185 (2013)

74. G. Scherrer, M. Hofman, W. Smigaj, M. Kadic, T.M. Chang, X. Melique, D. Lippens, O. Vanbesien, B. Cluzel, F. de Fornel, S. Guenneau, B. Gralak, Phys. Rev. B 88, 115110 (2013)

75. M. Hofman, D. Lippens, O. Vanbesien, Appl. Opt. 49, 5806 (2010)

76. M. Enachi, I. Tiginyanu, V. Sprincean, V. Ursaki, Self-organized nucleation layer for the formation of ordered arrays of double-walled TiO2 nanotubes with temperature controlled inner diameter. Phys. Status Solidi RRL 4, 100–102 (2010)

77. F. Wen, S. David, X. Checoury, M. El Kurdi, P. Boucaud, Opt. Express 16, 12278 (2008)

78. L.R. Moore, M. Zborowski, L. Sun, J.J. Chalmers, J. Biochem. Biophys. Methods 37, 11 (1998)

79. J. Escrig, P. Landeros, D. Altbir, E.E. Vogel, J. Magn. Magn. Mater. 310, 2448 (2007)

80. S.B. Lee, D.T. Mitchell, L. Trofin, T.K. Nevanen, H. Sderlund, C.R. Martin, Science 296, 2198 (2002)

81. C.R. Martin, P. Kohli, Nat. Rev. Drug Discov. 2, 29 (2003)

82. H. Hillebrenner, F. Buyukserin, J.D. Stewar, C.R. Martin, Nanomedicine 1, 39 (2006)

83. D.R. Baselt, G.L. Lee, M. Natesan, S.W. Metzger, P.E. Sheehan, R.J. Colton. Biosens. Bioelectron. 13, 731 (1998)

84. R. Fan, R. Karnik, M. Yue, D. Li, A. Majumdar, P. Yang, Nano Lett. 5, 1633 (2005)

2016, pag. 473-506

85. P. Ball. Nanowire sensors pass drugs test. Nat. Nanozone News (2005)

86. F.J. Alenghat, B. Fabry, K.Y. Tsai, W.H. Goldmann, D.E. Ingber, Biochem. Biophys. Res. Commun. 277, 93 (2000)

87. R.J. Mannix, S. Kumar, F. Cassiola, M. Montoya-Zavala, E. Feinstein, M. Prentiss, D.E. Ingber, Nature Nanotech. 3, 36 (2008)

88. K. Bullis, Technol. Rev. 109, 16 (2006)

89. R.R. Llinas, K.D. Walton, M. Nakao, I. Hunter, P.A. Anquetil, Neuro-vascular central nervous recording/stimulating system: using nanotechnology probes. J. Nanoparticle Res. 7, 111–127 (2005)