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- [1] Kivelson, S., & Heeger, A.J. Intrinsic conductivity of conducting polymers, *Synth. Met.* **22**(4), 371-384, 1988.
- [2] Shirakawa, H., Louis, E.J., MacDiarmid, A.G., Chiang, C.K. & Heeger, A.J. Synthesis of electrically conducting organic polymers: Halogen derivatives of polyacetylene, (CH)<sub>x</sub>. *J. Chem. Soc., Chem. Commun.* (16), 578-580, 1977.
- [3] Batchelder, D.N. Colour and chromism of conjugated polymers, *Contemp. Phys.* **29**(1), 3-31, 1988.
- [4] Kaake, L.G., Barbara, P.F. & Zhu, X.Y. Intrinsic Charge Trapping in Organic and Polymeric Semiconductors: A Physical Chemistry Perspective, *J. Phys. Chem. Lett.*, 1(3) 628-635, 2010.
- [5] Long, Y.Z., Li, M.M., Gu, C., Wan, M., Duvail, J.L., Liu, Z., & Fan, Z. Recent advances in synthesis, physical properties and applications of conducting polymer nanotubes and nanofibers, *Prog. Polym. Sci.* **36**(10), 1415-1442, 2011.
- [6] MacDiarmid, A.G. "Synthetic Metals": A Novel Role for Organic Polymers (Nobel Lecture), *Angew. Chem. Int. Ed.* **40**(14), 2581-2590, 2001.
- [7] Gerard, M., Chaubey, A., & Malhotra, B.D. Application of conducting polymers to biosensors, *Biosens. Bioelectron.* **17**(5) 345-359, 2002.
- [8] Bai, H. & Shi, G. Gas Sensors Based on Conducting Polymers, *Sensors* **7**(3), 267-307, 2007.
- [9] Ding, J., Zhou, D., Spinks, G., Wallace, G., Forsyth, S., Forsyth, M. & MacFarlan, D. Use of Ionic Liquids as Electrolytes in Electromechanical Actuator Systems Based on Inherently Conducting Polymers, *Chem. Mater.* **15**(12), 2392-2398, 2003.
- [10] Snook, G.A., Kao, P. & Best, A.S. Conducting-polymer-based supercapacitor devices and electrodes, *J. Power Sources* **96**(1), 1-12, 2011.
- [11] Cai, Z., Geng, M., & Tang, Z. Novel battery using conducting polymers: Polyindole and polyaniline as active materials, *J. Mater. Sci.* **39**(12), 4001-4003, 2004.

- [12] Coskun, Y., Cirpan, A., & Toppare, L. Construction of electrochromic devices using thiophene based conducting polymers, *J. Mater. Sci.* **42**(1), 368-372, 2007.
- [13] Price, W.E., Too, C.O., Wallace, G.G., & Zhou, D. Development of membrane systems based on conducting polymers, *Synth. Met.* **102**(1-3) 1338-1341, 1999.
- [14] Svirskis, D., Travas-Sejdic, J., Rodgers, A., & Garg, S. Electrochemically controlled drug delivery based on intrinsically conducting polymers, *J. Control. Release* **146**(1), 6-15, 2010.
- [15] Pei, J., Yu, W.L., & Huang, W. A Novel Series of Efficient Thiophene-Based Light-Emitting Conjugated Polymers and Application in Polymer Light-Emitting Diodes, *Macromolecules* **33**(7), 2462-2471, 2000.
- [16] Tallman, D.E., Spinks, G., Dominis, A., & Wallace, G.G. Electroactive conducting polymers for corrosion control, *J. Solid State Electrochem.* **6**(2), 73-84, 2002.
- [17] Facchetti A.  $\pi$ -Conjugated Polymers for Organic Electronics and Photovoltaic Cell Applications, *Chem. Mater.* **23**(3), 733-758, 2011.
- [18] Zhang, F., Johansson, M., Andersson, M.R., Hummelen, J.C., & Inganas, O. Polymer Photovoltaic Cells with Conducting Polymer Anode, *Adv. Mater.* **14**(9), 662-665, 2002.
- [19] Xue, F., Su, Y., & Varahramyan, K. Conducting Polypyrrole-based Field Effect Transistors Fabricated by Spin Coating and Inkjet Printing, *Spring MRS Conference Symposium I* **814**, 2004.
- [20] Covington, J.A., Gardner, J.W., Bartlett, P.N., & Toh, C.S. Conductive polymer gate FET devices for vapour sensing, *IEE Proceedings-Circuits Devices and Systems* **151**(4) 326-334, 2004.
- [21] Ashizawa, S., Shinohara, Y., Shindo, H., Watanabe, Y., & Okuzaki, H. Polymer FET with a Conducting Channel, *Synth. Met.* **153**(1-3), 41-44, 2005.
- [22] Liu, Y., Varahramyan, K., & Cui, T. Low-Voltage All-Polymer Field-Effect Transistor Fabricated Using an Inkjet Printing Technique, *Macromol. Rapid Commun.* **26**(24), 1955-1959, 2005.
- [23] Shrivastava, A.G., Bavane, R.G., & Mahajan, A.M. Electronic nose: A toxic gas sensor by polyaniline thin film conducting polymer, *International Workshop on Physics of Semiconductor Devices*, 621-623, 2007.

- [24] Sukeerthi, S. & Contractor, A.Q. Molecular Sensors and Sensor Arrays Based on Polyaniline Microtubules, *Anal. Chem.* **71**(11), 2231-2236, 1999.
- [25] Pringsheim, E., Zimin, D., & Wolfbei O.S. Fluorescent Beads Coated with Polyaniline: A Novel Nanomaterial for Optical Sensing of pH, *Adv. Mater.* **13**(11), 819-822, 2001.
- [26] Bossi, A., Piletsky, S.A., Piletska, E.V., Righetti, P.G., & Turner, A.P.F. An Assay for Ascorbic Acid Based on Polyaniline-Coated Microplates, *Anal. Chem.* **72**(18), 4296-4300, 2000.
- [27] Virji, S., Huang, J., Kaner, R.B. & Weiller B.H. Polyaniline Nanofiber Gas Sensors: Examination of Response Mechanisms, *Nano Lett.* **4**(3), 491-496, 2004.
- [28] Krishnamoorthy, K., Gokhale, R.S., Contractor, A.Q. & Kumar, A. Novel label-free DNA sensors based on poly(3,4ethylenedioxythiophene), *Chem. Commun.* (7), 820-821, 2004.
- [29] Wang, J., Bunimovich, Y.L., Sui, G.D., Savvas, S., Wang, J.Y., Guo, Y.Y., Heath, J.R., & Tseng H.R. Electrochemical Fabrication of Conducting Polymer Nanowires in an Integrated Microfluidic System, *Chem. Commun.* (29), 3075-3077, 2006.
- [30] Ramanathan, K., Bangar, M.A., Yun, M., Chen, W., Myung, N.V., & Mulchandani, A. Bioaffinity Sensing Using Biologically Functionalized Conducting-Polymer Nanowire, *J. Am. Chem. Soc.* **127**(2), 496-497, 2005.
- [31] Forzani, E.S., Zhang, H.Q., Nagahara, L.A., Amlani, I., Tsui, R., & Tao, N. A Conducting Polymer Nanojunction Sensor for Glucose Detection, *Nano Lett.* **4**(9), 1785-1788, 2004.
- [32] Colaneri, N.F., & Shacklette, L.W. EMI Shielding Measurements of Conductive Polymer Blends, *IEEE Trans. Instrum. Meas.* **41**, 291-297, 1992.
- [33] Ezquerra, T.A., Kremer, F., Mohammadi, M., Ruhe, J., Wegner, G., & Wessling, B. A.C. Conductivity Measurements in Polymeric Insulator Conductor Systems, *Synth. Met.* **28**(1-2), 83-88, 1989.
- [34] Taka, T. EMI shielding measurements on poly(3-octyl thiophene) blends, *Synth. Met.* **41**(3), 1177-1180, 1991.

- [35] Dhawan, S.K., Singh, N., & Venkatachalam, S. Shielding Effectiveness of Conducting Polyaniline Coated Fabrics at 101 GHz, *Synth. Met.* **125**(3), 389-393, 2001.
- [36] Lee, C.Y., Song, H.G., Jang, K.S., Oh, E.J., Epstein, A.J., & Joo, J. Electromagnetic interference shielding efficiency of polyaniline mixtures and multilayer films, *Synth. Met.* **102**(1-3), 1346-1349, 1999.
- [37] Koul, S., Chandra, R., & Dhawan, S.K. Conducting polyaniline composite for ESD and EMI at 101 GHz, *Polym.* **41**(26), 9305-9310, 2000.
- [38] Kim, H.K., Kim, M.S., Song, K., Park, Y.H., Kim, S.H., Joo, J., & Lee, J.Y. EMI Shielding Intrinsically Conducting Polymer/PET Textile Composites, *ICSM International Conference on Science and Technology of Synthetic Metals*, **135**(36), 881, 2002.
- [39] Burroughes, J.H., Bradley, D.D.C., Brown, A.R., Marks, R.N., Mackay, K., Friend, R.H., Burns, P.L. & Holmes, A. B. Light Emitting-Diodes Based on Conjugated Polymers, *Nature* **347**, 539-541, 1990.
- [40] Baughman, R.H. Conducting Polymer Artificial Muscles, *Synth. Met.* **78**(3), 339-353, 1996.
- [41] Hara, S., Zama, T., Takashima, W., Kaneto, K. Artificial Muscles Based on Polypyrrole Actuators with Large Strain and Stress Induced Electrically, *Polym. J.* **36**(2), 151-161, 2004.
- [42] Otero, T.F., & Broschart, M. Polypyrrole artificial muscles: a new rhombic element. Construction and electrochemomechanical characterization, *J. Appl. Electrochem.* **36**(2), 205-214, 2006.
- [43] Chiang, C.K., Fincher, C.R., Jr., Park, Y.W., Heeger, A.J., Shirakawa, H., Louis, E.J., & MacDiarmid, A.G. Electrical Conductivity in Doped Polyacetylene, *Phys. Rev. Lett.* **39**(17), 1098-1101, 1977.
- [44] Chiang, C.K., Drury, M.A., Gau, S.C., Heeger, A.J., Louis, E.J., MacDiarmid, A.G., Park, Y.W., & Shirakawa, H. Synthesis of highly conducting films of derivatives of polyacetylene, (CH)<sub>x</sub>, *J. Am. Chem. Soc.* **100**(3), 1013-1015, 1978.
- [45] Kumar, D., & Sharma, R.C. Advances in Conductive Polymers, *Eur. Polym. J.* **34**(8), 1053-1060, 1998.

- [46] Ziemelis, K.E., Hussain, A.T., Bradley, D.D.C., Friend, R.H., Rilhe, J., & Wegner, G. Optical spectroscopy of field-induced charge in poly(3-hexyl thienylene) metal-insulator-semiconductor structures: Evidence for polarons, *Phys. Rev. Lett.* **66**(17), 2231-2234, 1991.
- [47] Burroughes, J.H., Jones, C.A., & Friend, R.H. New semiconductor device physics in polymer diodes and transistors, *Nature* **335**, 137-141, 1988.
- [48] Chiang, J.C., MacDiarmid, A.G. 'Polyaniline': Protonic acid doping of the emeraldine form to the metallic regime, *Synth. Met.* **13**(1-3), 193-205, 1986.
- [49] MacDiarmid, A.G., & Epstein, A.J. Polyanilines: a novel class of conducting polymers, *Faraday Discuss. Chem. Soc.* **88**, 317-332, 1989.
- [50] Han, C.C., & Elsenbaumer, R.L., Protonic acids: Generally applicable dopants for conducting polymers, *Synth. Met.* **30**(1), 123-131, 1989.
- [51] Skotheim, T.A., & Reynolds, J.R., *Conjugated Polymers: Theory, Synthesis, Properties, and Characterization*, CRC press(Ed) Taylor & Francis Group, Florida, 2006.
- [52] Wallace, G.G., Spinks, G. M., Kane-Maguire, L.A.P., & Teasdale, P.R. *Handbook of Conductive Polymers*, 3<sup>rd</sup> ed., CRC Press Taylor & Francis Group, Florida, 2009.
- [53] Skotheim, T.A., & Reynolds, J.R. *Conjugated polymers processing and applications*, 3<sup>rd</sup> ed., CRC Press Taylor & Francis Group, Florida, 2007.
- [54] Bredas, J.L., & Street, G.B. Polaron, Bipolaron and Solitons in Conducting Polymers, *Acc. Chem. Res.* **18**(10), 309-315, 1985.
- [55] Wang, L.X., Li, X.G., & Yang Y.L. Preparation, properties and applications of polypyrroles, *React. Funct. Polym.* **47**(2), 125-139, 2001.
- [56] Zhang, X., & Manohar, S.K. Narrow Pore-Diameter Polypyrrole Nanotubes, *J. Am. Chem. Soc.* **127**(41), 14156-14157, 2005.
- [57] Pringle, J.M., Winther-Jensen, O., Lynam, C., Wallace, G.G., Forsyth, M., & MacFarlane, D.R. One-Step Synthesis of Conducting Polymer-Noble Metal Nanoparticle Composites using an Ionic Liquid, *Adv. Funct. Mater.* **18**(14), 2031-2040, 2008.
- [58] Zhang, X., & Manohar, S.K. Bulk Synthesis of Polypyrrole Nanofibers by a Seeding Approach, *J. Am. Chem. Soc.* **126**(40), 12714-12715, 2004.

- [59] Xu, P., Han, X., Zhang, B., Mack, N.H., Jeon, S.H., & Wang, H.L. Synthesis and characterization of nanostructured polypyrroles: Morphology-dependent electrochemical responses and chemical deposition of Au nanoparticles, *Polymer* **50**(12), 2624-2629, 2009.
- [60] Wanekay, A.K., Nosang, W.C., Myung, V., & Mulchandani, A. Nanowire-Based Electrochemical Biosensor, *Electroanal.* **18**(6), 533-550, 2006.
- [61] Wan, M. Some issues related to polyaniline micro/nanostructures, *Macromol. Rapid. Commun.* **30**(12), 963-975, 2009.
- [62] Wan, M. A. Template-Free Method Towards Conducting Polymer Nanostructures, *Adv. Mater.* **20**(15), 2926-2932, 2008.
- [63] Wan, M., Huang, J., & Shen, Y. Microtubes of conducting polymers, *Synth. Met.* **101**(1-3), 708-711, 1999.
- [64] Huang, J., & Kaner, R.B. Nanofiber Formation in the Chemical Polymerization of Aniline: A Mechanistic Study, *Angew. Chem. Int. Ed.* **116**(43), 5941-5945, 2004.
- [65] Chiou, N.R., & Epstein, A.J. Polyaniline Nanofibers Prepared by Dilute Polymerization, *Adv. Mater.* **17**(13), 1679-1683, 2005.
- [66] Jang, J., & Yoon, H. Facile fabrication of polypyrrole nanotubes using reverse microemulsion polymerization, *Chem. Commun.* (6), 720-721, 2003.
- [67] Liu, H., Hu, X.B, Wang, J.Y., & Boughton, R.I. Structure, Conductivity, and Thermopower of Crystalline Polyaniline Synthesized by the Ultrasonic Irradiation Polymerization Method, *Macromolecules* **35**(25), 9414-9419, 2002.
- [68] Pillalamarri, S.K., Blum, F.D., Tokuhiko, A.T., Story, J.G., & Bertino, M.F. Radiolytic Synthesis of Polyaniline Nanofibers: A New Templateless Pathway, *Chem. Mater.* **17**(2), 227-229, 2005.
- [69] Huang, W.S., Humphrey, B.D., & MacDiarmid, A.G. Polyaniline, a novel conducting polymer. Morphology and chemistry of its oxidation and reduction in aqueous electrolytes. *J. Chem. Soc., Faraday Trans.* **82**(8), 2385-2400, 1986.
- [70] Zhang, X.T., Zhang, J., Song, W.B., & Liu, Z.F. Controllable Synthesis of Conducting Polypyrrole Nanostructures, *J. Phys. Chem. B* **110**(3), 1158-1165, 2006.
- [71] Rao, J.P., & Geckeler, K.E. Polymer nanoparticles: Preparation techniques and size-control parameters, *Prog. Polym. Sci.* **36**(7), 887-913, 2011.

- [72] Klapper, M., Neno, S., Haschic, R., Mulle, K., & Mulle, K. Oil-in-Oil Emulsions: A Unique Tool for the Formation of Polymer Nanoparticles, *Acc. Chem. Res.* **41**(9), 1190-1201, 2008.
- [73] Jang, J., & Yoon, H. Formation Mechanism of Conducting Polypyrrole Nanotubes in Reverse Micelle Systems, *Langmuir* **21**(24), 11484-11489, 2005.
- [74] Zhang, X., Lee, J.S., Lee, G.S., Cha, D.K., Kim, M.J., Yang, D.J., & Manoha, S.K. Chemical Synthesis of PEDOT Nanotubes, *Macromolecules* **39**(2), 470-472, 2006.
- [75] AlMawiawi, D., Coombs, N., & Moskovits, M. Magnetic properties of Fe deposited into anodic aluminum oxide pores as a function of particle size, *J. Appl. Phys.* **70**(8), 4421-4425, 1991.
- [76] Fleischer, R.L., Price, P.B., & Walker, R.M. *Nuclear Tracks in Solids*, University of California Press, Berkeley, 1975.
- [77] Despic, A., & Parkhutik, V.P. *In Modern Aspects of Electrochemistry* (J.O. Bockris, R.E. White, B.E. Conway, Eds.), Plenum Press, New York, 1989.
- [78] Martin, C.R. Template Synthesis of Electronically Conductive Polymer Nanostructures, *Acc. Chem. Res.* **28**(2), 61-68, 1995.
- [79] Granstrom, M., & Inganas, O. Electrically conductive polymer fibres with mesoscopic diameters: 1. Studies of structure and electrical properties, *Polymer* **36**(15), 2867-2872, 1995.
- [80] Liu, R., II Cho, S. & Lee, S.B. Poly(3,4-ethylenedioxythiophene) nanotubes as electrode materials for a high-powered supercapacitor, *Nanotechnology* **19**(21), 215710(8pp), 2008.
- [81] Cho, S.I., & Lee, S.B. Fast Electrochemistry of Conductive Polymer Nanotubes: Synthesis, Mechanism, and Application, *Acc. Chem. Res.* **41**(6), 699-707, 2008.
- [82] Liu, R., & Lee, S.B. MnO<sub>2</sub>/Poly(3,4-ethylenedioxythiophene) Coaxial Nanowires by One-Step Coelectrodeposition for Electrochemical Energy Storage, *J. Am. Chem. Soc.* **130**(10), 2942-2943, 2008.
- [83] Beadle, P., Armes, S.P., Gottesfeld, S., Mombourquette, C., Houlton, R., Andrews, W.D., & Agnew, S.F. Electrically conductive polyaniline-copolymer latex composites, *Macromolecules* **25**(9), 2526-2530, 1992.



- [84] Niu, Z., Liu, J., Lee, L.A., Bruckman, M.A., Zhao, D., Koley, G., & Wang, Q. Biological Templated Synthesis of Water-Soluble Conductive Polymeric Nanowires, *Nano Lett.* **7**(12), 3729-3733, 2007.
- [85] Niu, Z.W., Bruckman, M.A., Li, S.Q., Lee, L.A., Lee, B., Pingali, S.V., Thiagarajan, P., & Wang, Q. Assembly of Tobacco Mosaic Virus into Fibrous and Macroscopic Bundled Arrays Mediated by Surface Aniline Polymerization, *Langmuir* **23**(12), 6719-6724, 2007.
- [86] Luo, S.C., Yu, H., Wan, A.C.A.; Han, Y., Ying, J.Y. A General Synthesis for PEDOT-Coated Nonconductive Materials and PEDOT Hollow Particles by Aqueous Chemical Polymerization, *Small* **4**(11), 2051-2058, 2008.
- [87] Fu, G.D., Zhao, J.P., Sun, Y.M., Kang, E.T., & Neoh, K.G. Conductive Hollow Nanospheres of Polyaniline via Surface-Initiated Atom Transfer Radical Polymerization of 4-Vinylaniline and Oxidative Graft Copolymerization of Aniline, *Macromolecules* **40**(6), 2271-2275, 2007.
- [88] Wu, C.G., & Bein, T., Conducting Polyaniline Filaments in a Mesoporous Channel Host, *Science* **264**(5166), 1757-1759, 1994.
- [89] Parthasarathy, R.V., & Martin C.R. Template-Synthesized Polyaniline Microtubules, *Chem. Mater.* **6**(10), 1627-1632, 1994.
- [90] Ozin, G.A. Nanochemistry: Synthesis in diminishing dimensions, *Adv. Mater.* **4**(10), 612-649, 1992.
- [91] Xia, L., Wei, Z., & Wan, M. Conducting polymer nanostructures and their application in biosensor, *J. Colloid Interface Sci.* **341**(1), 1-11, 2010.
- [92] Hulteen, J.C., & Martin, C.R. A general template-based method for the preparation of nanomaterials, *J. Mater. Chem.* (7), 1075-1087, 1997.
- [93] Huang, J., Virji, S., Weiller, B.H., & Kaner, R.B. Polyaniline nanofibers: Facile Synthesis and Chemical Sensors, *J. Am. Chem. Soc.* **125**(2), 314-315, 2003.
- [94] Huang, J., & Kaner, R.B. A General Chemical Route to Polyaniline Nanofibers, *J. Am. Chem. Soc.* **126**(3), 851-855, 2004.
- [95] Nuraje, N., Su, K., Yang, N.L., & Matsui, H. Liquid/Liquid Interfacial Polymerization To Grow Single Crystalline Nanoneedles of Various Conducting Polymers, *ACS Nano* **2**(3), 502-506, 2008.
- [96] Su, K., Nuraje, N., Zhang, L.Z., Chu, I.W., Peetz, R.M., Matsui, H., & Yang, N.L. Fast Conductance Switching in Single-Crystal Organic Nanoneedles



- Prepared from an Interfacial Polymerization-Crystallization of 3,4-Ethylenedioxythiophene, *Adv. Mater.* **19**(5), 669-672, 2007.
- [97] Huang, Z.M., Zhang, Y.Z., Kotaki, M., & Ramakrishna, S. A review on Polymer nanofibers by electrospinning and their applications in nanocomposites, *Compos. Sci. Technol.* **63**(15), 2223-2253, 2003.
- [98] Greiner, A., & Wendorff, J.H. Functional self-assembled nanofibers by electrospinning, *Adv. Polym. Sci.* **219**, 107-171, 2008.
- [99] Norris, I.D., Shaker, M.M., Ko, F.K., & MacDiarmid, A.G. Electrostatic fabrication of ultrafine conducting fibers: polyaniline/polyethylene oxide blends, *Synth. Met.* **114**(2), 109-114, 2000.
- [100] MacDiarmid, A.G., Jones Jr, W.E., Norris, I.D., Gao, J., Johnson Jr, A.T., Pinto, N.J., Hone, J., Han, B., Ko, F.K., Okuzaki, H., & Llaguno M. Electrostatically-generated nanofibers of electronic polymers, *Synth. Met.* **119**(1-3), 27-30, 2001.
- [101] Cardenas, J.R., de Franca, M.G.O., de Vasconcelos, E.A., de Azevedo W.M., da Silva Jr, E.F. Growth of sub-micron fibres of pure polyaniline using the electrospinning technique, *J. Phys. D: Appl. Phys.* **40**(4), 1068-1071, 2007.
- [102] Kang, T.S., Lee, S.W., Joo, J., & Lee, J.Y. Electrically conducting polypyrrole fibers spun by electrospinning, *Synth. Met.* **153**(1-3), 61-64, 2005.
- [103] Chronakis, I.S., Grapenson, S., & Jakob, A. Conductive polypyrrole nanofibers via electrospinning: Electrical and morphological properties, *Polymer* **47**(5), 1597-1603, 2006.
- [104] Sadki, S., Schottland, P., Brodie, N., & Sabouraud, G. The mechanisms of pyrrole electropolymerization, *Chem. Soc. Rev.* **29**(5), 283-293, 2000.
- [105] Jang, J., Oh, J.H., & Stucky, G.D. Fabrication of Ultrafine Conducting Polymer and Graphite Nanoparticles, *Angew. Chem. Int. Ed.* **41**(21), 4016-4019, 2002.
- [106] Yan, F., Xue, G., & Zhou, M. Preparation of electrically conducting polypyrrole in oil/water microemulsion, *J. Appl. Polym. Sci.* **77**(1), 135-140, 2000.
- [107] Zelenev, A., Sonnenberg, W., & Matijevic, E. Preparation, characterization, and adhesion of monodispersed polypyrrole particles, *Colloid Polym. Sci.* **276**(9), 838-841, 1998.

- [108] Zha, Z., Yue, X., Ren, Q., Dai, Z., Uniform Polypyrrole Nanoparticles with High Photothermal Conversion Efficiency for Photothermal Ablation of Cancer Cells, *Adv. Mater.* **25**(5), 777-782, 2013.
- [109] Jang, J., Oh, J.H., & Li, X.L. A novel synthesis of nanocapsules using identical polymer core/shell nanospheres, *J. Mater. Chem.* **14**(19), 2872-2880, 2004.
- [110] Marinakos, S.M., Shultz, D.A., & Feldheim, D.L. Gold Nanoparticles as Templates for the Synthesis of Hollow Nanometer-Sized Conductive Polymer Capsule, *Adv. Mater.* **11**(1), 34-37, 1999.
- [111] Cheng, D., Xia, H., & Chan, H.S.O. Facile Fabrication of AgCl@Polypyrrole-Chitosan Core-Shell Nanoparticles and Polymeric Hollow Nanospheres, *Langmuir* **20**(23), 9909-9912, 2004.
- [112] Cheng, D., Zhou, X., Xia, H., & Chan, H.S.O. Novel Method for the Preparation of Polymeric Hollow Nanospheres Containing Silver Cores with Different Sizes, *Chem. Mater.* **17**(14), 3578-3581, 2005.
- [113] Jang, J., Li, X.L., & Oh, J.H. Facile fabrication of polymer and carbon nanocapsules using polypyrrole core/shell nanomaterials, *Chem. Commun.* (7), 794-795, 2004.
- [114] Yang, X., & Li, L. Polypyrrole nanofibers synthesized via reactive template approach and their NH<sub>3</sub> gas sensitivity, *Synth. Met.* **160**(11-12), 1365-1367, 2010.
- [115] Chronakis, I.S., Grapenson, S., & Jakob, A. Conductive polypyrrole nanofibers via electrospinning: Electrical and morphological properties, *Polymer* **47**(5), 1597-1603, 2006.
- [116] J. Feng, W. Yan, L. Zhang, Synthesis of polypyrrole micro/nanofibers via a self-assembly process, *Microchim. Acta* **166**(3), 261-267, 2009.
- [117] Menon, V.P., Lei, J., & Martin, C.R. Investigation of Molecular and Supramolecular Structure in Template-Synthesized Polypyrrole Tubules and Fibrils, *Chem. Mater.* **8**(9), 2382-2390, 1996.
- [118] Jang, J., Oh, J.H. A facile synthesis of polypyrrole nanotubes using a template-mediated vapor deposition polymerization and the conversion to carbon nanotubes, *Chem. Commun.* (7), 882-883, 2004.

- [119] Cai, Z., & Martin, C.R. Electronically conductive polymer fibers with mesoscopic diameters show enhanced electronic conductivities, *J. Am. Chem. Soc.* **111**(11), 4138-4139, 1989.
- [120] Vito, S.D, & Martin, C.R., Toward Colloidal Dispersions of Template-Synthesized Polypyrrole Nanotubules, *Chem. Mater.* **10**(7), 1738-1741, 1998.
- [121] Demoustier-Champagne, S., & Stavaux, P.Y. Effect of Electrolyte Concentration and Nature on the Morphology and the Electrical Properties of Electropolymerized Polypyrrole Nanotubules, *Chem. Mater.* **11**(3), 829-834, 1999.
- [122] He, Y., Yuan, J., & Shi, G. Fabrication of gold nanocrystal-coated polypyrrole nanotubules, *J. Mater. Chem.* **15**(8), 859-862, 2005.
- [123] Jang, J., & Yoon, H., Fabrication of Magnetic Carbon Nanotubes Using a Metal-Impregnated Polymer Precursor, *Adv. Mater.* **15**(24), 2088-2091, 2003.
- [124] Yang, X., Zhu, Z., Dai, T., & Lu, Y. Facile Fabrication of Functional Polypyrrole Nanotubes via a Reactive Self-Degraded Template, *Macromol. Rapid Commun.* **26**(21), 1736-1740, 2005.
- [125] Balanzat, E., Bouffard, S., Moel, A.L., & Betz, N. Physico-chemical modifications induced in polymers by swift heavy ions, *Nucl. Instr. Meth. B* **91**(1-4), 140-145, 1994.
- [126] Srivastava, A., Singh, V., Chandra, A., Witte, K., Scherer, U.M., & Singh, T.V. Electrical conductivity studies of swift heavy ion modified PVC and PVC-PANI composite, *Nucl. Instr. Meth. B* **245**(1), 277-280, 2006.
- [127] Iyer, R.M., & Markovic, V. IAEA's programme on applied radiation chemistry-polymers, *Nucl. Instr. Meth. B* **105**(1-4), 238-240, 1995.
- [128] Apel, P.Y., Didyk, A.Y., Fursov, B.I., Kravets, L.I., Nesterov, V.G., & Zhadanov, G.S., Particle track detection and relaxation transitions in polymer, *Nucl. Instr. Meth. B* **105**(1-4), 91-96, 1995.
- [129] Kaur, M., Singh, S., & Mehta, R. The Effect of O<sup>6+</sup> and Si<sup>7+</sup> Ion Beam Irradiations on Poly(lactide-co-glycolide) (50 : 50) Copolymer, *Polym. Sci. Ser. B* **56**(5), 657-663, 2014.
- [130] Ramola, R.C., Chandra, S., Negi, A., Rana, J.M.S., Annapoorni, S., Sonkawade, R.G., Kulriya, P.K., & Srivastava, A. Study of optical band gap,

- carbonaceous clusters and structuring in CR-39 and PET polymers irradiated by 100 MeV  $O^{7+}$  ions, *Physica B* **404**(1), 26-30, 2009.
- [131] Kanjilal, D. Swift heavy ion induced modification and track formation in materials, *Curr. Sci.* **80**(12), 1560-1566, 2001.
- [132] Leuser, D., & Dunlop, A. Damage creation via electronic excitations in metallic targets part II: A theoretical model, *Radiat. Eff. Defect Solids* **126**(1-4), 163-172, 1993.
- [133] Szenes, G. General features of latent track formation in magnetic insulators irradiated with swift heavy ions, *Phys. Rev. B* **51**(13), 8026-8029, 1995.
- [134] Pron, A., & Rannou, P. Processible conjugated polymers: from organic semiconductors to organic metals and superconductors, *Prog. Polym. Sci.* **27**(1), 135-190, 2002.
- [135] Liu, L., Tian, F., Wang, X., Yang, Z., Zhou, M., & Wang, X. Porous polythiophene as a cathode material for lithium batteries with high capacity and good cycling stability, *React. Funct. Polym.* **72**(1), 45-49, 2012.
- [136] Sangian, D., Zheng, W., & Spinks, G.M. Optimization of the sequential polymerization synthesis method for polypyrrole films, *Synth. Met.* **189**, 53-56, 2014.
- [137] Ansari, M.O., & Mohammad, F. Thermal Stability of HCl-Doped-Polyaniline and  $TiO_2$  Nanoparticles-Based Nanocomposites, *J. Appl. Polym. Sci.* **124**(6), 4433-4442, 2011.
- [138] Bueno, V.B., Takahashi, S.H., Catalani, L.H., de Torresi, S.I.C., & Petri, D.F.S., Biocompatible xanthan/polypyrrole scaffolds for tissue engineering, *Mater. Sci. Eng. C* **52**, 121-128, 2015.
- [139] Hamilton, A., & Breslin, C.B. The development of a novel urea sensor using polypyrrole, *Electrochim. Acta* **145**, 19-26, 2014.
- [140] Madden, J.D., Cush, R.A., Kanigan, T.S., & Hunter, I.W. Fast contracting polypyrrole actuators, *Synth. Met.* **113**(1-2), 185-192, 2000.
- [141] Cheng, F., Tang, W., Li, C., Chen, J., Liu, H., Shen, P., & Dou, S. Conducting Poly(aniline) Nanotubes and Nanofibers: Controlled Synthesis and Application in Lithium/Poly(aniline) Rechargeable Batteries, *Chem. Eur. J.* **12**(11), 3082-3088, 2006.

- [142] Wang, Z.L., Guo, R., Li, G.R., Lu, H.L., Liu, Z.Q., Xiao, F.M., Zhang, M., & Tong, Y.X. Polyaniline nanotube arrays as high-performance flexible electrodes for electrochemical energy storage devices, *J. Mater. Chem.* **22**(6), 2401-2404, 2012.
- [143] Sharma, M., Waterhouse, G.I.N., Loader, S.W.C., Garg, S., & Svirskis, D. High surface area polypyrrole scaffolds for tunable drug delivery, *Int. J. Pharm.* **443**(1-2), 163-168, 2013.
- [144] Pages, H., Topart, P., & Lemordant, D. Wide band electrochromic displays based on thin conducting polymer films, *Electrochim. Acta* **46**(13-14), 2137-2143, 2001.
- [145] Wu, X., Liu, J., & He, G. A highly conductive PEDOT: PSS film with the dipping treatment by hydroiodic acid as anode for organic light emitting diode, *Org. Electron.* **22**, 160-165, 2015.
- [146] Tsumura, A., Fuchigami, H., & Koezuka, H. Field-effect transistor with a conducting polymer film, *Synth. Met.* **41**(3), 1181-1184, 1991.
- [147] Fan, L.Z., & Maier, J. High-performance polypyrrole electrode materials for redox supercapacitors, *Electrochem. Commun.* **8**(6), 937-940, 2006.
- [148] Gunes, S., Neugebauer, H., & Sariciftci, N.S. Conjugated Polymer-Based Organic Solar Cells, *Chem. Rev.* **107**(4), 1324-1338, 2007.
- [149] Saxena, V., & Malhotra, B.D. Prospects of conducting polymers in molecular electronics, *Curr. Appl. Phys.* **3**(2-3), 293-305, 2003.
- [150] Duchet, J., Legras, R., & Champagne, S.D. Chemical synthesis of polypyrrole: structure-properties relationship, *Synth. Met.* **98**(2), 113-122, 1998.
- [151] Adhikari, A., Radhakrishnan, S., & Patil, R. Influence of dopant ions on properties of conducting polypyrrole and its electrocatalytic activity towards methanol oxidation, *Synth. Met.* **159**(15-16), 1682-1688, 2009.
- [152] Migahed, M.D., Ishra, M., Fahmy, T., & Barakat, A. Electric modulus and AC conductivity studies in conducting PPy composite films at low temperature, *J. Phys. Chem. Solids* **65**(6), 1121-1125, 2004.
- [153] Zhang, X., Zhu, J., Haldolaarachchige, N., J. Ryu, Young, D.P., Wei, S., & Guo, Z. Synthetic process engineered polyaniline nanostructures with tunable morphology and physical properties, *Polymer* **53**, 2109-2120, 2012.

- [154] Gu, H., Guo, J., Yan, X., Wei, H., Zhang, X., Liu, J., Huang, Y., Wei, S., & Guo, Z. Electrical transport and magnetoresistance in advanced polyaniline nanostructures and nanocomposites, *Polymer* **55**, 4405-419, 2014.
- [155] Elliott, S.R. AC conduction in amorphous chalcogenide and pnictide semiconductors, *Adv. Phys.* **36**(2), 135-218, 1987.
- [156] Mott, N.F. & Davis, E.A., *Electronic Processes in Non-Crystalline Materials*, Oxford University Press, London, 1979.
- [157] Jonscher, A.K. *Dielectric Relaxation in Solids*, Chelsea Dielectric, London, 1983.
- [158] Pollak, M. On the frequency dependence of conductivity in amorphous solids, *Philos. Mag.* **23**(183), 519-542, 1971.
- [159] Ghosh, A. Frequency-dependent conductivity in bismuth-vanadate glassy semiconductors, *Phys. Rev. B* **41**(3), 1479-1488, 1990.
- [160] Pollak, M. Temperature Dependence of ac Hopping Conductivity, *Phys. Rev.* **138**(6A), A1822 (1965).
- [161] Long, A.R. Frequency-dependent loss in amorphous semiconductors, *Adv. Phys.* **31**(5), 553-637, 1982.
- [162] Pike, G.E. ac Conductivity of Scandium Oxide and a New Hopping Model for Conductivity, *Phys. Rev. B* **6**(4), 1572-1579, 1972.
- [163] Elliott S.R. A theory of a.c. conduction in chalcogenide glasses, *Philos. Mag.* **36**(6), 1291-1304, 1977.
- [164] Elliott, S.R. Temperature dependence of a.c. conductivity of chalcogenide glasses, *Philos. Mag. B* **37**(5), 553-560, 1978.
- [165] Barton, J.L. Dielectric relaxation of some ternary alkali-alkaline earth-silicate glasses, *Verres Refract.* **20**, 328, 1966.
- [166] Nakajima, T. *Proceedings of the Annual Report Conference on Electric Insulation and Dielectric Phenomena*, National Academy of Sciences, Washington, DC, 1972.
- [167] Namikawa, H. Characterization of the diffusion process in oxide glasses based on the correlation between electric conduction and dielectric relaxation, *J. Non-Cryst. Solids* **18**(2), 173-195, 1975.
- [168] Summerfield, S. Universal low-frequency behaviour in the a.c. hopping conductivity of disordered systems, *Philos. Mag. B* **52**(1), 9-22, 1985.

- [169] Sidebottom D.L. Universal Approach for Scaling the ac Conductivity in Ionic Glasses, *Phys. Rev. Lett.* **82**(18), 3653-3656, 1999.
- [170] Sidebottom, D.L. Colloquium: Understanding ion motion in disordered solids from impedance spectroscopy scaling, *Rev. Mod. Phys.* **81**(3), 999-1014, 2009.
- [171] Jonscher, A.K. The universal dielectric response, *Nature* **267**, 673-679, 1977.
- [172] Jonscher, A.K. *Universal Relaxation Law*, Chelsea Dielectrics, London, 1996.
- [173] Kilbride B.E., Coleman J.N., Fraysse, J., Fournet, P., Cadek, M., Drury, A., Hutzler, S., Roth, S. & Blau, W.J. Experimental observation of scaling laws for alternating current and direct current conductivity in polymer-carbon nanotube composite thin films, *J. Appl. Phys.* **92**(7), 4024-4030, 2002.
- [174] Planes, J., Wolter, A., Cheguettine, Y., Pron, A., Genoud, F., & Nechtschein, M. Transport properties of polyaniline-cellulose-acetate blends, *Phys. Rev. B* **58**(12-15), 7774-7785, 1998.
- [175] Y. Feldman, A. Andrianov, E. Polygalov, I. Ermolina, Romanychev, G., Zue, Y., Milgoti, B. Time domain dielectric spectroscopy: An advanced measuring system, *Rev. Sci. Instrum.* **67**(9), 3208-3216, 1996.
- [176] Iskander, M.F., & DuBow, J.B. Time and frequency domain matrix for measuring the dielectric properties of rocks: A review, *J. Microwave Power* **18**, 55-74, 1983.
- [177] Bottcher, C.F.S., & Bordewijk, P. *Theory of Electric Polarization*, 2<sup>nd</sup> ed., Elsevier, Amsterdam, 1998.
- [178] Cole, K.S., & Cole, R.S. Dispersion and absorption in dielectrics: I. alternating current characteristics, *J. Chem. Phys.* **9**(4), 1484-1490, 1941.
- [179] Davidson, D.W. & Cole, R.H. Dielectric relaxation in glycerol, propylene glycol and N-propanol, *J. Chem. Phys.* **19**(12), 341-351, 1941.
- [180] Havriliak, S., & Negami, S. A Complex plane representation of dielectric and mechanical relaxation processes in some polymers, *Polymer* **8**, 161-210, 1967.
- [181] Dutta, P., Biswas, S., & De, S.K. Dielectric relaxation in polyaniline-polyvinyl alcohol composites, *Mater. Res. Bul.* **37**(1), 193-200, 2002.
- [182] Macedo, P.B., Moynihan, C.T., & Bose, R. The long time aspects of this correlation function, which are obtainable by bridge techniques at temperatures approaching the glass transition, *Phys. Chem. Glasses* **13**, 171, 1972.



- [183] Tsangaris, G.M., Psarras, G.C. & Kouloumbi, N. Electric modulus and interfacial polarization in composite polymeric systems, *J. Mater. Sci.* **33**(8), 2027-2037, 1998.
- [184] Soares, B.G., Leyva, M.E., Barraand, G.M.O., & Khastgi, D. Dielectric behaviour of polyaniline synthesised by different techniques, *Eur. Polym. J.* **42**, 676-86, 2005.
- [185] Dixon, R.K. Specific-heat spectroscopy and dielectric susceptibility measurements of salol at the glass transition, *Phys. Rev. B* **42**(13), 8179-8186, 1990.
- [186] Vinoth Rathan, S., & Govindaraj, G. Electrical relaxation studies on  $\text{Na}_2\text{NbMP}_3\text{O}_{12}$  (M=Zn, Cd, Pb and Cu) phosphate glasses, *Mater. Chem. Phys.* **120**(2-3), 255-262, 2010.
- [187] Bethe, H.A. *Ann. Phys.* **397**(3), 325-400, 1930.
- [188] Bloch, F. *Ann. Phys.*, **408**(3), 285-320, 1933.
- [189] Ahlen, S.P. Theoretical and experimental aspects of the energy loss of relativistic heavily ionizing particles, *Rev. Mod. Phys.* **52**(1), 121-174, 1980.
- [190] Bonderup, E. Stopping of Swift Protons Evaluated from Statistical Atomic Model, *Kgl. Dan. Vidensk. Selsk. Mat.-Fys. Medd.* **35**(17), 1-19, 1967.
- [191] Fano, U. Penetration of Protons, Alpha Particles, and Mesons, *Annu. Rev. Nucl. Sci.* **13**, 1-66, 1963.
- [192] Sautter, G.D., & Bloom, S.D. Theory of Effective Charge and Stopping Power for Heavy Ions, *Phys. Rev. B* **6**, 699-712, 1972.
- [193] Ziegler, J.F., & Iafrate, G.J. The stopping of energetic ions in solids, *Radiat. Eff.* **46**(3-4), 199-219, 1980.
- [194] Gumus, H. Simple stopping power formula for low and intermediate energy electrons, *Radiat. Phys. Chem.* **72**(1), 7-12, 2005.
- [195] Lindhard, J., & Scharff, M. Energy loss in matter by fast particles of low charge, *Kgl. Dan. Vidensk. Selsk. Mat. Fys. Medd.* **27**(15), (1953).
- [196] Lindhard, J., Influence of Crystal Lattice on Motion of Energetic Charged Particles, *Kgl. Dan. Vidensk. Selsk., Mat.-Fys. Medd.* **33**(14), 1965.
- [197] Bohr, N. The penetration of atomic particles through matter, *Kgl. Dan. Vidensk. Selsk. Mat. Fys. Medd.* **18**(8), 1948.

- [198] Sugiyama, H. Electronic stopping power formula for intermediate energies, *Radiat. Eff.* **56**(3-4), 205-211, 1981.
- [199] Sugiyama, H. Modification of Lindhard-Scharff-Schi øtt Formula for Electronic Stopping Power, *J. Phys. Soc. Japan* **50**, 929-932, 1981.
- [200] Ziegler, J.F., Biersack, J.P. & Littmark, U. *The Stopping and Range of Ions in Solids*, Pergamon Press, New York, 1985.
- [201] Audouard, A., Dural, J., Toulemonde, M., Lovas, A., Szenes, G., & Thome, L. Growth phenomenon in amorphous solids irradiated with GeV heavy ions: Electronic-energy-loss dependence of the initial growth rate, *Phys. Rev. B* **54**(22), 15690-15694, 1996.
- [202] Toulemonde, M. Nanometric phase transformation of oxide materials under GeV energy heavy ion irradiation, *Nucl. Instrum. Meth. B* **156**(1-4), 1-11, 1999.
- [203] Itoh, N., Duffy, D.M., Khakshouri, S., & Stoneham, A.M. Making tracks: electronic excitation roles in forming swift heavy ion tracks, *J. Phys.: Condens. Matter* **21**(47), 474205(14pp), 2009.
- [204] Aumayr, F., Facsko, S., EI-Said, A.S., Trautmann, C., & Schleberger, M. Single ion induced surface nanostructures: a comparison between slow highly charged and swift heavy ions, *J. Phys.: Condens. Matter* **23**(39), 393001(23pp), 2011.
- [205] Facsko, S., Heller, R., EI-Said, A.S., Meissl, W., & Aumayr, F. Surface nanostructures by single highly charged ions, *J. Phys.: Condens. Matter* **21**(22), 224012(9pp), 2009.
- [206] Fink, D., Alegaonkar, P.S., Petrov, A.V., Wilhelm, M., Szimkowiak, P., Behar, M., Sinha, D., Fahrner, W.R., Hoppe, K., & Chadderton, L.T. High energy ion beam irradiation of polymers for electronic applications, *Nucl. Instr. Meth. B* **236**(1-4), 11-20, 2005.
- [207] Chen, J., Klaumunzer, S., Lux-Steiner, M.C., & Konenkamp, R. Vertical nanowire transistors with low leakage current, *Appl. Phys. Lett.* **85**(8), 1401-1403, 2004.
- [208] Toulemonde, M., Trautmann, C., Balanzat, E., Hjort, K., & Weidinger, A. Track formation and fabrication of nanostructures with MeV-ion beams, *Nucl. Instr. and Meth. B* **216**, 1-8, 2004.
- [209] Karlusic, M., & Jaksic, M. Thermal spike analysis of highly charged ion tracks, *Nucl. Instr. Meth. B* **280**, 103-110, 2012.

- [210] Toulemonde, M., Dufour, C., & Paumier, E. Transient thermal process after a high-energy heavy-ion irradiation of amorphous metals and semiconductors, *Phys. Rev. B* **46**(22), 14362-14369, 1992.
- [211] Szenes, G. Amorphous tracks in insulators induced by monoatomic and cluster ions, *Phys. Rev. B* **60**(5), 3140-3147, 1999.
- [212] Szenes, G. Analysis of tracks induced by cluster ions in CaF<sub>2</sub>, *Phys. Rev. B* **61**(21), 14267-14270, 2000.
- [213] Szenes, G., Horvath, Z.E., Pecz, B., Paszti, F., Toth, L. Tracks induced by swift heavy ions in semiconductors, *Phys. Rev. B* **65**(4), 045206, 2002.
- [214] Toulemonde, M., Dufour, C., Meftah, A., & Paumier, E. Transient thermal processes in heavy ion irradiation of crystalline inorganic insulators, *Nucl. Instrum. Meth. B* **166-167**, 903-912, 2000.
- [215] Dunlop, A., Lesueur, D., Legrand, P., Dammak, H., & Dural, J. Effects induced by high electronic excitations in pure metals: A detailed study in iron, *Nucl. Instr. Meth. B* **90**(1-4), 330-338, 1994.
- [216] Fleischer, R.L., Price, P.B., & Walker, R.M. Ion Explosion Spike Mechanism for Formation of Charged-Particle Tracks in Solids, *J. Appl. Phys.* **36**(11), 3645-3652, 1965.
- [217] Lesueur, D., & Dunlop, A. Damage creation via electronic excitations in metallic targets part II: A theoretical model, *Radiat. Eff. and Def. in Solids* **126**(1-4), 163-172, 1993.
- [218] Bringa, E.M., & Johnson, R.E. Coulomb Explosion and Thermal Spikes, *Phys. Rev. Lett.* **88**(16), 165501, 2002.
- [219] Reung-U-RAI, A., Prom-Jun, A., Prissanaroon-Ouajai, W., & Ouajai, S. Synthesis of Highly Conductive Polypyrrole Nanoparticles via Microemulsion Polymerization, *J. Met. Mater. Min.* **18**(2), 27-31, 2008.
- [220] Jang, J., & Lee, K. Facile fabrication of hollow polystyrene nanocapsules by microemulsion polymerization, *Chem. Commun.* (10), 1098-1099, 2002.
- [221] Kim, S.W., Cho, H.G., & Park, C.R. Fabrication of Unagglomerated Polypyrrole Nanospheres with Controlled Sizes From a Surfactant-Free Emulsion System, *Langmuir* **25**(16), 9030-9036, 2009.

- [222] Jang, J., & Oh, J.H. Novel crystalline supramolecular assemblies of amorphous polypyrrole nanoparticles through surfactant templating, *Chem. Commun.* (19), 2200-2201, 2002.
- [223] Wang, H., Lin, T., & Kaynak, A. Polypyrrole nanoparticles and dye absorption properties, *Synth. Met.* **151**(2), 136-140, 2005.
- [224] Ovando-Medina, V.M., Peralta, R.D., Mendizábal, E., Martínez-Gutiérrez, H., Lara Cenicerros, T.E., & Ledezma-Rodríguez, R. Synthesis of polypyrrole nanoparticles by oil-in-water microemulsion polymerization with narrow size distribution, *Colloid Polym. Sci.* **289**(7), 759-765, 2011.
- [225] Wu, A., Kolla, H., & Manohar, S.K. Chemical Synthesis of Highly Conducting Polypyrrole Nanofiber Film, *Macromolecules* **38**(19), 7873-7875, 2005.
- [226] Ikegame, M., Tajima, K., & Aida, T. Template Synthesis of Polypyrrole Nanofibers Insulated within One-Dimensional Silicate Channels: Hexagonal versus Lamellar for Recombination of Polarons into Bipolarons, *Angew. Chem. Int. Ed.* **42**(19), 2154-2157, 2003.
- [227] He, J., Chen, W., Xu, N., Li, L., Li, X., & Xue, G. SERS studies on the ordered structure of the surface of polypyrrole nanotubules, *Appl. Surf. Sci.* **221**(1-4), 87-92, 2004.
- [228] X. Zhang, Chan-Yu-King, R., Jose, A., Manohar, S.K. Nanofibers of polyaniline synthesized by interfacial polymerization, *Synth. Met.* **145**(1), 23-29, 2004.
- [229] Yanga, X., Dai, T., Zhu, Z., & Lu, Y. Electrochemical synthesis of functional polypyrrole nanotubes via a self-assembly process, *Polymer* **48**(14), 4021-4027, 2007.
- [230] Zhang, L., & Wan, M. Self-Assembly of Polyaniline-From Nanotubes to Hollow Microspheres, *Adv. Funct. Mater.* **13**(10), 815-820, 2003.
- [231] Zhang, Z., Wei, Z., & Wan, M. Nanostructures of Polyaniline Doped with Inorganic Acids, *Macromolecules* **35**(15), 5937-5942, 2002.
- [232] Wei, Z., Zhang, Z., & Wan, M. Formation Mechanism of Self-Assembled Polyaniline Micro/Nanotubes, *Langmuir* **18**(3), 917-921, 2002.
- [233] Zhang, Z., Wei, Z., Zhang, L., & Wan, M. Polyaniline nanotubes and their dendrites doped with different naphthalene sulfonic acids, *Acta Mater.* **53**(5), 1373-1379, 2005.

- [234] Kruger, D.H., Schneck, P., & Gelderblom, H.R. Helmut Ruska and the visualisation of viruses, *The Lancet* **355**(9216), 1713-1717, 2000.
- [235] Kaufmann, E.N., *Characterization of Materials*, John Wiley & Sons, New Jersey, 2003.
- [236] Capaccioli, S., Lucchesi, M., Rolla, P.A., & Ruggeri, G. Dielectric response analysis of a conducting polymer dominated by the hopping charge transport, *J. Phys. Condens. Matter* **10**(25), 5595-5617, 1998.
- [237] Papathanassiou, A.N., Grammatikakis, J., Sakellis, I., Sakkopoulos, S., Vitoratos, E., & Dalas, E. Hopping charge transport mechanisms in conducting polypyrrole: Studying the thermal degradation of the dielectric relaxation, *Appl. Phys. Lett.* **87**(15), 154107(3pp), 2005.
- [238] Ngai, K.L., Rendall, R.W., in: Skotheim T.A. (Ed.), *Handbook of Conducting Polymers*, Marcel Dekker, New York, 1986.
- [239] McCrum, N.G., Read, B.E., & Williams, G. *Anelastic and dielectric effects in polymeric solids*, John Wiley and Sons, New York, 1967.
- [240] Boltcher, C.J.F., & Bordewijk, P. *Theory of Electric Polarization*, 2<sup>nd</sup> Ed., Elsevier, New York, 1978.
- [241] Suri, K., Annapoorni, S., & Tandon, R.P. AC conduction in nanocomposites of polypyrrole, *J. Non-Cryst. Solids* **332**(1-3), 279-285, 2003.
- [242] Hummel, R.E. *Electronic Properties of Materials*, Springer, New York, 1993.
- [243] Acik, M., Baristiran, C., & Sonmez, G. Highly surfaced polypyrrole nano-networks and nano-fibers, *J. Mater. Sci.* **41**(14), 4678-4683, 2006.
- [244] Pumera, M., Smid, B., Peng, X., Golberg, D., Tang, J., & Ichinose, I. Spontaneous Coating of Carbon Nanotubes with an Ultrathin Polypyrrole Layer, *Chem. Eur. J.* **13**(27), 7644-7649, 2007.
- [245] Dey, A., & De, S.K. Conductivity Relaxation in Zirconia Nanoparticles Dispersed in Conducting Polymer, *J. App. Polym. Sci.* **105**, 2225-2235, 2007.
- [246] Dey, A., De, S., De, A., De, & S.K., Characterization and dielectric properties of polyaniline-TiO<sub>2</sub> nanocomposites, *Nanotechnology* **15**, 1277-1283, 2004.
- [247] Chiou, N.R., Lu, C., Guan, J., Lee, L.J., & Epstein, A.J. Growth and alignment of polyaniline nanofibres with superhydrophobic, superhydrophilic and other properties, *Nat. Nanotechnol.* **2**(6), 354-357, 2007.

- [248] Li, X.G., Wei, F., Huang, M.R., & Xie, Y.B. Facile Synthesis and Intrinsic Conductivity of Novel Pyrrole Copolymer Nanoparticles with Inherent Self-Stability, *J. Phys. Chem. B* **111**(21), 5829-5836, 2007.
- [249] Jang, J. Conducting Polymer Nanomaterials and Their Applications, *Adv. Polym. Sci.* **199**, 189-260, 2006.
- [250] Zhu, Z., Liu, C., Sun, Y., Liu, J., Tang, Y., & Du, J. Modification of polyethylene terephthalate under high-energy heavy ion irradiation, *Nucl. Instrum. Meth. B* **191**(1-4), 723-727, 2002.
- [251] Czvikovszky, T. Reactive recycling of multiphase polymer systems through electron beam, *Nucl. Instrum. Meth. B* **105**(1-4), 233-237, 1995.
- [252] Wesch, W., Kamarou, A., & Wendler, E. Effect of high electronic energy deposition in semiconductors, *Nucl. Instrum. Meth. B* **225**(1-2), 111-128, 2004.
- [253] Ruck, D.M. Ion induced modification of polymers at energies between 100 keV and 1 GeV applied for optical waveguides and improved metal adhesion, *Nucl. Instrum. Meth. B* **166-167**, 602-609, 2000.
- [254] Mishra, R., Tripathy, S.P., Sinha, D., Dwivedi, K.K., Ghosh, S., Khathing, D.T., Müller, M., Fink, D., & Chung, W. H. Optical and electrical properties of some electron and proton irradiated polymers, *Nucl. Instrum. Meth. B* **168**(1), 59-64, 2000.
- [255] Davenas, J., Boiteux, G., & Xu, X.L. Role of the modifications induced by ion beam irradiation in the optical and conducting properties of polyimide, *Nucl. Instrum. Meth. B* **32**(1-4), 136-14, 1988.
- [256] Ramola, R.C., Alqudami, A., Chandra, S., Annapoorni, S., Rana, J.M.S., Sonkawade R.G., Singh F., & Avasthi D.K. Effects of swift heavy ions irradiation on polypyrrole thin films, *Radiat. Eff. Defects Solids* **163**(2), 139-147, 2008.
- [257] Park, S.K., Lee, S.Y., Lee, C.S., Kim, H.M., Joo, J., Beag, Y.W., & Koh, K. High energy (MeV) ion-irradiated  $\pi$ -conjugated polyaniline: Transition from insulating state to carbonized conducting state, *J. Appl. Phy.* **96**(4), 1914-1918, 2004.
- [258] Kaur, A., Dhillon, A. & Avasthi, D.K. Effect of 100 MeV swift heavy ions [silver (Ag<sup>8+</sup>)] on morphological and electrical properties of polypyrrole, *J. Appl. Phy.* **106**(7), 073715(8pp), 2009.

- [259] Haldar, J., Aswal, V.K., Goyal, P.S., & Bhattacharya, S. Role of Incorporation of Multiple Headgroups in Cationic Surfactants in Determining Micellar Properties. Small-Angle-Neutron-Scattering and Fluorescence Studies, *J. Phys. Chem. B* **105**(51), 12803-12808, 2001.
- [260] Wynne, K.J. & Street, G.B. Poly(pyrrol-2-ylum tosylate), electrochemical synthesis and physical and mechanical properties, *Macromolecules* **18**(12), 2361-2368, 1985.
- [261] Hussain, A.M.P., Kumar, A., Saikia, D., Singh, F., & Avasthi, D.K. Study of 160 MeV Ni<sup>12+</sup> ion irradiation effects on electrodeposited polypyrrole films, *Nucl. Instrum. Meth. B* **240**(4), 871-880, 2005.
- [262] Klug, H.P., & Alexander, L.E. *X-ray Diffraction Procedures for Polycrystalline and Amorphous Materials*, 2<sup>nd</sup> ed., John Wiley & Sons, New York, 1974.
- [263] Bhadra, S. & Khastgir, D. Degradation and stability of polyaniline on exposure to electron beam irradiation (structure–property relationship), *Polym. Degrad. Stab.* **92**(10), 1824-1832, 2007.
- [264] Copeland, L.E., & Bragg, R.H. Quantitative X-Ray Diffraction Analysis, *Anal. Chem.* **30**(2), 196-201, 1958.
- [265] Joshi, A., Gangal, S.A., & Gupta, S.K. Ammonia sensing properties of polypyrrole thin films at room temperature, *Sens. Actuators B* **156**, 938-942, 2011.
- [266] Shi, W., Liang, P., Ge, D., Wang, J., & Zhang, Q. Starch-assisted synthesis of polypyrrole nanowires by a simple electrochemical approach, *Chem. Commun.* (23), 2414-2416, 2007.
- [267] Zhang, X., Zhang, J., Liu, Z., & Robinson, C. Inorganic/organic mesostructure directed synthesis of wire/ribbon-like polypyrrole nanostructures, *Chem. Commun.* (16), 1852-1853, 2004.
- [268] Li, X.G., Li, A., Huang, M.R., Liao, Y., & Lu, Y.G. Efficient and Scalable Synthesis of Pure Polypyrrole Nanoparticles Applicable for Advanced Nanocomposites and Carbon Nanoparticles, *J. Phys. Chem. C* **114**(45), 19244-19255, 2010.
- [269] Silverstein, R.M., Bassler, G.C., Morrill, T.C., in: *Spectroscopic Identification of Organic Compounds*, 5<sup>th</sup> ed., Wiley, 1992.



- [270] Lei, J., Cai, Z., & Martin, C.R. Effect of reagent concentrations used to synthesize polypyrrole on the chemical characteristics and optical and electronic properties of the resulting polymer, *Synth. Met.* **46**(1), 53-69, 1992.
- [271] Tian, B., Zerbi, G.J., Lattice dynamics and vibrational spectra of pristine and doped polypyrrole: Effective conjugation coordinate, *J. Chem. Phys.* **92**(6), 3892-3898, 1990.
- [272] Yang, C., Wang, X., Wang, Y., & Liu, P. Polypyrrole nanoparticles with high dispersion stability via chemical oxidative polymerization in presence of an anionic-non-ionic bifunctional polymeric surfactant, *Powder Technol.* **217**, 134-139, 2012.
- [273] Mott, N.F., & Gurney, R.W. *Electronic Processes in Ionic Crystals*, Oxford University Press, London, 1940.
- [274] Boukerma, K., Micusik, M., Mravcakova, M., Omastova, M., Vaulay, M.J., Beaunier, P., & Chehimi, M.M. Surfactant-assisted control of the surface energy and interfacial molecular interactions of polypyrrole, *Colloids Surf. A* **293**(1-3), 28-38, 2007.
- [275] Yang, R., Smyrl, W.H., Evan, D.F., & Hendrickson, W.A. Evolution of polypyrrole band structure: a scanning tunneling spectroscopy study, *J. Phys. Chem.* **96**(3), 1428-1430, 1992.
- [276] Singh, R., Arora, V., Tandon, R.P., Mansingh, A., & Chandra, S. Dielectric spectroscopy of doped polyaniline, *Synth. Met.* **104**(2), 137-144, 1999.
- [277] Bengoechea, M.R., Aliev, F.M., & Pinto, N.J. Effects of confinement on the phase separation in emeraldine base polyaniline cast from 1-methyl-2-pyrrolidinone studied via dielectric spectroscopy, *J. Phys.: Condens. Matter* **14**(45), 11769-11778, 2002.
- [278] Ghosh, S., & Ghosh, A. Relaxation dynamics of charge carriers in mixed alkali fluoride glasses, *J. Chem. Phys.* **119**(17), 9106-9110, 2003.
- [279] Neagu, R.M., Neagu, N., Bonanes, N., & Pissis, P. Electrical conductivity studies in nylon 11, *J. Appl. Phys.* **88**(11), 6669-6677, 2000.
- [280] Pakma, O., Serin, N., Serin, T., & Altındal, S. Influence of frequency and bias voltage on dielectric properties and electrical conductivity of Al/TiO<sub>2</sub>/p-Si/p<sup>+</sup> (MOS) structures, *J. Phys. D: Appl. Phys.* **41**(21), 215103(6pp), 2008.

- [281] Migahed, M.D., Bakr, N.A., Abdel-Hamid, M.I., El-Hanafy, O., & El-Nimr, M. *J. Appl. Polym. Sci.* **59**(4), 655-662, 1996.
- [282] Williams, G., & Watts, D.C. Non-symmetrical dielectric relaxation behaviour arising from a simple empirical decay function, *Trans. Faraday Soc.* **66**, 80-85, 1970.
- [283] Kohlrausch, R. *Prog. Ann.* **12**(3), 393-398, 1847.
- [284] Bergman, R. General susceptibility functions for relaxations in disordered systems, *J. Appl. Phys.* **88**(3), 1356-1365, 2000.
- [285] Javadi, H.H.S., Zuo, F., Cromack, K.R., Angelopoulos, M., MacDiarmid, A.G., & Epstein, A.J. Charge transport in the "emeraldine" form of polyaniline, *Synth. Met.* **29**(1), 409-416, 1989.
- [286] Kotkata, M.F., El-Fouly, M.H., Fayek, S.A., & El-Hakim, S.A. The effect of TI addition on the electrical and thermal transport properties of amorphous As<sub>2</sub>Se<sub>3</sub>, *Semicond. Sci. Technol.* **1**(5), 313-319, 1986.
- [287] Ziegler, J.F., Ziegler, M.D., & Biersack, J.P. *Stopping and Ranges of Ions in Matter*, SRIM Code, 2008.
- [288] Calcagno, L., & Foti, G. Density enhancement in ion implanted polymers, *Nucl. Instrum. Meth. B* **19-20**(2), 895-898, 1987.
- [289] Jeong, C.K., Jung, J.H., Kim, B.H., Lee, S.Y., Lee, D.E., Jang, S.H., Ryu, K.S., & Joo, J. Electrical, magnetic, and structural properties of lithium salt doped polyaniline, *Synth. Met.* **117**(1-3), 99-103, 2001.
- [290] M. Salehpour, P. Hakasson, B. Sundqvist, Damage cross sections for fast heavy ion induced desorption of biomolecules, *Nucl. Instr. Meth. B* **2**(1-3), 752-756, 1984.
- [291] Chen, J., Too, C.O., Wallace, G.G., & Swierers, G.F. Redox-active conducting polymers incorporating ferrocenes: 2. Preparation and characterisation of polypyrroles containing propyl- and butyl-tethered [1.1] ferrocenophane, *Electrochim. Acta* **49**(5), 691-702, 2004.
- [292] Singh, S., & Prasher, S. The etching and structural studies of gamma irradiated induced effects in CR-39 plastic track recorder, *Nucl. Instrum. Meth. B* **222**(3-4), 518-524, 2004.
- [293] Zaki, F.M., Gamma-induced modification on optical band gap of CR-39 SSNTD, *J. Phys. D: Appl. Phys.* **41**(17), 175404(5pp), 2008.

- [294] Tsocheva, T., Tsanov, T., Terlemezyan, L., & Vassilev, S. Structural Investigations of Polyaniline Prepared in the Presence of Dodecylbenzenesulfonic Acid, *J. Therm. Anal. Calorim* **63**(1), 133-141, 2001.
- [295] Mujahid, M., Srivastava, D.S., & Avasthi, D.K. Dielectric constant and loss factor measurement of polycarbonate, Makrofol KG using swift heavy ion  $O^{5+}$ , *Radiat. Phys. Chem.* **80**(4), 582-586, 2011.
- [296] Qureshi, A., Singh, N.L., Shah, S., Singh, F., & Avasthi, D.K. Ion Beam Modification of Polymethyl methacrylate (PMMA) Polymer Matrix Filled with Organometallic Complex, *J. Macromol. Sci., Pure Appl. Chem.* **45**(4), 265-270, 2008.
- [297] Saha, S., & Sinha, T.P. Low-temperature scaling behavior of  $BaFe_{0.5}Nb_{0.5}O_3$ , *Phys. Rev. B* **75**(6), 069901, 2002.
- [298] Patel, H.K., & Martin, S.W. Fast ionic conduction in  $Na_2S+B_2S_3$  glasses: Compositional contributions to nonexponentiality in conductivity relaxation in the extreme low-alkali-metal limit, *Phys. Rev. B* **45**(18), 10292-10300, 1992.
- [299] Ghosh, M., Barman, A., Das, A., Meikap, A.K., De, S.K. & Chatterjee, S. Electrical transport in paratoluene sulfonate doped polypyrrole films at low temperature, *J. Appl. Phys.* **83**, 4230-4235, 1998.
- [300] Pan, L., Qiu, H., Dou, C., Li, Y., Pu, L., Xu, J., & Shi, Y. Conducting Polymer Nanostructures: Template Synthesis and Applications in Energy Storage, *Int. J. Mol. Sci.* **11**(7), 2636-2657, 2010.
- [301] Omastova, M., Trchova, M., Kovarova, J., Stejskal, J., Synthesis and structural study of polypyrroles prepared in the presence of surfactants, *Synth. Met.* **138**(3), 447-455, 2003.
- [302] Lu, Q. Unstirred preparation of soluble electroconductive polypyrrole nanoparticles, *Microchim. Acta* **168**(3), 205-213, 2010.
- [303] Gilmore, K.J., Kita, M., Han, Y., Gelmi, A., Higgins, M.J., Moulton, S.E., Clark, G.M., Kapsa, R. & Wallace, G.G. Skeletal muscle cell proliferation and differentiation on polypyrrole substrates doped with extracellular matrix components, *Biomaterials* **30**(29), 5292-5304, 2009.
- [304] Guimard, N.K., Gomez, N. & Schmidt, C.E. Conducting polymers in biomedical engineering, *Prog. Polym. Sci.* **32**(8-9), 876-921, 2007.

- [305] Breads, J.L., Silbey, R. *Conjugated Polymers*, Kluwer Academic: Amsterdam, The Netherlands, 1991.
- [306] Sawall, D.D., Villahermosa, R.M., Lipeles, R.A., & Hopkins, A.R. Interfacial Polymerization of Polyaniline Nanofibers Grafted to Au Surfaces, *Chem. Mater.* **16**(9), 1606-1608, 2004.
- [307] Raut, B.T., Chougule, M.A., Ghanwat, A.A., Pawar, R.C., Lee, C.S. & Patil, V.B. Polyaniline-CdS nanocomposites: effect of camphor sulfonic acid doping on structural, microstructural, optical and electrical properties, *J. Mater. Sci. Mater. Electron.* **23**(12), 2104- 2109, 2012.
- [308] Basescu, N., Liu, Z.X., Moses, D., Heeger, A.J., Naarmann, H. & Theophilou, N. High electrical conductivity in doped polyacetylene, *Nature* **327**, 403-405, 1987.
- [309] Heeger, A.J. Semiconducting and Metallic Polymers: The Fourth Generation of Polymeric Materials, *J. Phys. Chem. B* **105**(36), 8475-8491, 2001.
- [310] Sinha, S., Bhadra, S. & Khastgir, D. Effect of dopant type on the properties of polyaniline, *J. Appl. Polym. Sci.* **112**(5), 3135- 3140, 2009.
- [311] Asmus, T., & Wolf, G.K. Modification and structuring of conducting polymer films on insulating substrates by ion beam treatment, *Nucl. Instrum. Meth. B* **166-167**, 732-736, 2000.
- [312] Svorcik, V., Proskova, K., Hnatowicz, V., Arenholz, E., & Kluge, A. Polyimide modified by irradiation with C<sup>+</sup> and N<sup>+</sup> ion beams, *Polym. Degrad. Stabil.* **65**(1), 131-135, 1999.
- [313] Nouh, S.A., Abdel-Salam, M.H., Radwan, Y. E., & Fouad, S.S. Thermal, electrical and optical properties of proton-irradiated Makrofol DE 7-2 nuclear track detector, *Radiat. Eff. Defects Solids* **166**(3), 178-189, 2011.
- [314] Balanzat, E., Betz, N., & Bufford, S. Swift heavy ion modification of polymers, *Nucl. Instrum. Meth. B* **105**(1-4), 46-54, 1995.
- [315] Cleland, M.R., Parks, L.A., & Cheng, S. Applications for radiation processing of materials, *Nucl. Instrum. Meth. B* **208**, 66-73, 2003.
- [316] Bouffard, S., Gervais, B., & Leroy, C., Basic phenomena induced by swift heavy ions in polymer, *Nucl. Instrum. Meth. B* **105**(1-4), 1-4, 1995.
- [317] Zaki M.F. Gamma-induced modification on optical band gap of CR-39 SSNTD, *Braz. J. Phys.* **38**(4), 558-562, 2008.

- [318] Fink, D., Klett, R., Chadderton, L.T., Cardosa, J., Montiel, R., Vazquez H., & Karanovich, A. A. Carbonaceous clusters in irradiated polymers as revealed by small angle X-ray scattering and ESR, *Nucl. Instrum. Meth. B* **111**(3-4), 303-314, 1996.
- [319] Shah, S., Qureshi, A., Singh, N.L., Kulriya, P.K., Singh, K.P., & Avasthi, D.K. Structural and chemical modification of polymer composite by proton irradiation, *Surf. Coat. Technol.* **203**(17-18), 2595-2599, 2009.
- [320] Zheng, W.Y., Wang, R.H., Levon, K., Rong, Z.Y., Taka, T. & W. Pan, Self-assembly of the electroactive complexes of polyaniline and surfactant, *Macromol. Chem. Phys.* **196**(8), 2443-2462, 1995.
- [321] Chalmers, M., Hannah, R.W. & Mayo, D.W. *Handbook of Vibrational Spectroscopy*, John Wiley and Sons, New York, 2002.
- [322] Xing, S., & Zhao, G. Morphology, Structure, and Conductivity of Polypyrrole Prepared in the Presence of Mixed Surfactants in Aqueous Solutions, *J. Appl. Polym. Sci.* **104**(3), 1987-1996, 2007.
- [323] Selvaraj, M., Palraj, S., Maruthan, K., Rajagopal, G. & Venkatachari, G. Synthesis and characterization of polypyrrole composites for corrosion protection of steel, *Appl. Polym. Sci.* **116**(3), 1524-1537, 2010.
- [324] Mokrini, A. & Acosta, J.L. New ion conducting systems based on star branched block copolymer, *Polymer* **42**(21), 8817-8824, 2001.
- [325] Cabala, R., Skarda, J. & Kamloth, K.P. Spectroscopic investigation of thermal treatment of doped polypyrrole, *Phys. Chem. Chem. Phys.* **2**(14), 3283-3291, 2000.
- [326] Bredas, J.L., Scott, J.C., Yakushi, K. & Street, G.B. Polarons and bipolarons in polypyrrole: Evolution of the band structure and optical spectrum upon doping, *Phys. Rev. B* **30**(2), 1023-1025, 1984.
- [327] Ku, C.C., & Liepins, D. *Electrical properties of polymers*, Hanser Publishers, Munich, 1987.
- [328] Martinez, R., Kumar, A., Palai, R., Scott, J.F., & Katiyar, R.S. Impedance spectroscopy analysis of  $\text{Ba}_{0.7}\text{Sr}_{0.3}\text{TiO}_3/\text{La}_{0.7}\text{Sr}_{0.3}\text{MnO}_3$  heterostructure, *J. Phys. D: Appl. Phys.* **44**, 105302(8pp), 2011.

- [329] Viciosa, M.T., Dionisio, M., & Gomez Ribelles, J.L. Kinetics of free radical polymerization probed by dielectric relaxation spectroscopy under high conductivity conditions, *Polymer* **52**(9), 1944-1953, 2011.
- [330] Karmakar, A., & Ghosh A. Ac conductivity and relaxation in CdO doped poly ethylene oxide-LiI nanocomposite electrolyte, *J. Appl. Phy.* **110**(3), 034101(6pp), 2011.
- [331] Anantha, P.S., & Hariharan, K. ac Conductivity analysis and dielectric relaxation behaviour of NaNO<sub>3</sub>-Al<sub>2</sub>O<sub>3</sub> composites, *Mater. Sci. Eng. B* **121**(1-2), 12-19, 2005.
- [332] Ahmad, M.M., Yamada, K., & Okuda, T. Frequency dependent conductivity and dielectric studies on RbSn<sub>2</sub>F<sub>5</sub>, *Solid State Commun.* **123**(5), 185-189, 2002.
- [333] Ghosh, A. & Sural, M. A new scaling property of fluoride glasses: Concentration and temperature independence of the conductivity spectra, *Europhys. Lett.* **47**(6), 688-693, 1999.
- [334] Elliott, S.R. Frequency-dependent conductivity in ionic glasses: A possible model, *Solid State Ion.* **27**(3), 131-149, 1988.
- [335] Rouahi, A., Kahouli, A., Challali, F., Besland, M.P., Vallee, C., Yangui, B., Salimy, S., Goulet, A., & Sylvestre, A. Impedance and electric modulus study of amorphous TiTaO thin films: highlight of the interphase effect, *J. Phys. D: Appl. Phys.* **46**(6), 065308(7pp), 2013.
- [336] Bottger, H., & Bryskin, U.V. *Hopping Conduction in Solids*, Verlag Akademie, Berlin, 1985.
- [337] Ghosh, A., & Pan, A. Scaling of the Conductivity Spectra in Ionic Glasses: Dependence on the Structure, *Phys. Rev. Lett.* **84**(10), 2188-2190, 2000.
- [338] Hussain, A.M.P., Kumar, A., Singh, F., & Avasthi, D.K. Effects of 160 MeV Ni<sup>12+</sup> ion irradiation on HCl doped polyaniline electrode, *Phys. D: Appl. Phys.* **39**(4), 750-755., 2006.
- [339] Compagnini, G., Foti, G., Reitano, R., & Mondio, G., Graphitic clusters in hydrogenated amorphous carbon induced by keV-ion irradiation, *Appl. Phys. Lett.* **57**(24), 2546-2548, 1990.
- [340] Rizk, R.A.M., Abdul-Kader, A.M., Ali M., Ali, Z.I., Influence of ion-beam bombardment on the optical properties of LDPE polymer blends, *Phys. D: Appl. Phys.* **41**(20), 205304(5pp), 2008.

- [341] Siddhartha, Aarya, S., Dev, K., Raghuvanshi, S.K., Krishna, J.B.M., & Wahab, M.A. Effect of gamma radiation on the structural and optical properties of Polyethyleneterephthalate (PET) polymer, *Radiat. Phys. Chem.* **81**(4), 458-462, 2012.
- [342] Robertson, J., & O'Reilly, E.P. Electronic and atomic structure of amorphous carbon, *Phys. Rev. B* **35**(6), 2946-2957, 1987.
- [343] Fink, D., Chung, W.H., Klett, R., Schmoldt, A., Cardosa, J., Montiel, R., Vazquez, M.H., Wang, L., Hosoi, F., Omichi, H., & Langer P.G. Carbonaceous clusters in irradiated polymers as revealed by UV-Vis spectrometry, *Radiat. Eff. Defects Solids* **133**(3), 193-208, 1995.
- [344] Sambasiva Rao, K., Murali Krishna, P., Madhava Prasad, D., Joon-Hyung, L., Jin-Soo K., Electrical, electromechanical and structural studies of lead potassium samarium niobate ceramics, *J. Alloys Compd.* **464**(1-2), 497-507, 2008.
- [345] Geetha, S., Rao, C.R.K., Vijayan, M., & Trivedi, D.C. Biosensing and drug delivery by polypyrrole, *Analytica. Chimica. Acta.* **568**(1-2), 119-125, 2006.
- [346] Armelin, E., Pla, R., Liesa, F., Ramis, X., Iribarren, J.I., Alemán, Corrosion protection with polyaniline and polypyrrole as anticorrosive additives for epoxy paint, *C. Corros. Sci.* **50**(3), (2008) 721-728.
- [347] Song, H.K., & Palmore, G.T.R. Redox-Active Polypyrrole: Toward Polymer-Based Batteries, *Adv. Mater.* **18**(13), 1764-1768, 2006.
- [348] Aleshin, A.N. Polymer Nanofibers and Nanotubes: Charge Transport and Device Applications, *Adv. Mater.* **18**(1), 17-27, 2006.
- [349] S.K. Saha, Room-temperature single-electron tunneling in conducting polypyrrole nanotube, *Appl. Phys. Lett.* **81**(19), 3645-3647, 2002.
- [350] Park, J.W., Lee, C., & Jang, J. High-performance field-effect transistor-type glucose biosensor based on nanohybrids of carboxylated polypyrrole nanotube wrapped graphene sheet transducer, *Sens. Actuators B* **208**, 532-537, 2015.
- [351] Park, J.W., Park, S.J., Kwon, O.S., Lee, C., & Jang J. Polypyrrole Nanotube Embedded Reduced Graphene Oxide Transducer for Field-Effect Transistor-Type H<sub>2</sub>O<sub>2</sub> Biosensor, *Anal. Chem.* **86**(3), 1822-1828, 2014.
- [352] Yang, Y., Liu, J., & Wan, M. Self-assembled conducting polypyrrole micro/nanotubes, *Nanotechnology* **13**(6), 771-774, 2002.



- [353] Huang, K., & Wan, M.X. Self-Assembled Polyaniline Nanostructures with Photoisomerization Function, *Chem. Mater.* **14**(8), 3486-3492, 2002.
- [354] Rao, G.R., & Lee, E.H. Effects of sequential He<sup>+</sup> and Ar<sup>+</sup> implantation on surface properties of polymers, *J. Mater. Res.* **11**(10), 2661-2667, 1996.
- [355] Calcagno, L., Compagnini, G., & Foti, G., Structural modification of polymer films by ion irradiation, *Nucl. Instrum. Meth. B* **65**(1-4), 413-422, 1992.
- [356] Lee, E. H. Ion-beam modification of polymeric materials-fundamental principles and applications, *Nucl. Instrum. Meth. B* **151**(1-4), 29-41, 1999.
- [357] Hussain, A.M.P., Saikia, D., Singh, F., Avasthi, D.K. & Kumar, A. *Nucl. Instrum. Meth. B* **240**(4), 834-841, 2005.
- [358] Wan, M., & Li, J., Formation mechanism of polyaniline microtubules synthesized by a template-free method, *J. Polym. Sci. A* **38**(13), 2359-2364, 2000.
- [359] Kim, B.J., Oh, S.G., Han, M.G., & Im, S.S. Synthesis and characterization of polyaniline nanoparticles in SDS micellar solutions, *Synth. Met.* **122**(2), 297-304, 2001.
- [360] Kim, B.J., Oh, S.G., Han, M.G., & Im, S.S. Preparation of Polyaniline Nanoparticles in Micellar Solutions as Polymerization Medium, *Langmuir* **16**(14), 5841-5845, 2000.
- [361] Harada, M., & Adachi, M. Surfactant-Mediated Fabrication of Silica Nanotubes, *Adv. Mater.* **12**(11), 839-841, 2000.
- [362] Yang, C., & Liu, P. Water-Dispersed Conductive Polypyrroles Doped with Lignosulfonate and the Weak Temperature Dependence of Electrical Conductivity, *Ind. Eng. Chem. Res.* **48**(21), 9498-9503, 2009.
- [363] Gade, V.K., Shirale, D.J., Gaikwad, P.D., Kakde, K.P., Savale, P.A., Kharat, H.J., & Shirsat, M.D. Synthesis and Characterization of Ppy-PVS, Ppy-pTS, and Ppy-DBS Composite Films, *Int. J. Polymer. Mater.* **56**(2), 107-114, 2007.
- [364] Liu, Y., Chu, Y., & Yang, L. Adjusting the inner-structure of polypyrrole nanoparticles through microemulsion polymerization, *Mater. Chem. Phys.* **98**(2-3), 304-308, 2006.
- [365] J. Zang, C.M. Li, S.J. Bao, X. Cui, Q. Bao, C.Q. Sun, Template-Free Electrochemical Synthesis of Superhydrophilic Polypyrrole Nanofiber Network, *Macromolecules* **41**(19), 7053-7057, 2008.

- [366] Kim, D.Y., Lee, J.Y., Moon, D.K., & Kim, C.Y. Stability of reduced polypyrrole, *Synth. Met.* **69**(1-3), 471-474, 1995.
- [367] Khiew, P.S., Huang, N.M., Radiman, S., & Ahmad, M.S. Synthesis and characterization of conducting polyaniline-coated cadmium sulphide nanocomposites in reverse microemulsion, *Mater. Lett.* **58**(3-4), 516-521, 2004.
- [368] Xi, Y., Bin, Y., Chiang, C.K., & Matsuo, M. Dielectric effects on positive temperature coefficient composites of polyethylene and short carbon fibers, *Carbon* **45**(6), 1302-1309, 2007.
- [369] Smyth, C.P. *Dielectric behavior and structure: dielectric constant and loss, dipole moment and molecular structure*, McGraw-Hill Book Company Inc., New York, 1955.
- [370] Riande, E., & Calleja, R.D. *Electrical properties of polymers*, Marcel Dekker Inc., New York, 2004.
- [371] Bhattacharya, S., & Ghosh, A. ac relaxation in silver vanadate glasses, *Phys. Rev. B* **68**(22), 224202, 2003.
- [372] Bhattacharya, S., & Ghosh, A. Conductivity spectra in fast ion conducting glasses: Mobile ions contributing to transport process, *Phys. Rev. B* **70**(17), 172203, 2004.
- [373] Papathanassiou, A.N., Grammatikakis, J., Sakkopoulos, S., Vitoratos, E., & Dalas, E.J. Localized and long-distance charge hopping in fresh and thermally aged conductive copolymers of polypyrrole and polyaniline studied by combined TSDC and dc conductivity, *Phys. Chem. Solids* **63**(9), 1771-1178, 2002.
- [374] Mallick, P., Rath, C., Prakash, J., Mishra, D.K., Choudhary, R.J., Phase, D.M., Tripathi, A., Avasthi, D.K., Kanjilal, D., & Mishra, N.C. Swift heavy ion irradiation induced modification of the microstructure of NiO thin films, *Nucl. Instrum. Meth. B* **268**(10), 1613-1617, 2010.
- [375] Sharma, T., Aggarwal, S., Sharma, A., Kumar, S., Kanjilal, D., Deshpande, S.K., & Goyal P.S. Effect of nitrogen ion implantation on the optical and structural characteristics of CR-39 polymer, *J. Appl. Phys.* **102**(6), 063527(4pp), 2007.

## References

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- [376] Rizk R.A.M., Abdul-Kader, A.M., Ali, Z.I., & Ali, M. Effect of ion bombardment on the optical properties of LDPE/EPDM polymer blends, *Vacuum* **83**(5), 805-808, 2009.
- [377] Virk, H.S., Chandi, P.S., & Srivastava, A.K. Physical and chemical changes induced by 70 MeV carbon ions in polyvinylidene difluoride (PVDF) polymer, *Nucl. Instrum. Meth. B* **183**(3-4), 329-336, 2001.

# List of Publications

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## A. In refereed International/National journals

1. **J. Hazarika** and A. Kumar, “*Structural and optical properties of self-assembled polypyrrole nanotubes*”, **J. Polym. Res.** (Under Review).
2. **J. Hazarika** and A. Kumar, “*Swift heavy ion irradiation effects on structural, optical properties and ac conductivity of polypyrrole nanofibers*”, **Radiat. Eff. Defect Solids** (Under Review).
3. **J. Hazarika** and A. Kumar, “*Studies of structural, optical, dielectric relaxation and ac conductivity of different alkylbenzenesulfonic acids doped polypyrrole nanofibers*”, **Physica B** **481** (2016) **268-279**.
4. **J. Hazarika** and A. Kumar, “*Electric modulus based relaxation dynamics and ac conductivity scaling of polypyrrole nanotubes*”, **Synth. Met.** **198** (2014) **239-247**.
5. **J. Hazarika** and A. Kumar, “*Enhanced AC conductivity and dielectric relaxation properties of polypyrrole nanoparticles irradiated with Ni<sup>12+</sup> swift heavy ions*” **Nucl. Instrum. Meth. B** **333** (2014) **73-79**.
6. **Jayanta Hazarika**, Chandrani Nath and A. Kumar, “*Swift heavy ion irradiation-induced enhancement in structural, conformational and electrical properties of polyaniline nanofibers*”, **Radiat. Eff. Defects Solids** **169** (2014) **30-40**.
7. **J. Hazarika** and A. Kumar, “*160 MeV Ni<sup>12+</sup> ion irradiation effects on structural, optical and electrical properties of spherical polypyrrole nanoparticles*” **Nucl. Instrum. Meth. B** **318** (2014) **269-275**.
8. **J. Hazarika** and A. Kumar, “*Controllable synthesis and characterization of polypyrrole nanoparticles in sodium dodecylsulphate (SDS) micellar solutions*”, **Synth. Met.** **175** (2013) **155-162**.
9. **J. Hazarika**, Chandrani Nath and A. Kumar, “*160 MeV Ni<sup>12+</sup> ion irradiation effects on dielectric properties of Polyaniline nanotubes*”, **Nucl. Instrum. Meth. B** **288** (2012) **74-80**.

## B. Conference proceedings:

1. **J. Hazarika** and A. Kumar, “*Investigation of temperature dependant dielectric relaxation and charge transport mechanism of PPy nanoparticles*” ISBN No: 978-9382746-02-7.

## C. International/National Conference attended:

1. **J. Hazarika** and A. Kumar, *IXth National conference of Physics Academy of North East, NERIST, Nirjuli, Arunachal Pradesh, 18<sup>th</sup>-20<sup>th</sup> December, 2014 (Oral Presentation).*
2. **J. Hazarika** and A. Kumar, *National Seminar on Recent Trends in Science and Technology, Cotton College, Cotton College State University, Guwahati, 29<sup>th</sup> March, 2014 (Oral Presentation).*
3. **J. Hazarika** and A. Kumar, *International Conference on Functional Materials (ICFM-2014), IIT-Kharagpur, 5<sup>th</sup>-7<sup>th</sup> February, 2014 (Poster Presentation).*
4. **J. Hazarika** and A. Kumar, *National seminar on current trends in physics research (NSCTPR-2014), Department of Physics, Darrang College, Tezpur, 30<sup>th</sup> January-1<sup>st</sup> February, 2014 (Oral Presentation).*
5. **J. Hazarika** and A. Kumar, *National conference on physical sciences, Department of Physics, D.H.S.K. College, Dibrugarh, 13<sup>th</sup>-14<sup>th</sup> September, 2013 (Oral Presentation).*
6. **J. Hazarika** and A. Kumar, *National conference on condensed matter physics, Department of Physics, NIT Rourkela, 29<sup>th</sup>-31<sup>th</sup> August, 2013 (Oral Presentation).*
7. **Jayanta Hazarika**, Chandrani Nath and A. Kumar, *International conference on Swift Heavy Ions in Materials Engineering and Characterization, IUAC, New Delhi, 9<sup>th</sup>-12<sup>th</sup> October, 2012 (Poster Presentation).*

#### **D. Workshops/Symposiums/Schools/Refresher Course Attended:**

- 1. Inter-University Accelerator Centre (IUAC) Acquaintance Programme on “Accelerator based multi-disciplinary scientific research”**, Department of Physics, Guahati University, Assam, India.
- 2. “Workshop cum Training on Patent Search and Analysis”** organized by Tezpur University Intellectual Property Right Cell in collaboration with TIFAC, DST, New Delhi, 21<sup>st</sup> November, 2015.
- 3. “Science Academies’ Refresher Course in Theoretical Physics”**, organized by Department of Physics, Tezpur University held during January 06-20, 2015.
- 4. “Workshop on Electron Microscopy in Physical Sciences”** (4<sup>th</sup>-6<sup>th</sup> March, 2014) held at Sophisticated Analytical Instrument Facility, North-Eastern Hill University, Shillong.
- 5. “One Day Workshop on Smart Materials and Thin Films”** organized by the Department of Physics, NIT Rourkela, August 28, 2013.
- 6. “1<sup>st</sup> inhouse symposium on Research in physics on 2012 & the role of IPR,”** December 21, 2012, Department of Physics, Tezpur University.
- 7. “International School on Ion beams in Materials Science”** organized by the Inter University Accelerator Centre (IUAC), New Delhi, October 3-8, 2012.