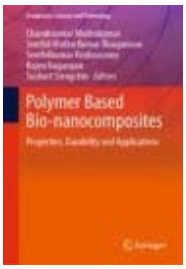

Polymer Based Bio-nanocomposites pp 51–68Cite as

Thermal Stabilities of Bionanocomposites at Elevated Temperatures

- Samuel Eshorame Sanni,
- Emmanuel Rotimi Sadiku &
- Emmanuel Emeka Okoro

- Chapter
- First Online: 29 March 2022
- **360** Accesses

Part of the Composites Science and Technology book series (CST)

Abstract

Bionanocomposites are polymer-composites, comprising of nanosized materials blended into polymers, plastics and fibres for industrial and other applications. Although similarities exist among several varieties of this class of compounds, their properties vary owing to the methods employed in producing them, hence, they appear nacre-like or stacked and are differentiated into an array of biomacromolecules which in turn influence their thermal/chemical stabilities alongside their functionalities, biodegradability, biocompatibilities as well as their modes of application. At higher temperatures, the nature of particle-reinforcements, packings, tensile strength, thermal stability, nanoparticle-dispersion, interface-morphology, matrix-materials, nature and bulk modulus, are largely responsible for their thermal stabilities when compared with those of their pristine counterparts. Their large

surface area to volume ratios are also responsible for their abilities to allow for the even distribution of thermal properties across the whole thickness or diameter of the materials. Furthermore, their methods of preparation, degree of compactness and change in pH, have a way of influencing their thermal properties which in turn stimulates electrostatic interactions that result in jellification or biofilm production/altered viscosities prior casting. Thus, they may become thermally fatigue or deformed if stretched beyond their permissible limits when in use. In this chapter, the properties that influence the thermal stabilities of bionanocomposites are discussed.

Keywords

- **Bionanocomposites**
- **Biomacromolecule**
- **High temperature**
- **Particle-reinforcements**
- **Thermal fatigue**
- **Thermal resistance**
- **Thermal stability**

References

- Agius L (2015) Role of glycogen phosphorylase in liver glycogen metabolism. Mol Aspects Med 46:3445

CrossRef Google Scholar

- Angellier H, Choisnard L, Molina-Boisseau S, Ozil P, Dufresne A (2004) Optimization of the preparation of aqueous suspensions of waxy maize starch nanocrystals using a response surface methodology. Biomacromol 5(4):1545–1551

CrossRef CAS Google Scholar

- Araujo EM, Barbosa R, Oliveira AD, Morais CRS, de Melo TJA, Souza AG (2007) Thermal and mechanical properties of PE/organoclay nanocomposites. J Thermal Anal Calorimetry 87:811. https://doi.org/10.1007/s10973-006-7758-0
- Avella M, Vlieger JDJ, Errico MA, Fischer S, Vacca P, Volpa MG (2005) Biodegradable starch/clay nanocomposites for food packaging applications. Food Chem 93(3):467–474

CrossRef CAS Google Scholar

- Bakar MSA, Cheang P, Khor KA (2003) Tensile properties and microstructural analysis of spheroidized hydroxyapatite-poly (ether ether ketone) biocomposites. Mat Sci Eng A 345:55–63

Google Scholar

- Behazin E, Misra M, Mohanty AK (2017) Sustainable biocarbon from pyrolyzed perennial grasses and their effects on impact modified polypropylene biocomposites. Compos B 118:116–124

CrossRef CAS Google Scholar

- Blanco M, Sarasua JA, Lopez M, Gonzalo O, Marcaide A, Muniesa M, Fernandez A (2012) Ultrasound assisted extrusion of polyamide 6 nanocomposites based on carbon nanotubes. Macromol Symposia 321–322:80–83

Google Scholar

- Bule´on A, Colonna P, Planchot V, Ball S (1998) Starch granules: structure and biosynthesis? Int J Biol Macromol 23(2):85–112

Google Scholar

- Campbell BWNA, Heyden RJ (2006) Biology: exploring life, 1st edn. Pearson Prentice Hall, Boston, MA

Google Scholar

- Chang C, Zhang L (2011) Cellulose-based hydrogels: present status and application prospects. Carbohyd Polym 84(1):40–53

CrossRef CAS Google Scholar

- Chauvet M, Sauceau M, Fages J (2017) Extrusion assisted by supercritical CO_2: a review on its application to biopolymers. J Supercrit Fluids 120:408–420

CrossRef CAS Google Scholar

- Chen B, Evans JRG (2005) Thermoplastic starch–clay nanocomposites and their characteristics. Carbohyd Polym 61(4):455–463

CrossRef CAS Google Scholar

- Chrissafis K, Paraskevopoulos KM, Papageorgiou GZ, Bikiaris DN (2008) Thermal and dynamic mechanical behavior of bionanocomposites: fumed silica nanoparticles dispersed in poly(vinyl pyrrolidone), chitosan, and poly(vinyl alcohol). J Appl Polym Sci 110:1739–1749. https://doi.org/10.1002/app.28818

CrossRef CAS Google Scholar

- Codou A, Misra M, Mohanty AK (2018) Sustainable biocarbon reinforced nylon 6/polypropylene compatibilized blends: effect of particle size and morphology on performance of the biocomposites. Compos A 112:1–10

CrossRef CAS Google Scholar

- Cooper CJ, Abdelwahab MA, Mohanty AK, Misra M (2019) Hybrid green bionanocomposites of bio-based poly(butylene succinate) reinforced with pyrolyzed perennial grass microparticles and graphene nanoplatelets. ACS Omega 4:20476–20485. https://doi.org/10.1021/acsomega.9b01771

CrossRef CAS Google Scholar

- Dash S, Swain SK (2013) Synthesis of thermal and chemical resistant oxygen barrier starch with reinforcement of nano silicon carbide. Carbohyd Polym 97:758–763. https://doi.org/10.1016/j.carbpol.2013.05.061

CrossRef CAS Google Scholar

- Dennis HR, Hunter DL, Chang D, Kim S, White JL, Cho JW, Paul DR (2001) Effect of melt processing conditions on the extent of exfoliation in organoclay-based nanocomposites. Polymer 42:9513–9522

CrossRef CAS Google Scholar

- Díez-Pascual AM, Díez-Vicente AL (2014) Poly(3-hydroxybutyrate)/ZnO bionanocomposites with improved mechanical, barrier and antibacterial properties. Int J Mol Sci 15:10950–10973. https://doi.org/10.3390/ijms150610950

CrossRef CAS Google Scholar

- Eichhorn SJ, Baillie CA, Zafeiropoulos N, Mwaikambo LY, Ansell MP, Dufresne A et al (2001) Current international research into cellulosic fibres and composites. J Mat Sci 36(9):2107–2131

CrossRef CAS Google Scholar

- El-Sheikh MA (2017) New technique in starch nanoparticles synthesis. Carbohyd Polym 176:214–219

CrossRef CAS Google Scholar

- Filippov SK, Sedlacek O, Bogomolova A, Vetrik M, Jirak D, Kovar J et al (2012) Glycogen as a biodegradable construction nanomaterial for in vivo use. Macromol Biosci 12(12):17318

CrossRef Google Scholar

- Gao Y, Picot OT, Bilotti E, Peijs T (2017) Influence of filler size on the properties of poly(lactic acid) (PLA)/graphene nanoplatelet (GNP) nanocomposites. Eur Polymer J 86:117–131

CrossRef CAS Google Scholar

- Grassie N, Murray EJ (1984) The thermal degradation of poly(-(D)-β-hydroxybutyric acid): part 3—the reaction mechanism. Polym Degrad Stab 6:127–134

CrossRef CAS Google Scholar

- Guo Z, Kim TY, Lei K, Pereira T, Sugar JG, Hahn HT (2008) Strengthening and thermal stabilization of polyurethane nanocomposites with silicon carbide nanoparticles by a surface-initiated-polymerization approach. Composite Sci Technol 68:164–170

CrossRef CAS Google Scholar

- Huang ZX, Tang ZA, Yu J, Bai S (2011) Thermal conductivity of nanoscale polycrystalline ZnO thin films. Physica B 406(4):818–823

CrossRef CAS Google Scholar

- Ifuku S, Urakami T, Izawa H, Morimoto M, Saimoto H (2015) Preparation of a protein-chitin nanofiber complex from crab shells and its application as a reinforcement filler or substrate for biomineralization. R Soc Chem Adv 5(79):64196–64201

CAS Google Scholar

- Istrate OM, Paton KR, Khan U, O'Neill A, Bell AP, Coleman JN (2014) Reinforcement in melt-processed polymer−graphene composites at extremely low graphene loading level. Carbon 78:243–249

CrossRef CAS Google Scholar

- Jayakumar R, Menon D, Manzoor K, Nair SV, Tamura H (2010) Biomedical applications of chitin and chitosan based nanomaterials—a short review. Carbohydrate Polym 82(2):227–232

Google Scholar

- Kalaitzidou K, Fukushima H, Drzal LT (2007) Multifunctional polypropylene composites produced by incorporation of exfoliated graphite nanoplatelets. Carbon 45:1446–1452

CrossRef CAS Google Scholar

- Kalambur SB, Rizvi SSH (2004) Starch-based nanocomposites by reactive extrusion processing. Polym Int 53:1413–1416

CrossRef CAS Google Scholar

- Kim Y, Kwon OH, Park WH, Cho D (2013) Thermomechanical and flexural properties of chopped silk fiber-reinforced poly(butylene succinate) green composites: effect of electron beam treatment of worm silk. Adv Composite Mater 22:437–449

CrossRef CAS Google Scholar

- Kim EH, Han GD, Noh SH, Kim JW, Lee JG, Ito Y et al (2017) Photo-reactive natural polymer derivatives for medical application. Ind Eng Chem Res 54:1–3

CrossRef CAS Google Scholar

- Kisku SK, Swain SK, Kisku SK, Swain SK (2012) Synthesis and characterization of chitosan/boron nitride composites. J Am Ceramic Soc 95(9):2753–2757

Google Scholar

- Krause B, Mende M, Pötschke P, Petzold G (2010) Dispersability and particle size distribution of cnts in an aqueous surfactant dispersion as a function of ultrasonic treatment time. Carbon 48:2746–2754

CrossRef CAS Google Scholar

- Le Corre D, Bras J, Dufresne A (2010) Starch nanoparticles: a review. Biomacromol 11(5):1139–1153

CrossRef Google Scholar

- Lecouvet B, Sclavons M, Bourbigot S, Devaux J, Bailly C (2011) Water-assisted extrusion as a novel processing route to prepare polypropylene/halloysite nanotube nanocomposites: structure and properties. Polymer 52:4284–4295

CrossRef CAS Google Scholar

- Li H, Xiao Q, Zhang C, Du J, Li X, Huang H et al (2017) Identification and characterization of transcription factor ZmEREB94 involved in starch synthesis in maize. J Plant Physiol 216:11–16

CrossRef CAS Google Scholar

- Manners DJ (1991) Recent developments in our understanding of glycogen structure. Carbohyd Polym 16(1):3782

CrossRef Google Scholar

- Marosfoi BB, Szabo A, Marosi G, Tabuani D, Camino G, Pagliari S (2006) Linear viscoelastic properties and crystallization behavior of multi-walled carbon nanotube/polypropylene composites. J Thermal Anal Calorimetry 86:669

Google Scholar

- Mc Gloshan SA, Hally PJ (2003) Preparation and characterization of biodegradable starch-based nanocomposite materials. Polym Int 52:1767–1773

CrossRef Google Scholar

- Moon RJ, Martini A, Nairn J, Simonsen J, Youngblood J (2011) Cellulose nanomaterials review: structure, properties and nanocomposites. Chem Soc Rev 40(7):3941–3994

CrossRef CAS Google Scholar

- Navarro-Baena I, Kenny JM, Peponi L (2014) Thermally-activated shape memory behaviour of bionanocomposites reinforced with cellulose nanocrystals. Cellulose 21:4231–4246. https://doi.org/10.1007/s10570-014-0446-5

CrossRef CAS Google Scholar

- Nazarian-Firouzabadi F, Visser RG (2017) Potato starch synthases: functions and relationships. Biochem Biophys Rep 10:7–16

Google Scholar

- Nga NK, Hoai TT, Viet PH (2015) Biomimetic scaffolds based on hydroxy-apatite nanorod/poly (d, l) lactic acid with their corresponding apatite-forming capability and biocompatibility for bone-tissue engineering. Colloids Surf B Biointerf 128:506–514

CrossRef Google Scholar

- Nur M, Vasiljevic T (2017a) Can natural polymers assist in delivering insulin orally? Int J Biol Macromol 103:889–901

CrossRef CAS Google Scholar

- Nur M, Vasiljevic T (2017b) Can natural polymers assist in delivering insulin orally? Int J Biol Macromol 103:889–901

CrossRef CAS Google Scholar

- Odier A (1929) Memoir on the chemical composition of the horny parts of insects. Me´moires de la Socie´te´ d'Histoire Naturelle de Paris 1:29–42

Google Scholar

- Ogawa Y, Azuma K, Izawa H, Morimoto M, Ochi K, Osaki T et al (2017) Preparation and biocompatibility of a chitin nanofiber/gelatin composite film. Int J Biol Macromol 104:1882–1889

CrossRef CAS Google Scholar

- Ogunsona EO, Misra M, Mohanty AK (2017) Sustainable biocomposites from biobased polyamide 6, 10 and biocarbon from pyrolyzed *miscanthus* fibers. J Appl Polym Sci 134(4):44221–44232. https://doi.org/10.1002/app.44221

CrossRef CAS Google Scholar

- Ojijo V, Ray SS (2013) Processing strategies in bionanocomposites. Prog Polym Sci 38(10–11):1543–1589

CrossRef CAS Google Scholar

- Park C, Ounaies Z, Watson KA, Crooks RE, Smith J, Lowther SE, Connell JW, Siochi EJ, Harrison JS, Clair TLS (2002) Dispersion of single wall carbon

nanotubes by in situ polymerization under sonication. Chem Phys Lett 364:303–308

CrossRef CAS Google Scholar

- Peppas NA, Huang Y, Torres-Lugo M, Ward JH, Zhang J (2000) Physicochemical foundations and structural design of hydrogels in medicine and biology. Annu Rev Biomed Eng 2(1):9–29

CrossRef CAS Google Scholar

- Potts JR, Dreyer DR, Bielawski CW, Ruoff RS (2011) Graphene-based polymer nanocomposites. Polymer 52:5–25

CrossRef CAS Google Scholar

- Quiles-Díaz S, Enrique-Jimenez P, Papageorgiou DG, Ania F, Flores A, Kinloch IA, Gomez-Fatou MA, Young RJ, Salavagione HJ (2017) Influence of the chemical functionalization of graphene on the properties of polypropylene-based nanocomposites. Compos Part A 100:31–39

Google Scholar

- Rezwan K, Chen QZ, Blaker JJ, Boccaccini AR (2006) Biodegradable and bioactive porous polymer/inorganic composite scaffolds for bone tissue engineering. Biomaterials 27(18):3413–3431

CrossRef CAS Google Scholar

- Rybicka KK (1996) Glycosomes-the organelles of glycogen metabolism. Tissue Cell 28(3):25365

CrossRef Google Scholar

- Sagheer FA, Muslim S (2010) Thermal and mechanical properties of chitosan/hybrid composites. J Nanomater 2:1–7. https://doi.org/10.1155/2010/490679

CrossRef CAS Google Scholar

- Salehizadeh H, Yan N, Farnood R (2018) Recent advances in polysaccharide bio-based flocculants. Biotechnol Adv 36(1):92–119

CrossRef CAS Google Scholar

- Saravanan L, Subramanian SS, Vishnu Kumar AB, Tharanathan RN (2006) Surface chemical studies on SiC suspension in presence of chitosan. Ceram Int 32:637–646

CrossRef CAS Google Scholar

- Shabanzadeh P, Yusof R, Shameli K (2015) Artificial neural network for modeling the size of silver nanoparticles' prepared in montmorillonite/starch bionanocomposites. J Ind Eng Chem 24:42–50

CrossRef CAS Google Scholar

- Shearer J, Graham TE (2002) New perspectives on the storage and organization of muscle glycogen. Canadian J Appl Physiol 27(2):179203

Google Scholar

- Shenhar R, Norsten TB, Rotello VM (2005) Polymer-mediated nanoparticle assembly: structural control and applications. Adv Mater 17:657–669

CrossRef CAS Google Scholar

- Shi Z, Gao X, Ullah MW, Li S, Wang Q, Yang G (2016) Electroconductive natural polymer-based hydrogels. Biomaterials 111:40–54

CrossRef CAS Google Scholar

- Swain SK, Dash S, Kisku SK, Singh RK (2014) Thermal and oxygen barrier properties of chitosan bionanocomposites by reinforcement of calcium carbonate nanopowder. J Mat Sci Technol 1–5

Google Scholar

- Swetha M, Sahithi K, Moorthi A, Srinivasan N, Ramasamy K, Selvamurugan N (2010) Biocomposites containing natural polymers and hydroxyapatite for bone tissue engineering. Int J Biol Macromol 47(1):1–4

CrossRef CAS Google Scholar

- Thakur VK, Thakur MK, Raghavan P, Kessler MR (2014) Progress in green polymer composites from lignin for multifunctional applications: a review. Am Chem Soc Sustain Chem Eng 2(5):1072–1092

CAS Google Scholar

- Tirone TA, Brunicardi FC (2001) Overview of glucose regulation. World J Surg 25(4):4617

CrossRef Google Scholar

- Uddin Md-N, Dhanasekaran PS, Asmatulu R (2019) Mechanical properties of highly porous PEEK bionanocomposites incorporated with carbon and hydroxyapatite nanoparticles for scaffold applications. Progress Biomater 8:211–221

Google Scholar

- Vassiliou A, Bikiaris DN, Pavlidou E (2007) Optimizing melt-processing conditions for the preparation of iPP/fumed silica nanocomposites:

morphology, mechanical and gas permeability properties. Macromol React Eng 1:488

CrossRef CAS Google Scholar

- Wang Q, Yan X, Chang Y, Ren L, Zhou J (2018) Fabrication and characterization of chitin nanofibers through esterification and ultrasound treatment. Carbohyd Polym 180:81–87

CrossRef CAS Google Scholar

- Williams D (2008) Polyetheretherketone for long-term implantable devices. Med Dev Technol 19(1):8

Google Scholar

- Yang KK, Wang XL, Wang YZ (2007) Progress in nanocomposite of biodegradable polymer. J Ind Eng Chem 13(4):485–500

CAS Google Scholar

- Zheng Y, Xiong C, Zhang S, Li X, Zhang L (2015) Bone-like apatite coating on functionalized poly (etheretherketone) surface via tailored silaniza-tion layers technique. Mat Sci Eng C Mater Biol Appl 55:512–523

CrossRef CAS Google Scholar

Download references

Author information

Authors and Affiliations

1. **Department of Chemical Engineering, Covenant University, P.M.B. 1023, Ota, Ogun State, Nigeria**
   Samuel Eshorame Sanni

2. **Department of Metallurgy, Polymer and Chemical Engineering, Tshwane University of Technology, Pretoria, South Africa**
   Emmanuel Rotimi Sadiku
3. **Department of Petroleum Engineering, Covenant University, P.M.B. 1023, Ota, Ogun State, Nigeria**
   Emmanuel Emeka Okoro

Corresponding author

Correspondence to Samuel Eshorame Sanni .

Editor information

Editors and Affiliations

1. **School of Aeronautical Sciences, Hindustan Institute of Technology and Science, Chennai, India**
   Dr. Chandrasekar Muthukumar
2. **Department of Mechanical Engineering, Kalasalingam Academy of Research and Education, Krishnankoil, India**
   Dr. Senthil Muthu Kumar Thiagamani
3. **Department of Mechanical Engineering, Francis Xavier Engineering College, Tirunelveli, Tamil Nadu, India**
   Dr. Senthilkumar Krishnasamy
4. **Department of Mechanical Engineering, Kalasalingam Academy of Research And Education, Krishnan Kovil, Tamil Nadu, India**
   Dr. Rajini Nagarajan
5. **Department of Materials and Production Engineering, The Sirindhorn International Thai–German Graduate School of Engineering (TGGS) King Mongkut's University of Technology North Bangkok, Bangkok, Thailand**
   Dr. Suchart Siengchin

Rights and permissions

Copyright information

About this chapter

Cite this chapter

Sanni, S.E., Sadiku, E.R., Okoro, E.E. (2022). Thermal Stabilities of Bionanocomposites at Elevated Temperatures. In: Muthukumar, C., Thiagamani, S.M.K., Krishnasamy, S., Nagarajan, R., Siengchin, S. (eds) Polymer Based Bio-nanocomposites. Composites Science and Technology . Springer, Singapore. https://doi.org/10.1007/978-981-16-8578-1_3

Download citation

- .RIS
- .ENW
- .BIB
- DOIhttps://doi.org/10.1007/978-981-16-8578-1_3
- Published29 March 2022
- Publisher NameSpringer, Singapore
- Print ISBN978-981-16-8577-4
- Online ISBN978-981-16-8578-1
- eBook PackagesChemistry and Materials ScienceChemistry and Material Science (R0)

EUR 169.99

Tax calculation will be finalised at checkout

Purchases are for personal use only

Learn about institutional subscriptions