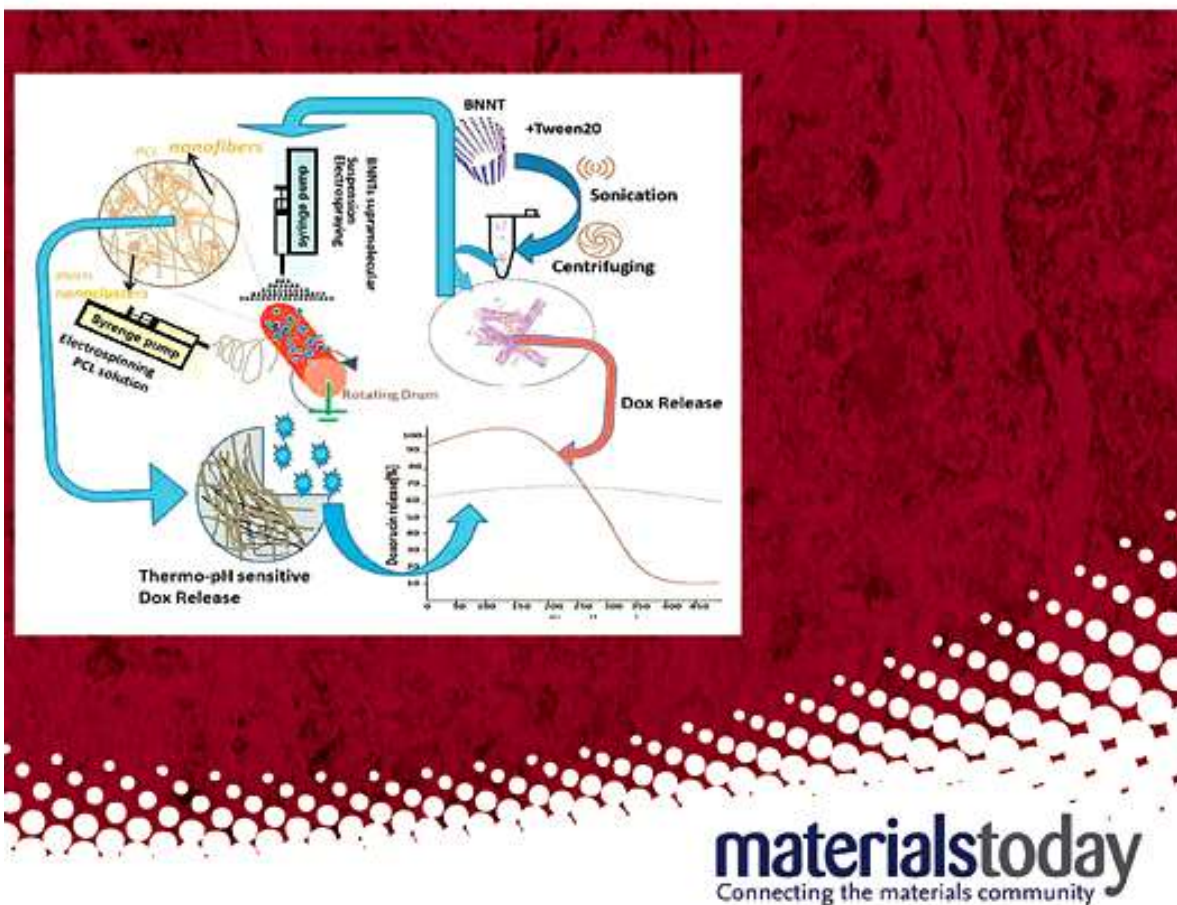


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2. Feature Article

1. ☐ select article Biobased thiol-epoxy shape memory networks from gallic acid and vegetable oils

Research articleAbstract only

Biobased thiol-epoxy shape memory networks from gallic acid and vegetable oils
Yechang Feng, Yang Hu, Limin Man, Teng Yuan, ... Zhuohong Yang

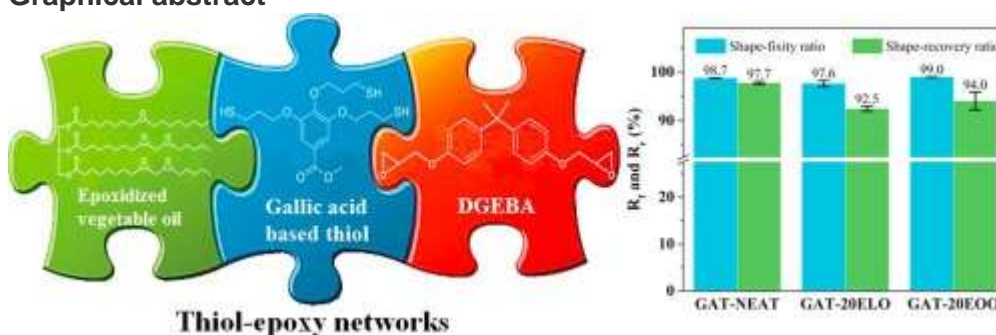
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2. ☐ select article Synthesis and characterization of biocompatible copolymers containing plant-based cardanol and zwitterionic groups for antifouling and bactericidal coating applications

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Synthesis and characterization of biocompatible copolymers containing plant-based cardanol and zwitterionic groups for antifouling and bactericidal coating applications

Na Kyung Kim, Jinseok Kim, Da-Jung Shon, Ju-Ro Lee, ... Jong-Chan Lee

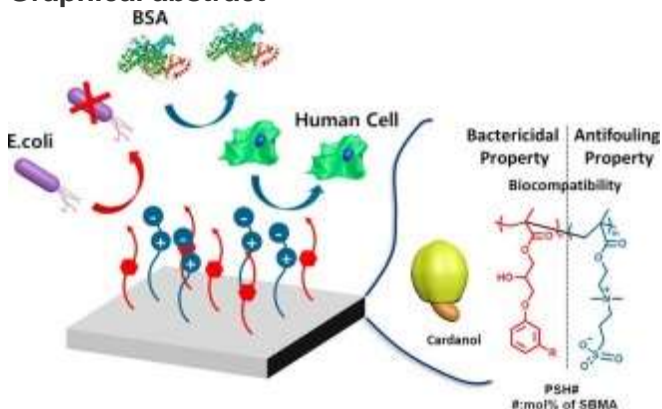
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3. Virtual Special Section on: Poly(ionic liquid)s: innovative electrolytes for cutting-edge applications; Edited by Eric Drockenmuller and Alexander S. Shaplov

1. ☐ select article Facile preparation of structured zwitterionic polymer substrate via sub-surface initiated atom transfer radical polymerization and its synergistic marine antifouling investigation

Research articleAbstract only

Facile preparation of structured zwitterionic polymer substrate via sub-surface initiated atom transfer radical polymerization and its synergistic marine antifouling investigation

Hui Liu, Zhengfeng Ma, Wufang Yang, Xiaowei Pei, Feng Zhou

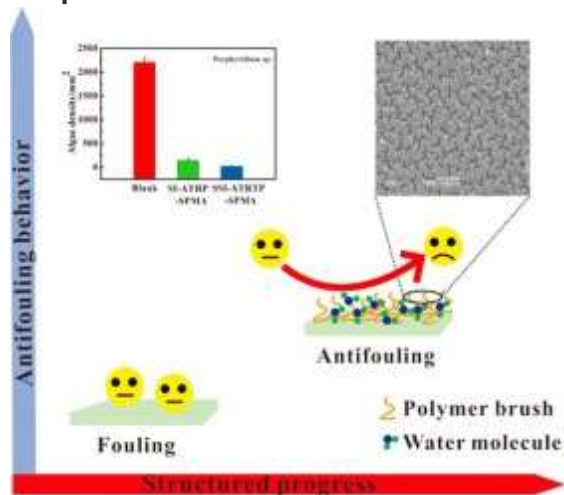
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4. Virtual Special Section on: The current state in the field of SMALP; Edited by Bert Klumperman and Michael Overduin

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Examining the stability of membrane proteins within SMALPs

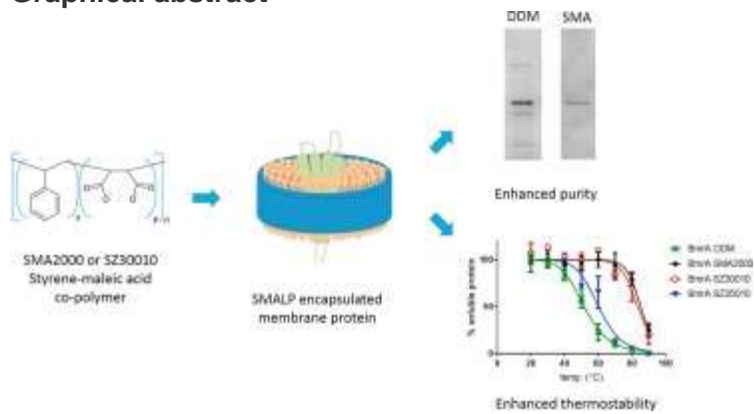
Aiman A. Gulamhussein, Danyall Meah, Damian D. Soja, Stephen Fenner, ... Alice J. Rothnie

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5. Virtual Special Section on: Materials Today EPJ Award 2018

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Research articleAbstract only

Electrical dual-percolation in MWCNTs/SBS/PVDF based thermoplastic elastomer (TPE) composites and the effect of mechanical stretching

Christopher Ellingford, Henry Smith, Xue Yan, Christopher Bowen, ... Chaoying Wan

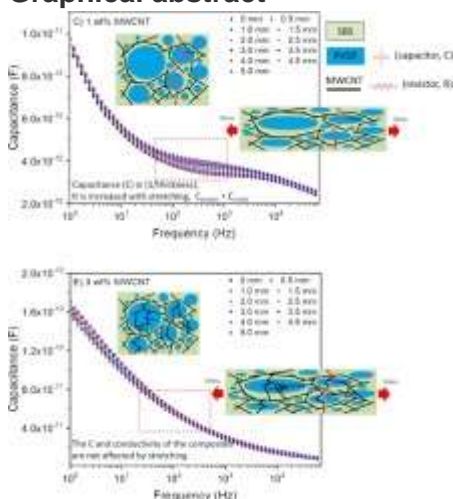
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6. Review Articles

1. ☐ select article Elaboration of new modified electrodes (MEs) by electropolymerization of Cu(II)-Schiff base complexes bearing pyrrole moieties: Application in electroreduction of acetophenone and carbon dioxide

Review article Abstract only

Elaboration of new modified electrodes (MEs) by electropolymerization of Cu(II)-Schiff base complexes bearing pyrrole moieties: Application in electroreduction of acetophenone and carbon dioxide

Ahcene Ait Amer, Hocine Ilikti, Christophe Beyens, Joël Lyskawa, Ulrich Maschke

Pages 569-580

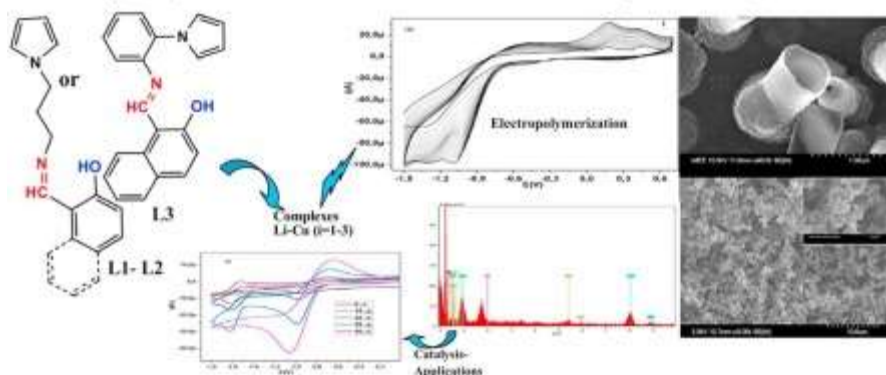
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Poly (L-Cu)-ITO/Pt Modified electrodes for electroreduction of acetophenone and CO₂.



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Haicheng Jiang, Lijie Duan, Xiuyan Ren, Guanghui Gao

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3. ☐ select article Guar gum: Versatile natural polymer for drug delivery applications

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Guar gum: Versatile natural polymer for drug delivery applications

Archana George, Priyanka A. Shah, Pranav S. Shrivastav

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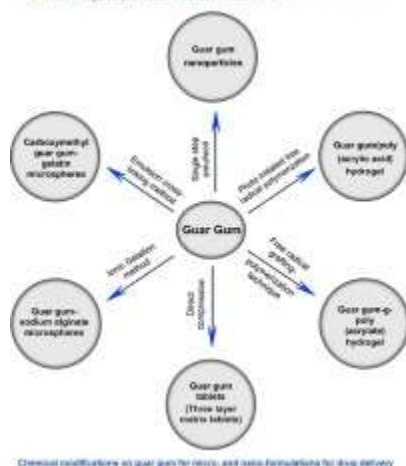
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Guar gum: Versatile natural polymer for drug delivery applications
Archana George, Priyanka A. Shah, Pranav S. Shrivastav



Chemical modifications in guar gum for micro- and nano-formulations for drug delivery

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Morphology, rheology, and physical properties of polymer-modified asphalt binders

Ali Behnood, Mahsa Modiri Gharehveran

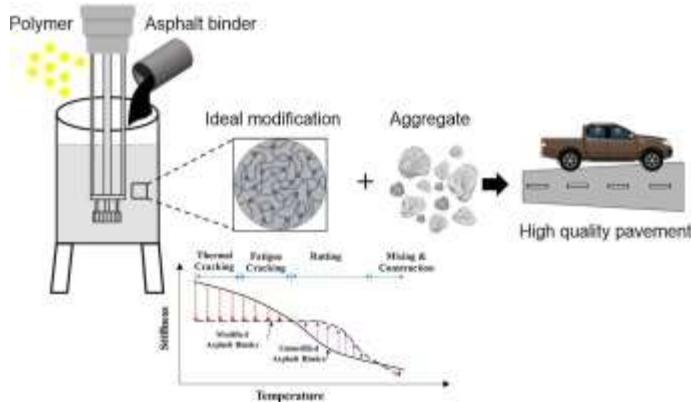
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7. Research Insights

1. ☐ select article Development of nanostructured nickel reinforced polyacrylamide via frontal polymerization for a reliable room temperature humidity sensor

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Development of nanostructured nickel reinforced polyacrylamide via frontal polymerization for a reliable room temperature humidity sensor

Priyanka Chaudhary, Dheeraj Kumar Maurya, Samiksha Sikarwar, B.C. Yadav, ... Rajiv Prakash

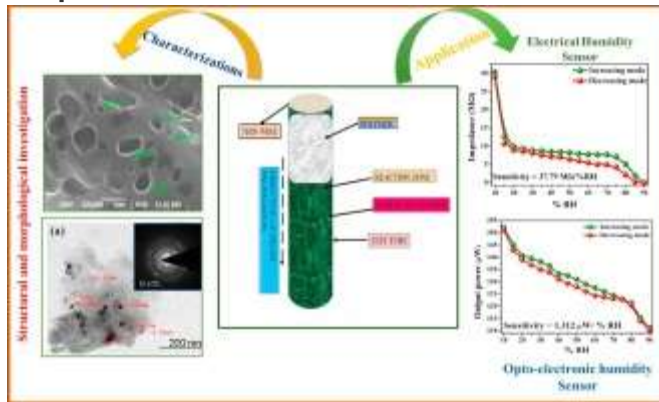
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Wood-lignin: Supply, extraction processes and use as bio-based material

Amélie Tribot, Ghenima Amer, Maarouf Abdou Alio, Hélène de Baynast, ... Claude-Gilles Dussap

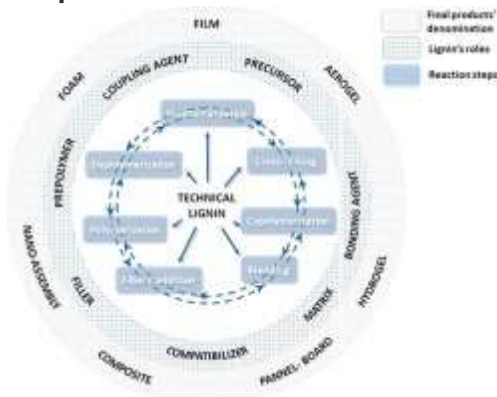
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8. Tutorial Articles

1. Short Communication

1. ☐ select article Heptyl mannose decorated glyconanoparticles with tunable morphologies through polymerization induced self-assembly. Synthesis, functionalization and interactions with type 1 piliated *E. coli*

Short communicationAbstract only

Heptyl mannose decorated glyconanoparticles with tunable morphologies through polymerization induced self-assembly. Synthesis, functionalization and interactions with type 1 piliated *E. coli*

Xibo Yan, Veronica La Padula, Sabine Favre-Bonte, Julien Bernard

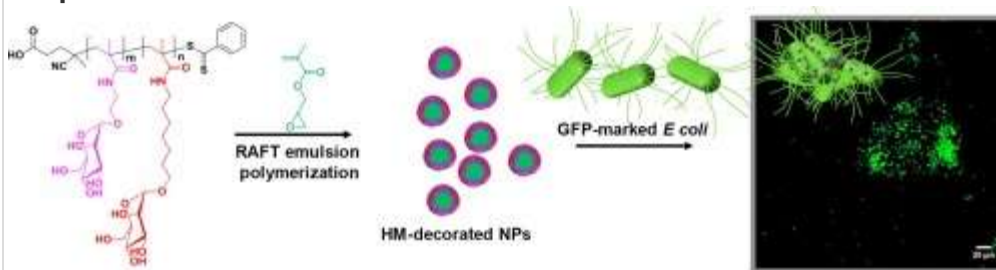
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2. ☐ select article Synthesis and post-polymerization modification of polyester containing pendant thiolactone units

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Synthesis and post-polymerization modification of polyester containing pendant thiolactone units

Elif Baysak, Ufuk Saim Gunay, Ozgun Daglar, Hakan Durmaz

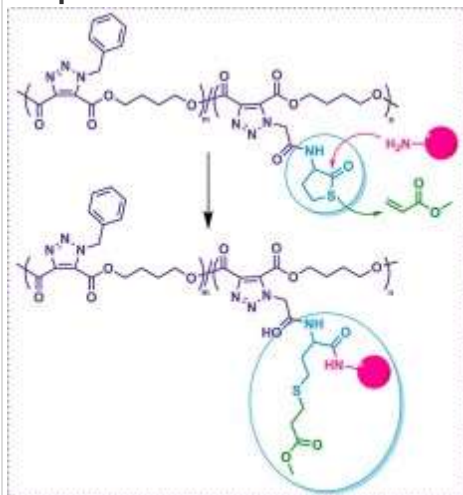
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3. ☐ select article Bonded-luminescent foam based on europium complexes as a reversible copper (II) ions sensor in pure water

Short communicationAbstract only

Bonded-luminescent foam based on europium complexes as a reversible copper (II) ions sensor in pure water

Yan Su, Dan Zhang, Peng Jia, Weichen Gao, ... Chaolong Yang

Pages 461-465

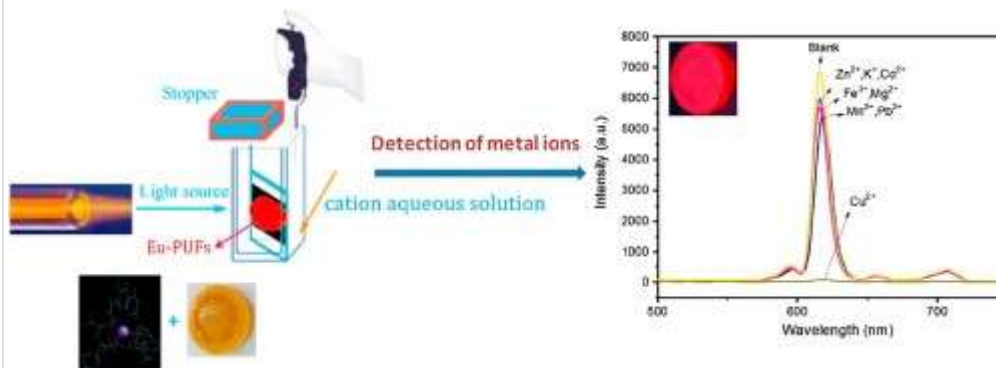
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A series long luminescence lifetime luminescent Eu-complex polyurethane foams (Eu-PUFs) sensors for Cu^{2+} ions detection in pure water has been successfully assembled by simple one-step co-polycondensation reaction. To the best of our knowledge, this is the first example of Cu^{2+} ion sensors based on bonded luminescent Eu-complex polyurethane foams.



4. ☐ select article Online monitoring of dopamine particle formation via continuous light scattering intensity measurement

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Online monitoring of dopamine particle formation via continuous light scattering intensity measurement

Aide Wu, Nurettin Sahiner, Wayne F. Reed

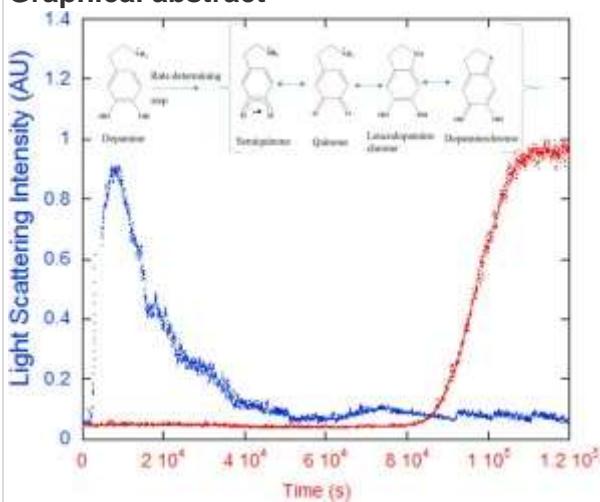
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5. ☐ select article Enhancement of the growth of polymer brushes via ATRP initiated from ions-releasing indium tin oxide substrates

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Enhancement of the growth of polymer brushes via ATRP initiated from ions-releasing indium tin oxide substrates

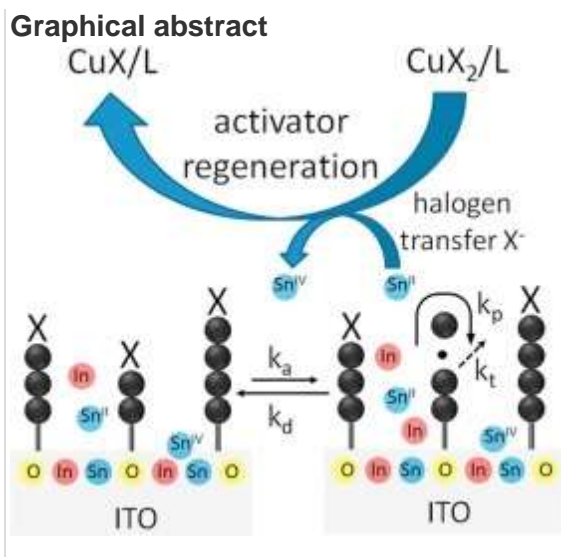
Anna Gruszkiewicz, Monika Słowikowska, Gabriela Grześ, Artur Wójcik, ... Szczepan Zapotoczny

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9. Regular Articles

1. ☐ select article Sustainable thermoplastics from renewable resources: Thermal behavior of poly(1,4-cyclohexane dimethylene 2,5-furandicarboxylate)

Research articleAbstract only

Sustainable thermoplastics from renewable resources: Thermal behavior of poly(1,4-cyclohexane dimethylene 2,5-furandicarboxylate)

Nejib Kasmi, Niki Pouloupoulou, Zoi Terzopoulou, Dimitrios G. Papageorgiou, ... George Z. Papageorgiou

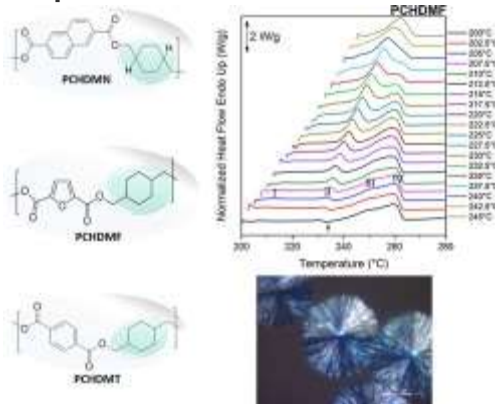
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2. ☐ select article A simple environment-friendly process for preparing high-concentration alkali lignin nanospheres

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A simple environment-friendly process for preparing high-concentration alkali lignin nanospheres

Chao Liu, Youming Li, Yi Hou

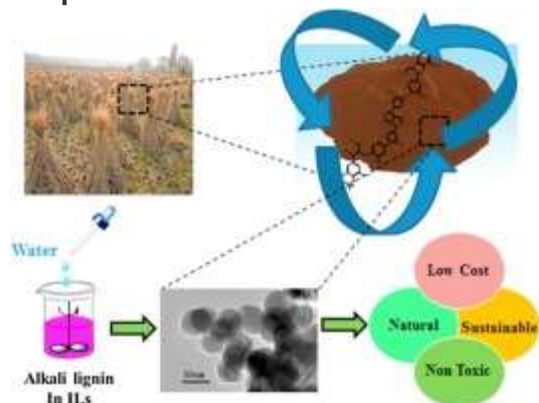
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3. ☐ select article Effect of crosslinking stage on photocrosslinking of benzophenone functionalized poly(2-ethyl-2-oxazoline) nanofibers obtained by aqueous electrospinning

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Effect of crosslinking stage on photocrosslinking of benzophenone functionalized poly(2-ethyl-2-oxazoline) nanofibers obtained by aqueous electrospinning

Yin Li, Maarten Vergaelen, Ella Schoolaert, Richard Hoogenboom, Karen De Clerck

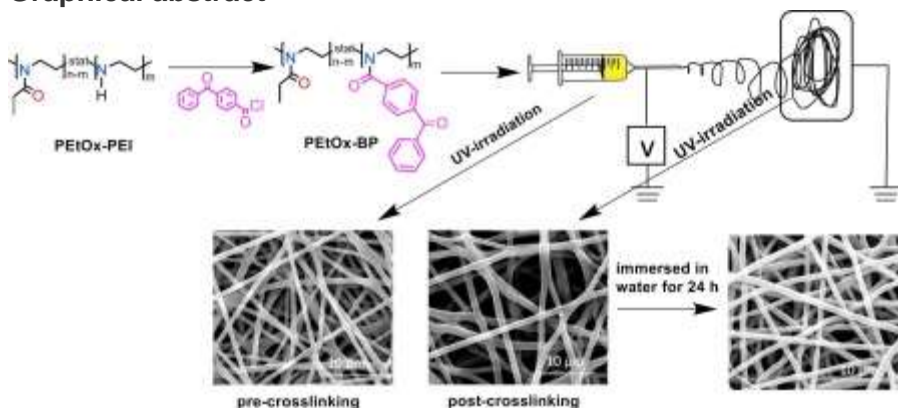
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4. ☐ select article Development of multiactive antibacterial multilayers of hyaluronic acid and chitosan onto poly(ethylene terephthalate)

Research articleAbstract only

Development of multiactive antibacterial multilayers of hyaluronic acid and chitosan onto poly(ethylene terephthalate)

Leyre Pérez-Álvarez, Leire Ruiz-Rubio, Iñigo Azua, Vanessa Benito, ... José Luis Vilas-Vilela

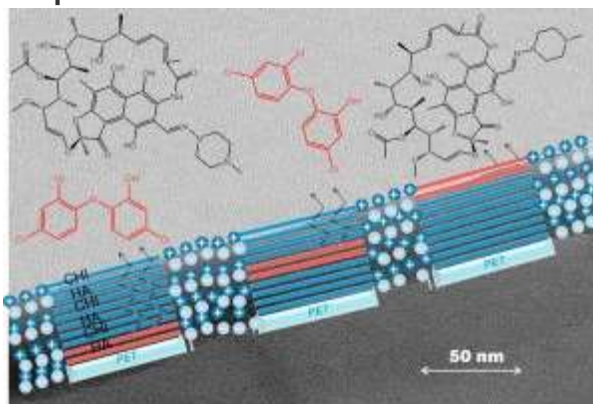
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5. ☐ select article Influence of the intramolecular donor-acceptor distance on the performance of double-cable polymers

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Influence of the intramolecular donor-acceptor distance on the performance of double-cable polymers

Jurong Lu, Xingcui Feng, Yihong Huan, Naiwu Chen, ... Wei Huang

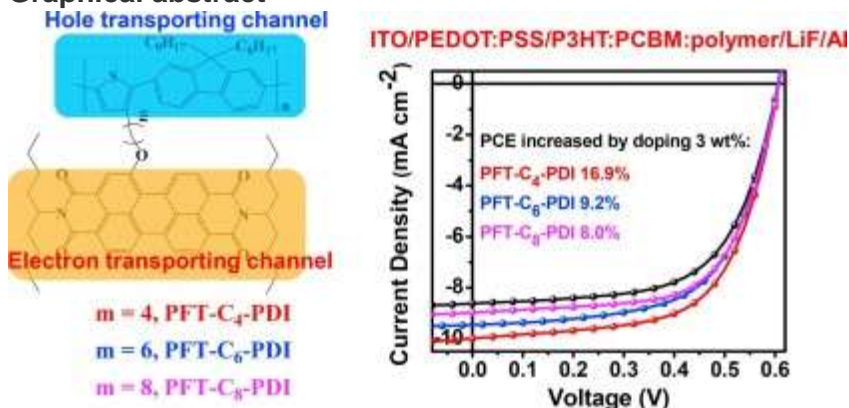
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6. ☐ select article Re-evaluation of the ring-opening polymerization of ϵ -caprolactone catalyzed by dialkylmagnesium reagents

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Re-evaluation of the ring-opening polymerization of ϵ -caprolactone catalyzed by dialkylmagnesium reagents

Swarup Ghosh, Thi Nhan Nguyen, Thuy Tran Thi, Esteban Mejía

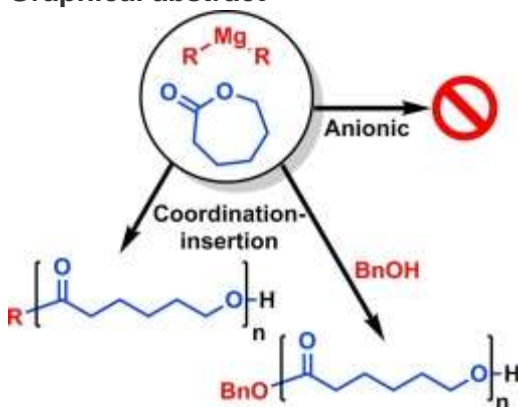
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7. ☐ select article The *in vitro* enzymatic degradation of poly(trimethylene carbonate-co-2, 2'-dimethyltrimethylene carbonate)

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The *in vitro* enzymatic degradation of poly(trimethylene carbonate-co-2, 2'-dimethyltrimethylene carbonate)

Zhipeng Hou, Wei Zhang, Jing Guo, Zhangpei Chen, ... Liquan Yang

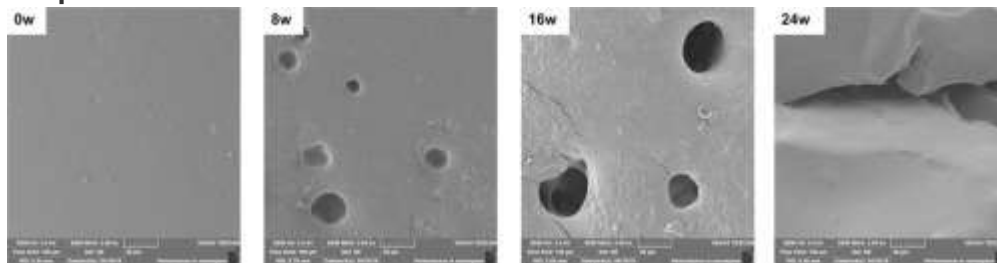
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8. ☐ select article Regioselective ring-opening metathesis polymerization of limonene oxide-substituted cyclooctene: The highly functional ethylene/vinyl ester copolymers

Research articleAbstract only

Regioselective ring-opening metathesis polymerization of limonene oxide-substituted cyclooctene: The highly functional ethylene/vinyl ester copolymers

Chulu Zhou, Yang Wang, Lanxiao Zhao, Zhizhou Liu, Jianhua Cheng

Pages 60-66

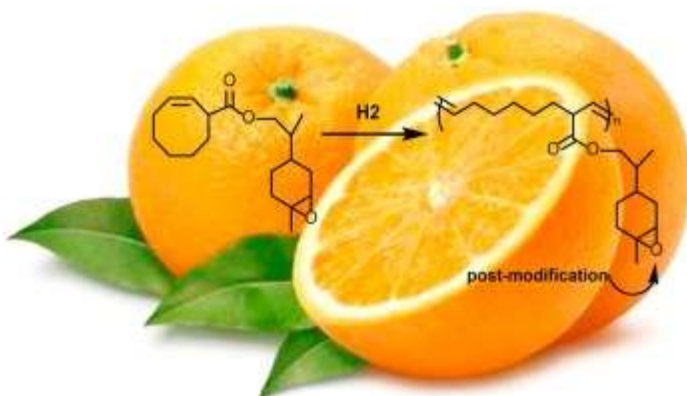
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A new cyclooctene monomer with abundant biorenewable limonene oxide as side group which could be polymerised by regio-/stereoselective ring-opening metathesis polymerization (ROMP) using Hoveyda-Grubbs second-generation catalyst (**H2**). Moreover, the oxiane in limonene oxide side chain could be efficiently modified by many functional group.



9. ☐ select article Effects of active ingredients from traditional Chinese medicines on glycogen molecular structure in diabetic mice

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Effects of active ingredients from traditional Chinese medicines on glycogen molecular structure in diabetic mice

Cheng Li, Hua Gan, Xinle Tan, Zhenxia Hu, ... Robert G. Gilbert

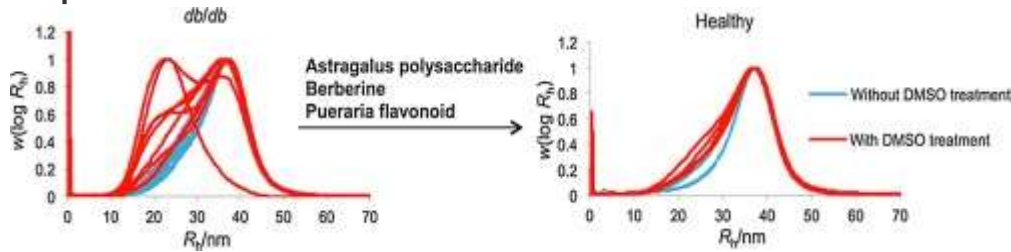
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10. ☐ select article Multifunctional layer-by-layer modified chitosan/poly(ethylene glycol) hydrogels

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Multifunctional layer-by-layer modified chitosan/poly(ethylene glycol) hydrogels

Bora Onat, Sinem Ulasan, Sreeparna Banerjee, Irem Erel-Goktepe

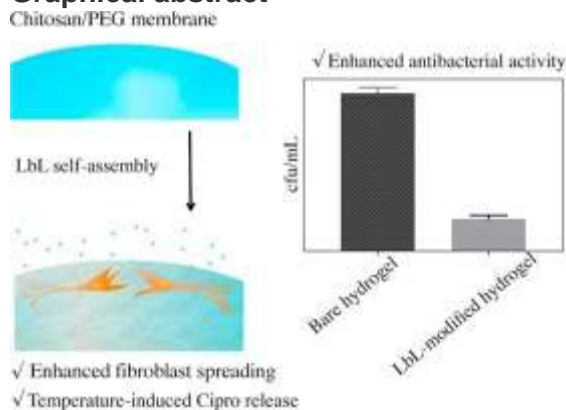
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11. ☐ select article Development of superhydrophobic electrospun fibrous membrane of polymers of intrinsic microporosity (PIM-2)

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Development of superhydrophobic electrospun fibrous membrane of polymers of intrinsic microporosity (PIM-2)

Bekir Satilmis, Tamer Uyar

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12. ☐ select article Preparation and characterization of silsesquioxane-graphene oxide modified soluble polyimide nanocomposites with excellent dispersibility and enhanced tensile properties

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Preparation and characterization of silsesquioxane-graphene oxide modified soluble polyimide nanocomposites with excellent dispersibility and enhanced tensile properties

Sheng-Yaw Hsu, Sheng-Chi Lin, Jeng-An Wang, Tzu-Yu Cheng,
... Chen-Chi M. Ma

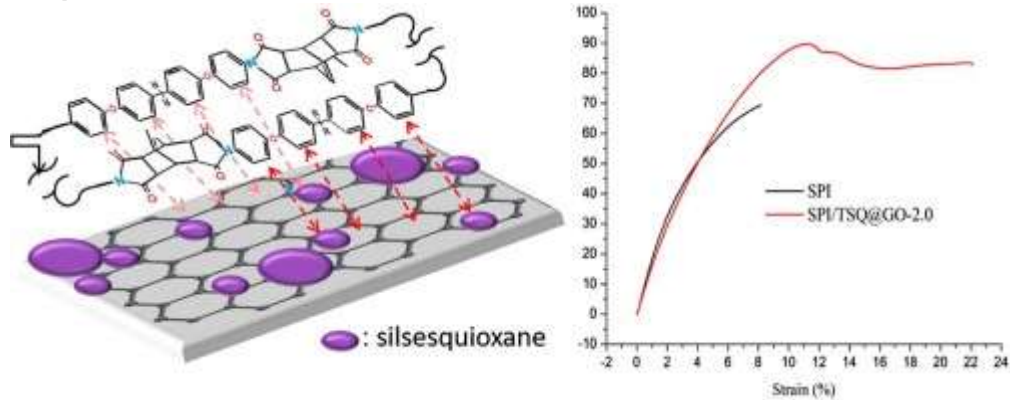
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13. ☐ select article The morphology of crystallisation of PHBV/PHBV copolymer blends

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The morphology of crystallisation of PHBV/PHBV copolymer blends

Alexandra Langford, Clement Matthew Chan, Steven Pratt,
Christopher J. Garvey, Bronwyn Laycock

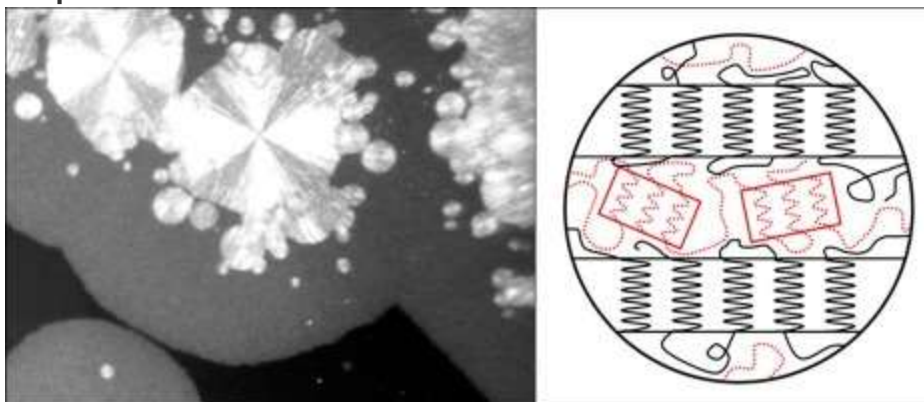
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14. ☐ select article On the use of benzaldehyde to improve the storage stability of one-pot, epoxy ionic liquid formulations

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On the use of benzaldehyde to improve the storage stability of one-pot, epoxy ionic liquid formulations

Fiona C. Binks, Gabriel Cavalli, Michael Henningsen, Brendan J. Howlin, Ian Hamerton

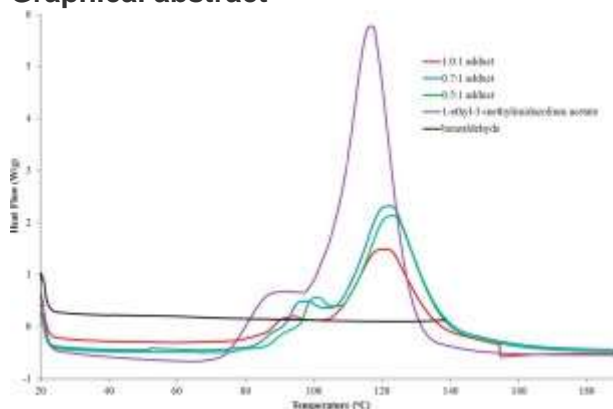
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Low-temperature argon and ammonia plasma treatment of poly-3-hydroxybutyrate films: Surface topography and chemistry changes affect fibroblast cells *in vitro*

R.A. Surmenev, R.V. Chernozem, D.S. Syromotina, C. Oehr, ...
M.A. Surmeneva

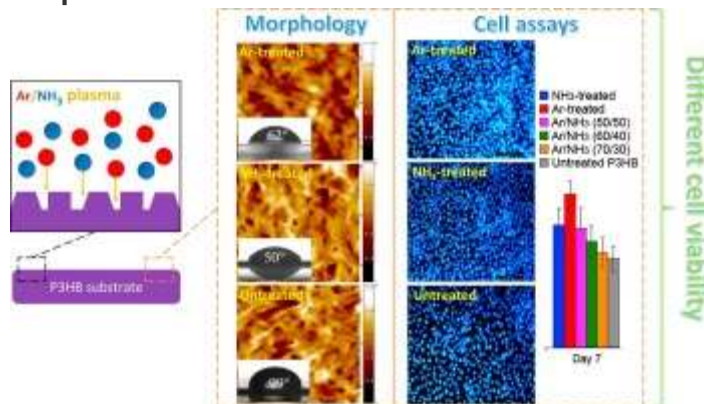
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Cereal straw and their physical modifications with hydrophilic and hydrophobic silica – The influence of functional hybrid material on natural rubber biocomposites

Marcin Masłowski, Justyna Miedzianowska, Krzysztof Strzelec

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17. ☐ select article Polymer brushes grafted from nanostructured zinc oxide layers – Spatially controlled decoration of nanorods

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Polymer brushes grafted from nanostructured zinc oxide layers – Spatially controlled decoration of nanorods

Agata Pomorska, Karol Wolski, Magdalena Wytrwal-Sarna, Andrzej Bernasik, Szczepan Zapotoczny

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18. ☐ select article New insight into the use of latent catalysts for the synthesis of urea formaldehyde adhesives and the mechanical properties of medium density fiberboards bonded with them

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New insight into the use of latent catalysts for the synthesis of urea formaldehyde adhesives and the mechanical properties of medium density fiberboards bonded with them

Ali Dorieh, Nosrat O. Mahmoodi, Manochehr Mamaghani,
Antonio Pizzi, ... Amin moslemi

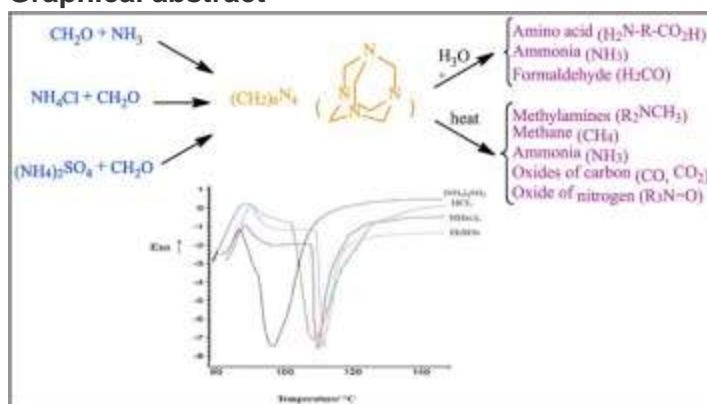
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Multi-arm polymers prepared by atom transfer radical polymerization (ATRP) and their electrospun films as oxygen sensors and pressure sensitive paints

Jiayan Shi, Yifei Zhou, Jiapei Jiang, Tingting Pan, ... Yanqing Tian

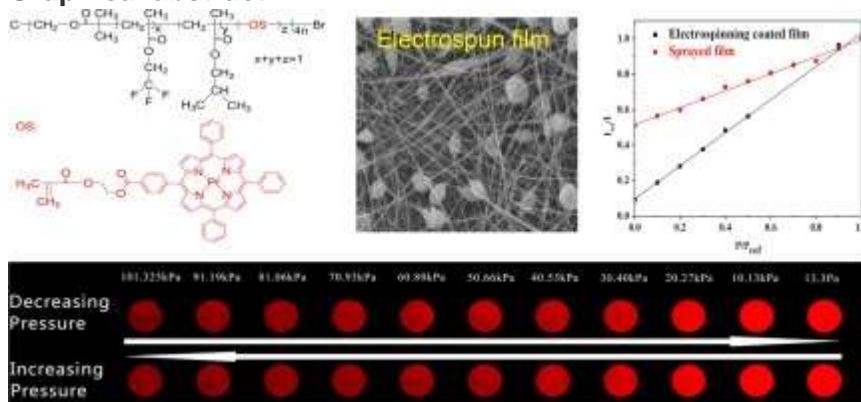
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20. ☐ select article Specific anion effects on the hydration and tribological properties of zwitterionic phosphorylcholine-based brushes

Research articleOpen access

Specific anion effects on the hydration and tribological properties of zwitterionic phosphorylcholine-based brushes

Yunlong Yu, Yongchao Yao, Simone van Lin, Sissi de Beer

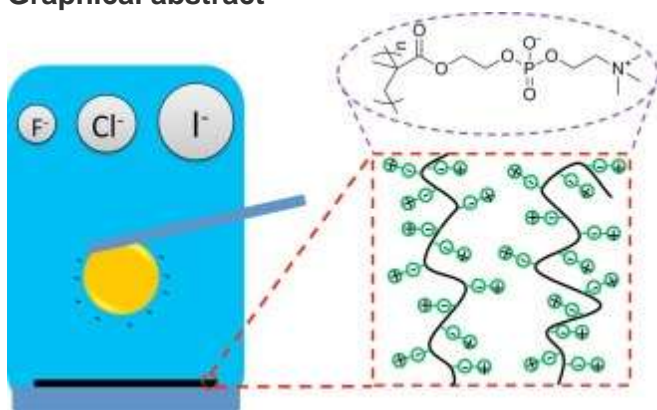
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21. ☐ select article A novel luminescent sensor for disaccharide detection in food: Synthesis and application of a water-soluble rod-coil ionic block copolymer

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A novel luminescent sensor for disaccharide detection in food: Synthesis and application of a water-soluble rod-coil ionic block copolymer

Na Wu, Jie Li, Mi Zhou

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22. ☐ select article Stimuli-responsive amphoteric ion exchange polymers bearing carboxylic and amine groups grafted to a cross-linkable silica network

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Stimuli-responsive amphoteric ion exchange polymers bearing carboxylic and amine groups grafted to a cross-linkable silica network

Emanuela Sgreccia, Luca Pasquini, Gianfranco Ercolani,
Philippe Knauth, Maria Luisa Di Vona

Pages 255-262

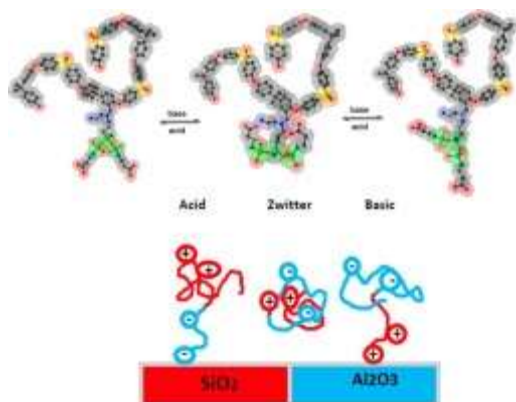
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Stimulus-sensitive properties of hybrid organic-inorganic bio-compatible polyelectrolytes: ionic conductivity, hydration, and selective deposition.



23. ☐ select article Modulation of protein activity and assembled structure by polymer conjugation: PEGylation vs glycosylation

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Modulation of protein activity and assembled structure by polymer conjugation: PEGylation vs glycosylation

Chunyang Bao, Qiang Zhang

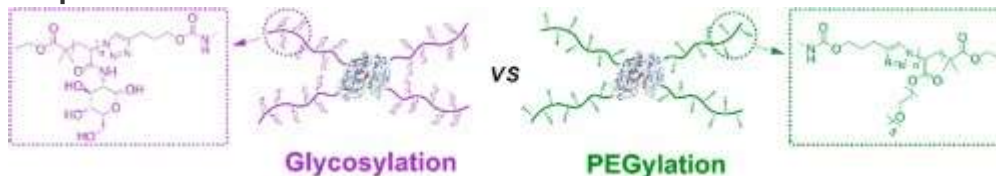
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24. ☐ select article Design of novel “imprinting synchronized with crosslinking” surface imprinted technique and its application for selectively removing phenols from aqueous solution

Research articleAbstract only

Design of novel “imprinting synchronized with crosslinking” surface imprinted technique and its application for selectively removing phenols from aqueous solution

Fu-Qiang An, Hu-Fei Li, Xu-Dong Guo, Tuo-Ping Hu, ... Jian-Feng Gao

Pages 273-282

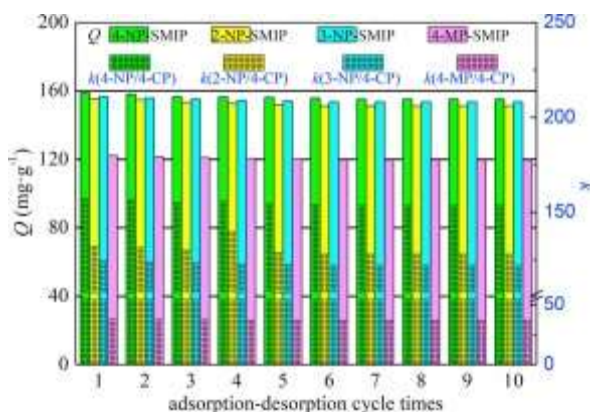
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The exhausted surface molecularly imprinted polymers (SMIP) could be effectively regenerated by 1 mol L⁻¹ of hydrochloric acid aqueous solution, and the regenerative SMIP could be reused at least 10 times without significant reduction of adsorption capacity and selectivity coefficient.



25. ☐ select article Synthesis, characterization, aggregation-induced emission and nanoaggregates of the copolymers containing different ratios of carbazoles and tetraphenylethylenes

Research articleAbstract only

Synthesis, characterization, aggregation-induced emission and nanoaggregates of the copolymers containing different ratios of carbazoles and tetraphenylethylenes

Yu-Wei Tu, Chao-Chi Wang, Alis Shano Godana, Chin-Yang Yu

Pages 283-290

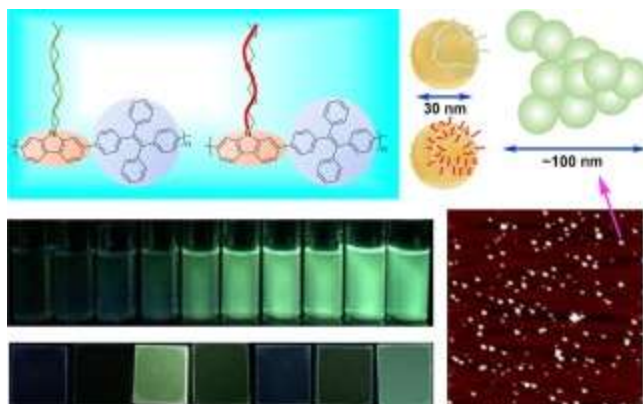
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Polymers comprising of different ratios of *N*-decyl substituted or *N*-triethylene glycol substituted 2,7-carbazoles and tetraphenylethylenes were synthesized by palladium-catalyzed Suzuki Miyaura cross-coupling reaction. The copolymers showed aggregation induced emission characteristics when the composition of the tetraphenylethylenes reached to 50%. The higher composition of the tetraphenylethylenes, the deeper HOMO level and the larger bandgap of the polymers. Polymers with 1:1 M ratio of the carbazoles and the tetraphenylethylenes exhibited sphere-like nanoaggregates with an average diameter of around 30 nm. The polymers containing carbazole and TPE units in 3:1 or 1:3 M ratio self-assembled to form nanoaggregates with a size of around 100 nm.



26. ☐ select article Multi-stimuli responsive novel polyimide smart materials bearing triarylamine and naphthalimide groups

Research articleAbstract only

Multi-stimuli responsive novel polyimide smart materials bearing triarylamine and naphthalimide groups

Xu Zhang, Qingyi Lu, Caiyu Yang, Shuo Zhao, ... Wen Wang

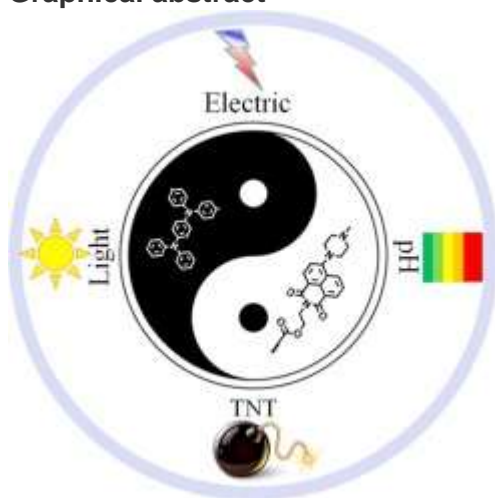
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27. ☐ select article Smart, biocompatible, responsive surfaces on pH, temperature and ionic strength of titanium oxide and niobium oxide with polymer brushes of poly(acrylic acid), poly(*N*-isopropylacrylamide) and poly([2-(methacryloyloxy)ethyl]trimethylammonium chloride)

Research articleAbstract only

Smart, biocompatible, responsive surfaces on pH, temperature and ionic strength of titanium oxide and niobium oxide with polymer brushes of poly(acrylic acid), poly(*N*-isopropylacrylamide) and poly([2-(methacryloyloxy)ethyl] trimethylammonium chloride)

Nikolaos Politakos, Eleftheria Diamanti, Sergio E. Moya

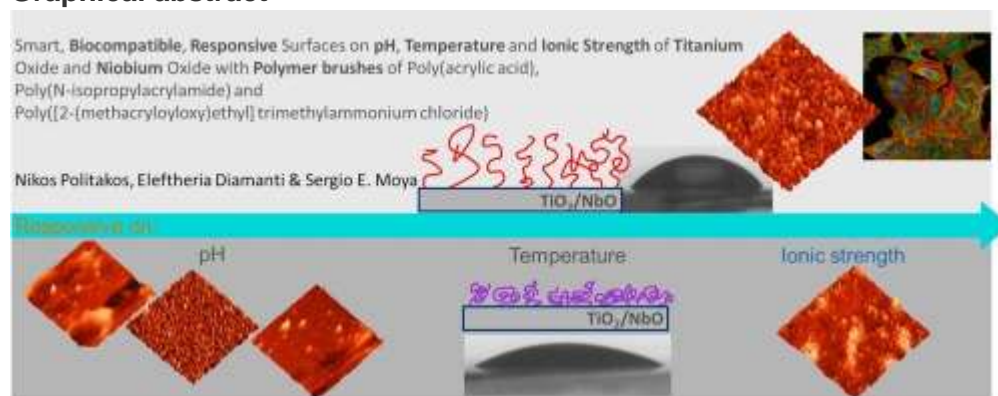
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28. ☐ select article Property modification of a silicone acrylic pressure-sensitive adhesive with oligomeric silicone urethane methacrylate

Research articleAbstract only

Property modification of a silicone acrylic pressure-sensitive adhesive with oligomeric silicone urethane methacrylate

Hee-Woong Park, Ji-Won Park, Jung Hyun Lee, Hyun-Joong Kim, Seunghan Shin

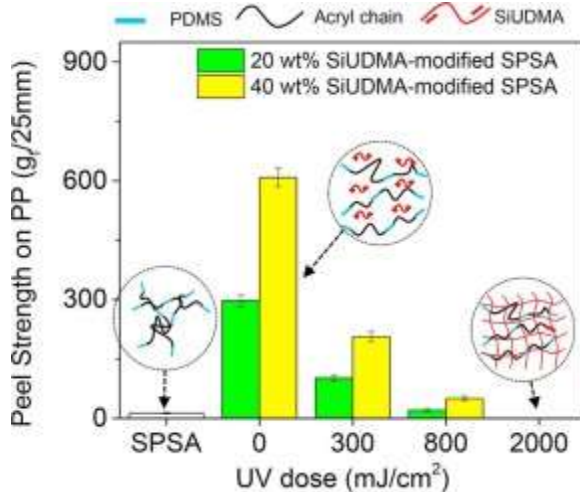
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29. ☐ select article Temperature-dependent transmittance nanocomposite hydrogel with high mechanical strength and controllable swelling memory behavior

Research articleAbstract only

Temperature-dependent transmittance nanocomposite hydrogel with high mechanical strength and controllable swelling memory behavior

Wenpeng Zhao, Hong Xu, Yanxia Liu, Jun Xu, ... Xianqi Feng

Pages 328-333

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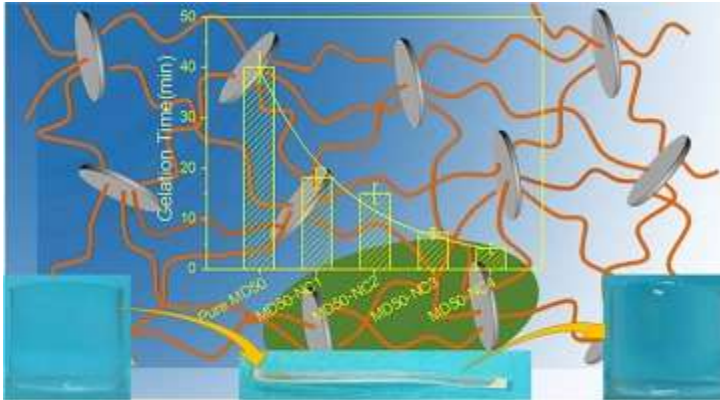
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The physical cross-linking nanocomposite hydrogels with superior transparency were facilely fabricated using in situ polymerization methods. The temperature-dependent nature of transmittance and the controllable swelling memory behaviors of

the hydrogels could propose a promising prospect in many actual applications, such as biomaterials, padding matters, and tissue engineering.



30. ☐ select article Synthesis and characterization of a ROMP-based polycationic antimicrobial hydrogel

Research articleAbstract only

Synthesis and characterization of a ROMP-based polycationic antimicrobial hydrogel

Arzu Palantoken, Muge Sari Yilmaz, Nihan Aytekin Unubol, Elçin Yenigul, ... Tarik Eren

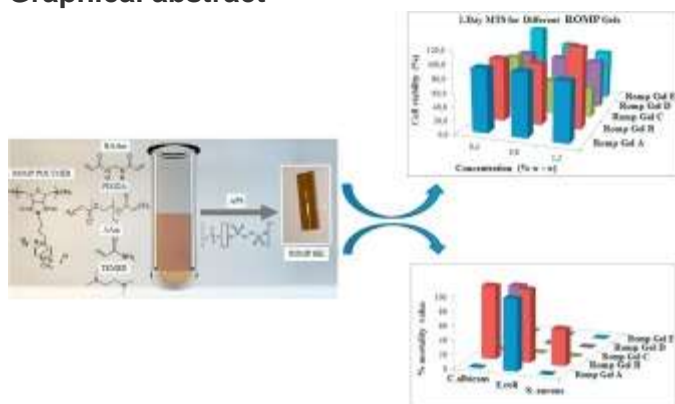
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31. ☐ select article Characterization of sequential dual-curing of thiol-acrylate-epoxy systems with controlled thermal properties

Research articleAbstract only

Characterization of sequential dual-curing of thiol-acrylate-epoxy systems with controlled thermal properties

Claudio Russo, Àngels Serra, Xavier Fernández-Francos, Silvia De la Flor

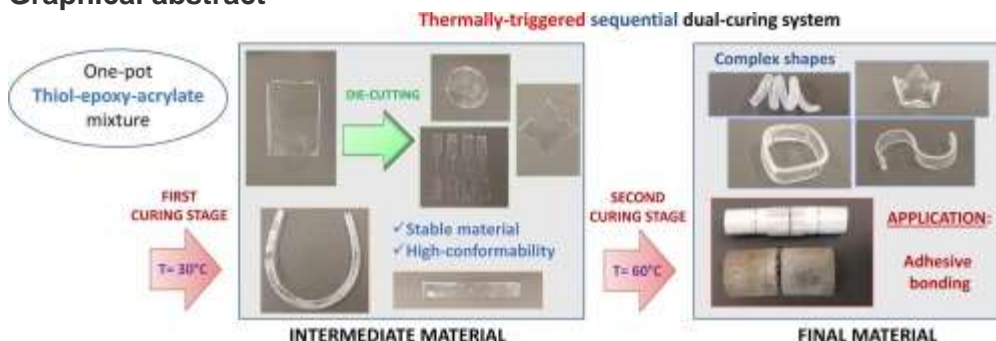
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32. ☐ select article Post-synthesis modification of thermo-responsive hydrogels: Hydrazone crosslinking of α -oxoaldehyde obtained from NIPAm-based polymers

Research articleAbstract only

Post-synthesis modification of thermo-responsive hydrogels: Hydrazone crosslinking of α -oxoaldehyde obtained from NIPAm-based polymers

Alexis Wolfel, Marcelo R. Romero, Cecilia I. Alvarez Igarzabal

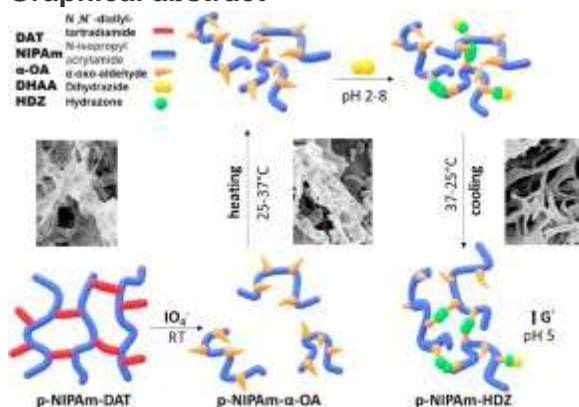
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33. ☐ select article Biopolymer-hydrophobic drug fibers and the delivery mechanisms for sustained release applications

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Biopolymer-hydrophobic drug fibers and the delivery mechanisms for sustained release applications

Alexsandra Valério, Erasmo Mancusi, Fabienne Ferreira, Selene M.A. Guelli Ulson de Souza, ... Sergio Yesid Gómez González

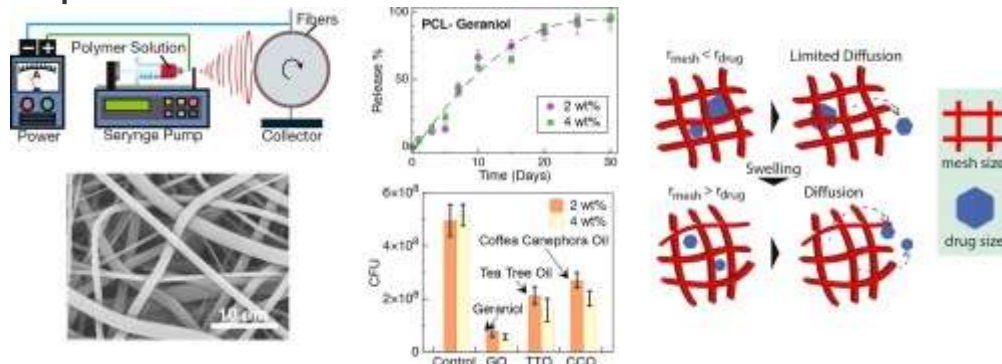
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34. ☐ select article Synthesis of mechanically strong waterborne poly(urethane-urea)s capable of self-healing at elevated temperatures

Research articleAbstract only

Synthesis of mechanically strong waterborne poly(urethane-urea)s capable of self-healing at elevated temperatures

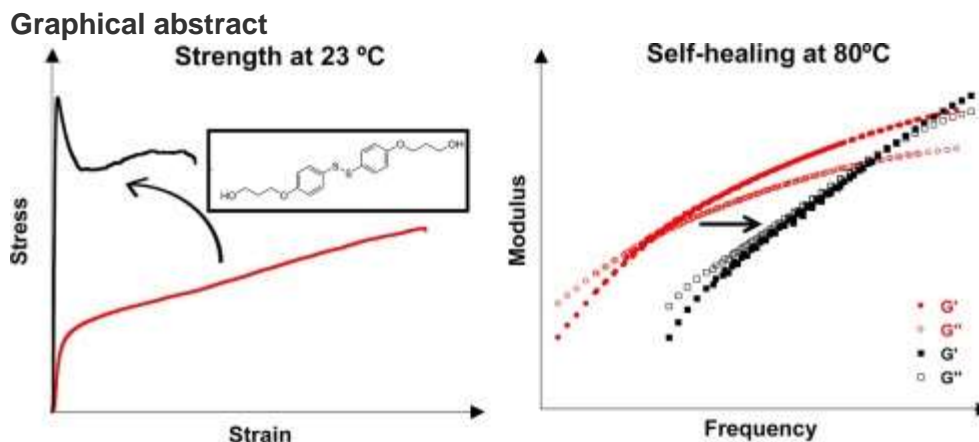
Sil Nevejans, Nicholas Ballard, Iván Rivilla, Mercedes Fernández, ... José M. Asua

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35. ☐ select article The varying mass ratios of soft and hard segments in waterborne polyurethane films: Performances of thermal conductivity and adhesive properties

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The varying mass ratios of soft and hard segments in waterborne polyurethane films: Performances of thermal conductivity and adhesive properties

Rui Li, J.A. Ton Loontjens, Zhihua Shan

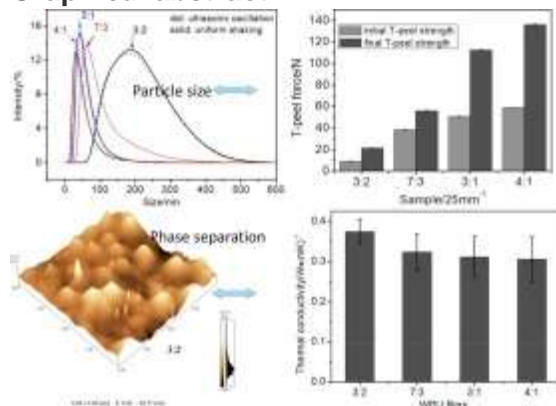
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36. ☐ select article Synthesis and characterization of different sodium hyaluronate nanoparticles to transport large neurotherapeutic molecules through blood brain barrier after stroke

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Synthesis and characterization of different sodium hyaluronate nanoparticles to transport large neurotherapeutic molecules through blood brain barrier after stroke

Sebastián Peralta, Santos Blanco, Raquel Hernández, Herminia Castán, ... María Adolfinia Ruiz

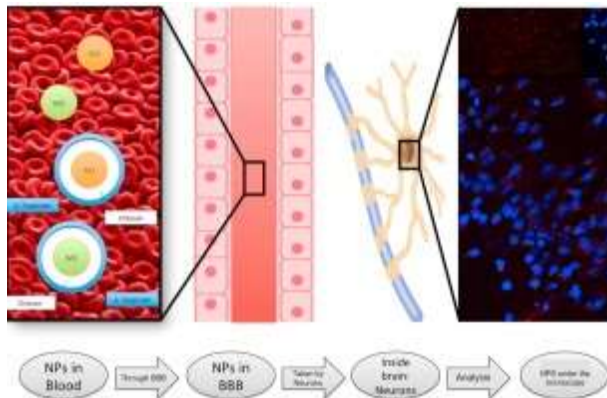
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37. ☐ select article Preparation and characterization of a piezoelectric poly (vinylidene fluoride)/nanohydroxyapatite scaffold capable of naproxen delivery

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Preparation and characterization of a piezoelectric poly (vinylidene fluoride)/nanohydroxyapatite scaffold capable of naproxen delivery

Saeid Karimi, Azadeh Ghaee, Jalal Barzin

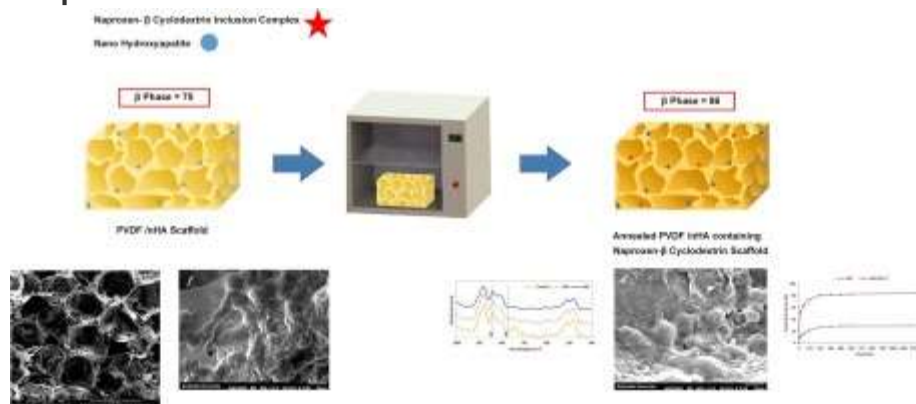
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38. ☐ select article Influence of the chemical composition and formulation of fluorinated epoxy resin on its surface characteristics

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Influence of the chemical composition and formulation of fluorinated epoxy resin on its surface characteristics

Benoit Minisini, Sébastien Rolère, Jean-François Coulon,
Fabienne Poncin-Epaillard

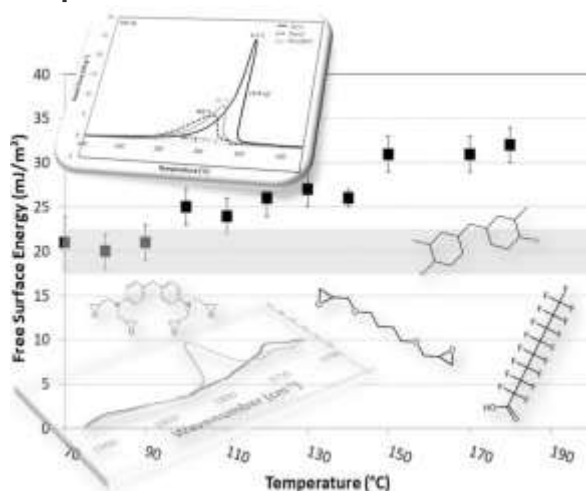
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39. ☐ select article Water-soluble extracts from banana pseudo-stem as functional additives for polylactic acid: Thermal and mechanical investigations

Research articleAbstract only

Water-soluble extracts from banana pseudo-stem as functional additives for polylactic acid: Thermal and mechanical investigations

Thomas Sango, Gregory Stoclet, Nicolas Joly, Adeline Marin, ...
Jean-Marc Lefebvre

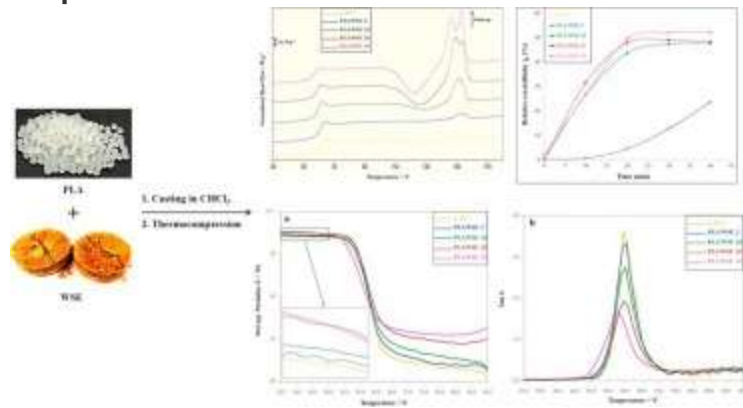
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40. ☐ select article Nanostructured poly(lactic acid)/soy protein/HPMC films by electrospinning for potential applications in food industry

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Nanostructured poly(lactic acid)/soy protein/HPMC films by electrospinning for potential applications in food industry

Ayca Aydogdu, Eda Yildiz, Zehra Ayhan, Yıldırım Aydogdu, ...
Serpil Sahin

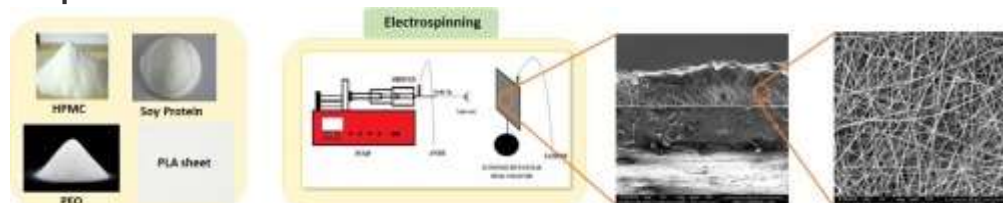
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41. ☐ select article Preparation of anisotropic conductive graphene aerogel/polydimethylsiloxane composites as LEGO® modulars

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Preparation of anisotropic conductive graphene aerogel/polydimethylsiloxane composites as LEGO® modulars

Yunpeng Wang, Bowen Yao, Hongwu Chen, Heyun Wang, ...
Zhongqiang Yang

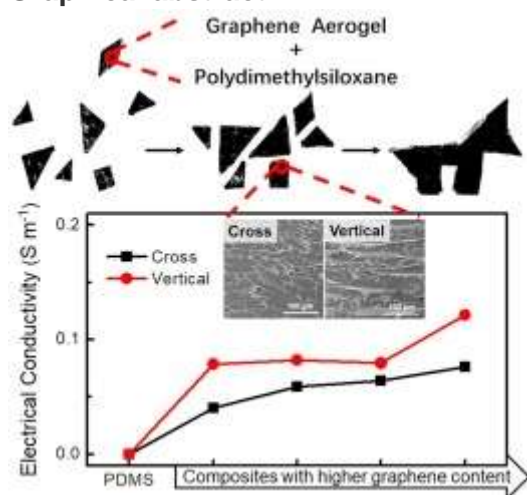
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42. ☐ select article Influence of poly(ϵ -caprolactone) end-groups on the temperature-induced macroscopic gelation of Pluronic in aqueous media

Research articleOpen access

Influence of poly(ϵ -caprolactone) end-groups on the temperature-induced macroscopic gelation of Pluronic in aqueous media

Natalie Gjerde, Kaizheng Zhu, Kenneth D. Knudsen, Bo Nyström

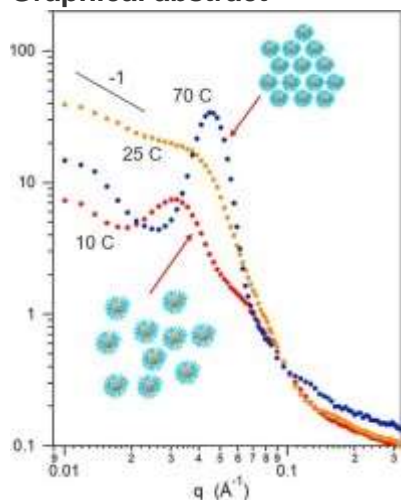
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43. ☐ select article Polysiloxane-based hyperbranched fluorescent materials prepared by thiol-ene “click” chemistry as potential cellular imaging polymers

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Polysiloxane-based hyperbranched fluorescent materials prepared by thiol-ene “click” chemistry as potential cellular imaging polymers

Yu Zhang, Yujing Zuo, Tingxin Yang, Zhiming Gou, Weiying Lin

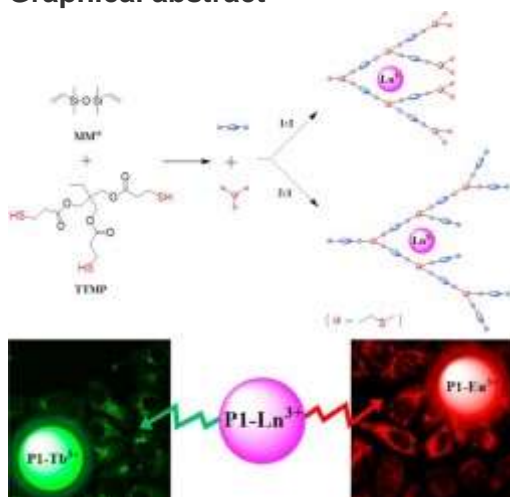
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44. ☐ select article Magnetically steerable Fe₃O₄@Ni²⁺-NTA-polystyrene nanoparticles for the immobilization and separation of his₆-protein

Research articleAbstract only

Magnetically steerable Fe₃O₄@Ni²⁺-NTA-polystyrene nanoparticles for the immobilization and separation of his₆-protein

Leeja Jose, Chaeyeon Lee, Aran Hwang, Ji Hyun Park, ... Hyun-jong Paik

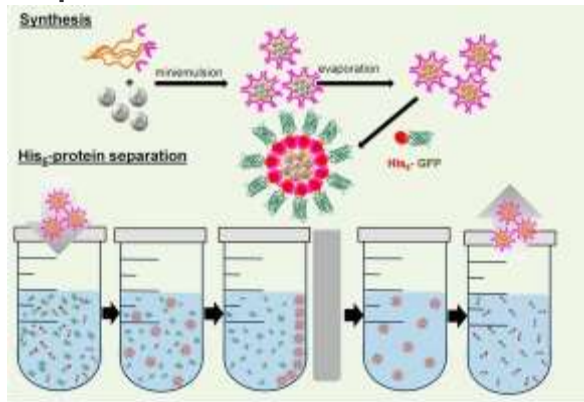
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45. ☐ select article Effect of synthetic colloidal nanoparticles in acrylic resin of dental use

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Effect of synthetic colloidal nanoparticles in acrylic resin of dental use

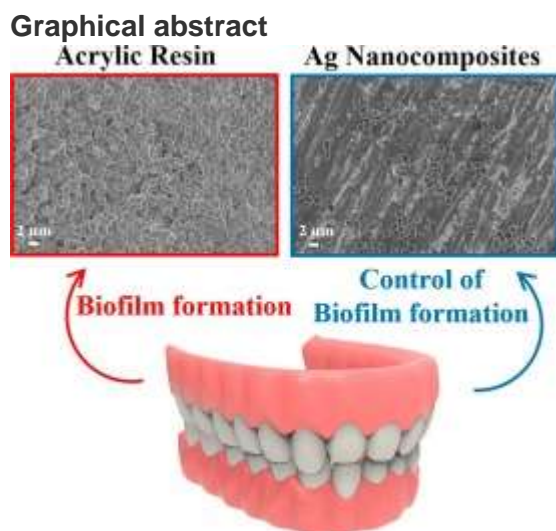
Francisco Nunes de Souza Neto, Renata Lang Sala, Renan Aparecido Fernandes, Tatieli Pardim Oliveira Xavier, ...
Emerson Rodrigues de Camargo

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46. ☐ select article OEGylated polypeptide bearing Y-Shaped pendants with a LCST close to body temperature: Synthesis and thermoresponsive properties

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OEGylated polypeptide bearing Y-Shaped pendants with a LCST close to body temperature: Synthesis and thermoresponsive properties

Xiongliang He, Rongtao Zhou, Chenglong Ge, Ying Ling, ...
Haoyu Tang

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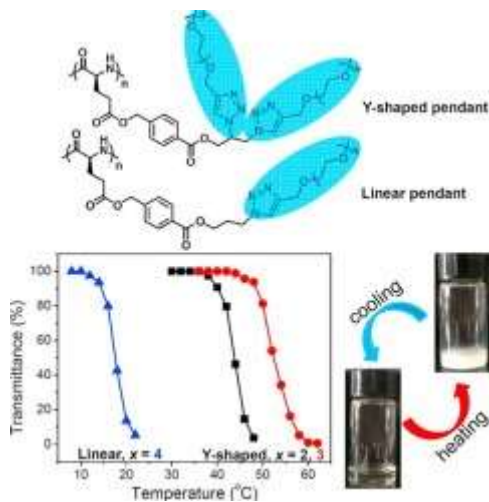
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We developed a new type of OEGylated polypeptides bearing Y-shaped pendants (8-OEGx, x = 2, 3) that showed a reversible LCST-type phase transition in a broad polymer concentration range and the LCST-type T_{cp} can be tuned close to human body temperature. We have demonstrated that the water-solubility and

LCST-type T_{cp} can be improved by incorporation of Y-shaped and OEG pendants due to the increment of hydrophilicity.



47. ☐ select article Magnesium-particle/polyurethane composite layer coating on titanium surfaces for orthopedic applications

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Magnesium-particle/polyurethane composite layer coating on titanium surfaces for orthopedic applications

Abdalla Abdal-hay, Mahmoud Agour, Yu-Kyoung Kim, Min-Ho Lee, ... Sašo Ivanovski

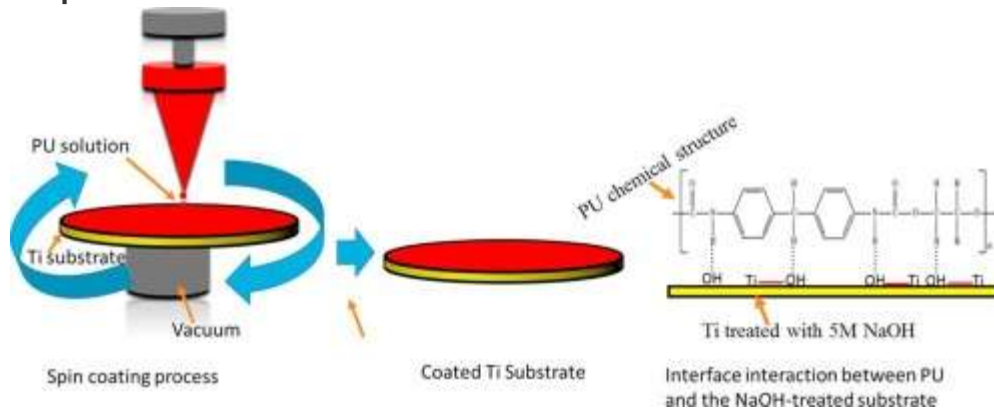
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48. ☐ select article 4-formyl dibenzo-18-crown-6 grafted polyvinyl alcohol as anion exchange membranes for fuel cell

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4-formyl dibenzo-18-crown-6 grafted polyvinyl alcohol as anion exchange membranes for fuel cell

XuYing Zheng, ShiYang Song, JiaRui Yang, JiLin Wang, Lulu Wang

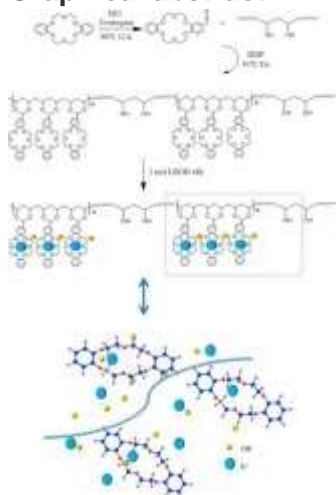
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49. ☐ select article Photopolymerization under various monochromatic UV/visible LEDs and IR lamp: Diamino-anthraquinone derivatives as versatile multicolor photoinitiators

Research articleAbstract only

Photopolymerization under various monochromatic UV/visible LEDs and IR lamp: Diamino-anthraquinone derivatives as versatile multicolor photoinitiators

J. Zhang, J. Lalevée, F. Morlet-Savary, B. Graff, P. Xiao

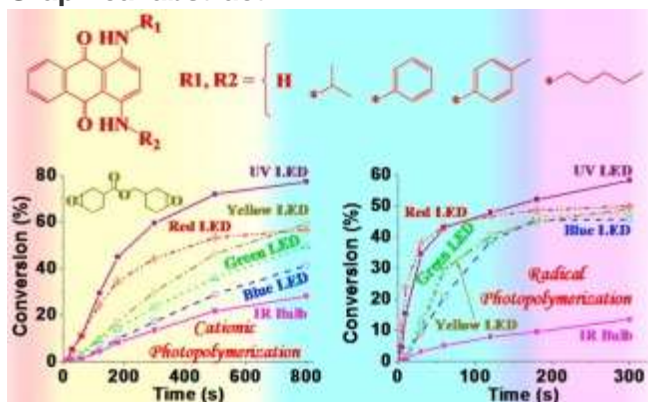
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50. ☐ select article Effect of pressurized CO_2 and N_2 on the rheology of PLA

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Effect of pressurized CO_2 and N_2 on the rheology of PLA

María P. Fernández-Ronco, Rudolf Hufenus, Manfred Heuberger

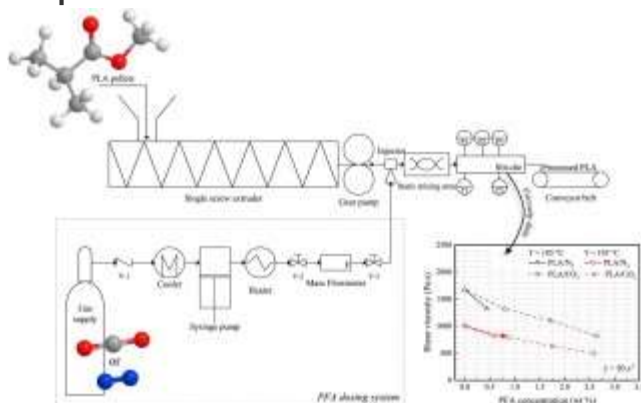
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51. ☐ select article Enzymatically obtaining hydrogels of PVA crosslinked with ferulic acid in the presence of laccase for biomedical applications

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Enzymatically obtaining hydrogels of PVA crosslinked with ferulic acid in the presence of laccase for biomedical applications

Patrícia Alessandra Bersanetti, Victor Hugo Escobar, Regina Freitas Nogueira, Fernando dos Santos Ortega, ... Andreia de Araújo Morandim-Giannetti

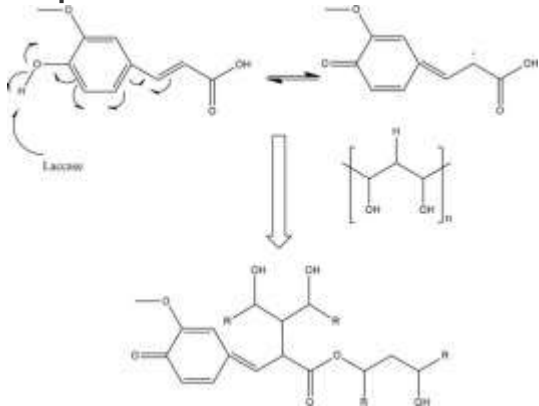
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52. ☐ select article Synthesis of a novel isosorbide-based dental material with improved water sorption

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Synthesis of a novel isosorbide-based dental material with improved water sorption

Jun Seok Kim, Hee Woong Park, Jung-Hyun Lee, Sang-Hyeup Lee, ... Seunghan Shin

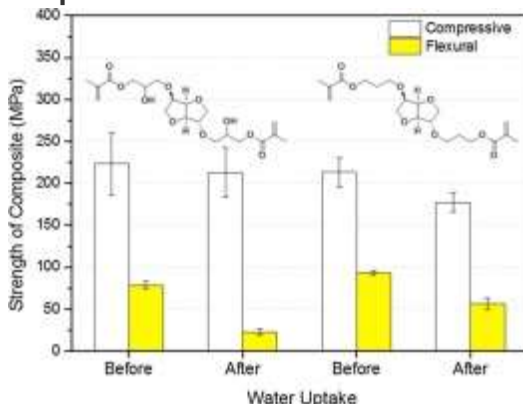
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53. ☐ select article Anticorrosive and self-healing waterborne poly(urethane-triazole) coatings made through a combination of click polymerization and cathodic electrophoretic deposition

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Anticorrosive and self-healing waterborne poly(urethane-triazole) coatings made through a combination of click polymerization and cathodic electrophoretic deposition

Nafise Babaei, Hamid Yeganeh, Reza Gharibi

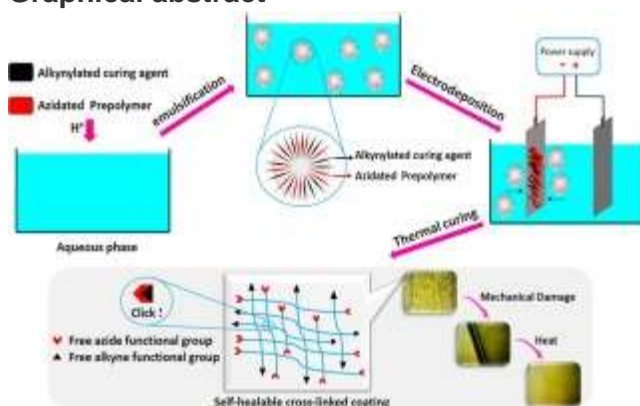
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54. ☐ select article Trimethoxysilyl end-capped hyperbranched polyglycidol/polycaprolactone copolymers for cell delivery and tissue repair: synthesis, characterisation and aqueous solution properties

Research articleAbstract only

Trimethoxysilyl end-capped hyperbranched polyglycidol/polycaprolactone copolymers for cell delivery and tissue repair: synthesis, characterisation and aqueous solution properties

Clara González-Chomón, Vasil M. Garamus, Stanislav Rangelov, John R. Ebdon, ... Silvia S. Halacheva

Pages 648-659

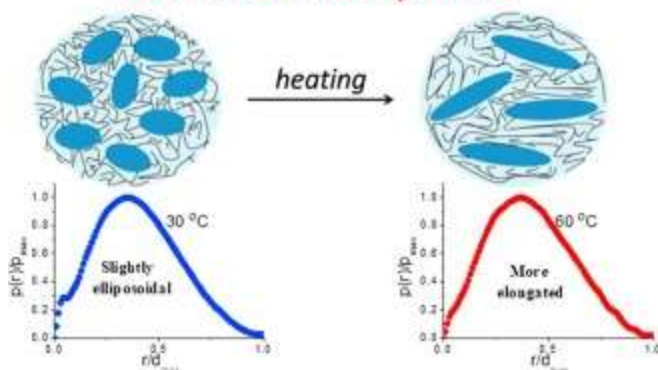
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PCL-HBPG/SiHBPG particles



55. ☐ select article Noncovalently connected supramolecular metathesis graft copolymers: One-pot synthesis and self-assembly

Research articleAbstract only

Noncovalently connected supramolecular metathesis graft copolymers: One-pot synthesis and self-assembly

Liang Ding, Juan Li, Ruiyu Jiang, Lingfang Wang, ... Lei Zhu

Pages 670-677

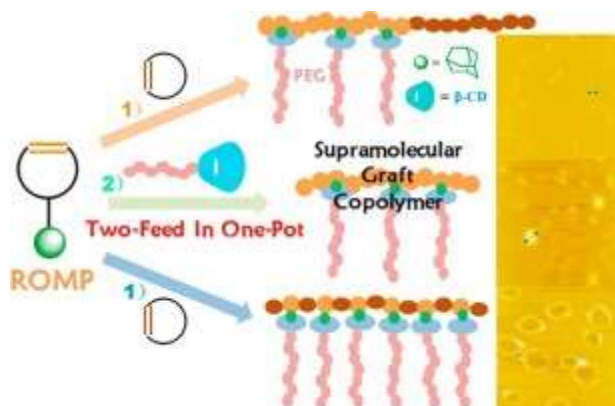
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Three types of noncovalently connected amphiphilic supramolecular graft copolymers were prepared relying on ring-opening metathesis polymerization and host–guest interaction via a two-feed procedure in one-pot; The polymers further self-assemble into supramolecular nanostructures with diverse morphologies.



56. ☐ select article Novel biodegradable hydrogel based on natural polymers: Synthesis, characterization, swelling/reswelling and biodegradability

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Novel biodegradable hydrogel based on natural polymers: Synthesis, characterization, swelling/reswelling and biodegradability

Warunee Tanan, Jate Panichpakdee, Sayant Saengsuwan

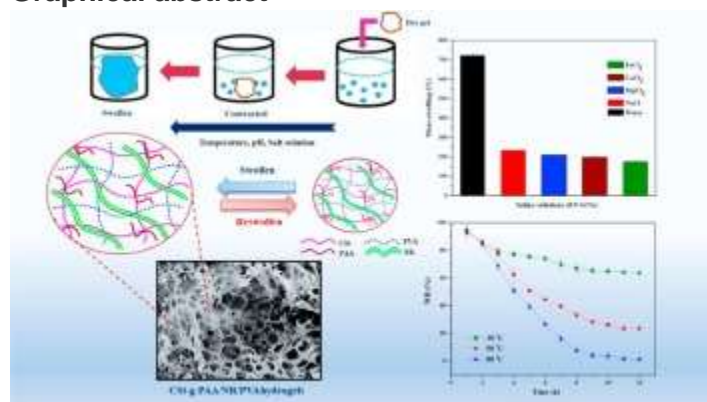
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57. ☐ select article Polyaniline coated sulfonated TiO₂ nanoparticles for effective application in proton conductive polymer membrane fuel cell

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Polyaniline coated sulfonated TiO₂ nanoparticles for effective application in proton conductive polymer membrane fuel cell

S. Elakkiya, G. Arthanareeswaran, A.F. Ismail, Diganta B. Das, R. Suganya

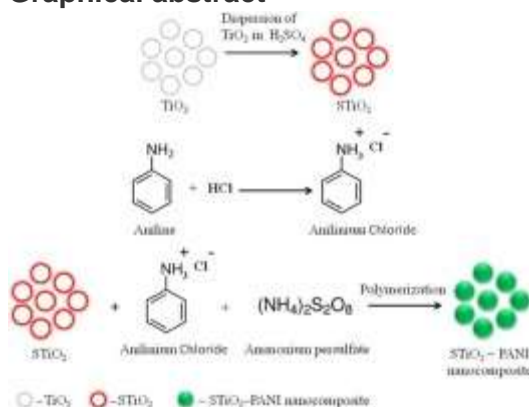
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58. ☐ select article Photopolymerization-assisted self-assembly as a strategy to obtain a dispersion of very high aspect ratio nanostructures in a polystyrene matrix

Research articleAbstract only

Photopolymerization-assisted self-assembly as a strategy to obtain a dispersion of very high aspect ratio nanostructures in a polystyrene matrix

Ú.M. Montoya Rojo, C.C. Riccardi, M.D. Ninago, A.E. Ciolino, ... W.F. Schroeder

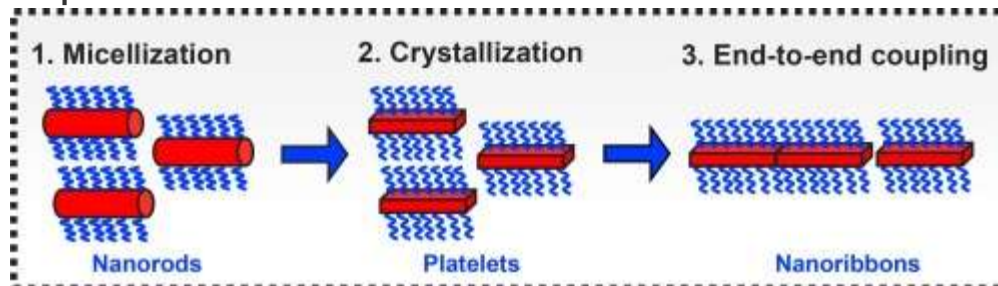
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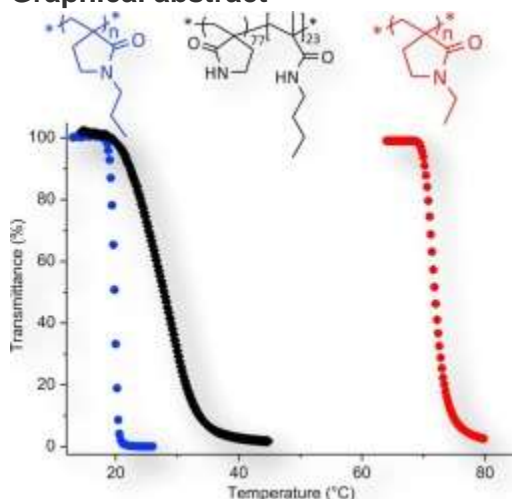
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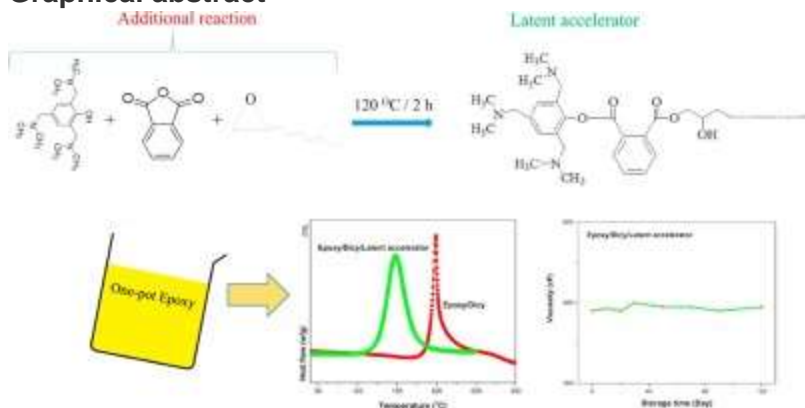
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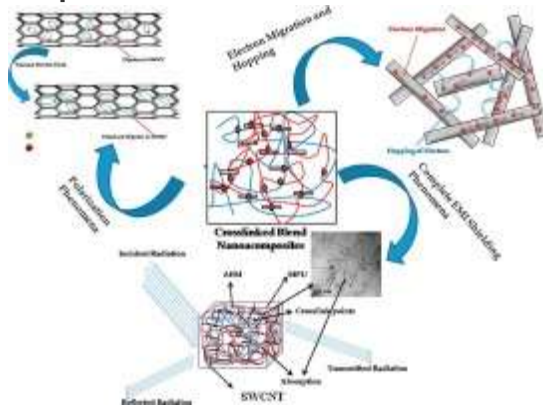
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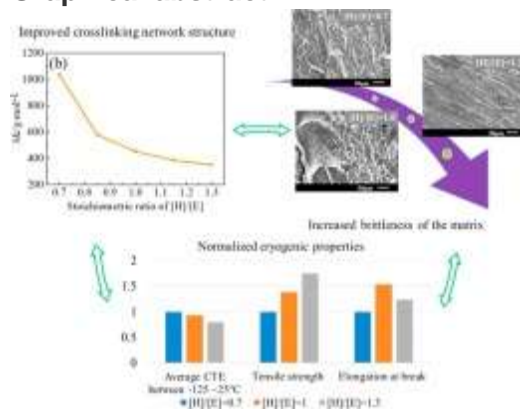
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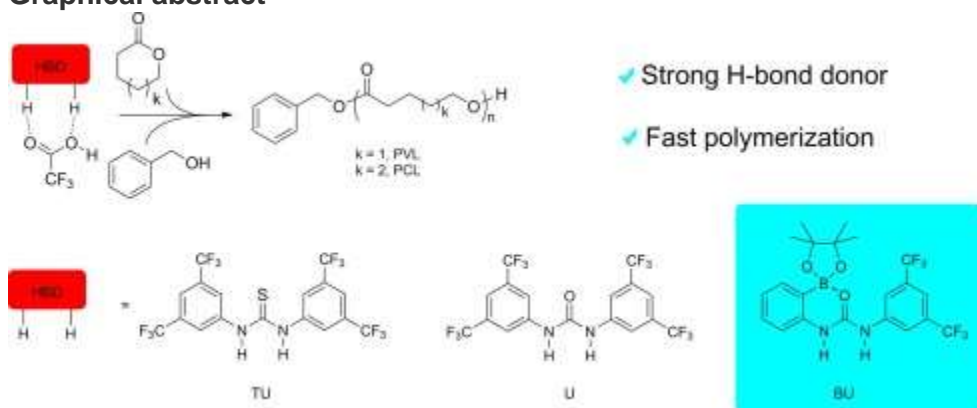
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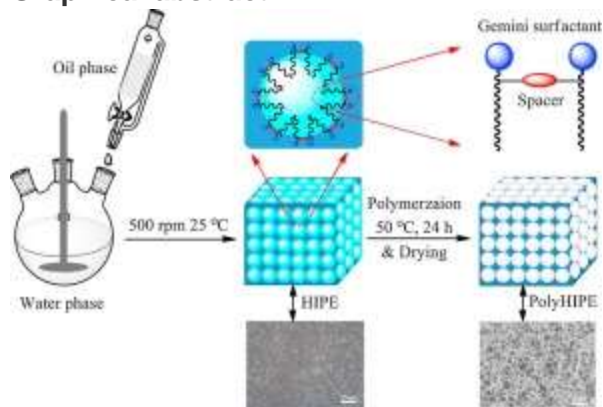
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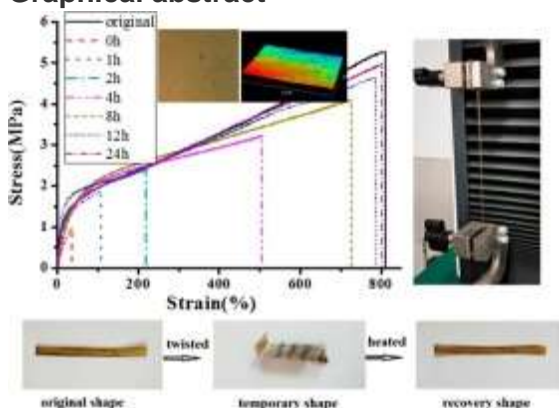
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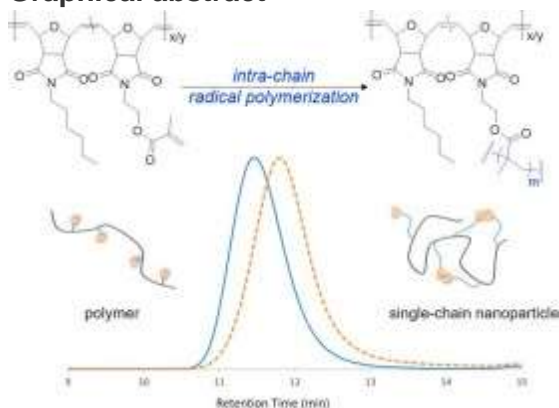
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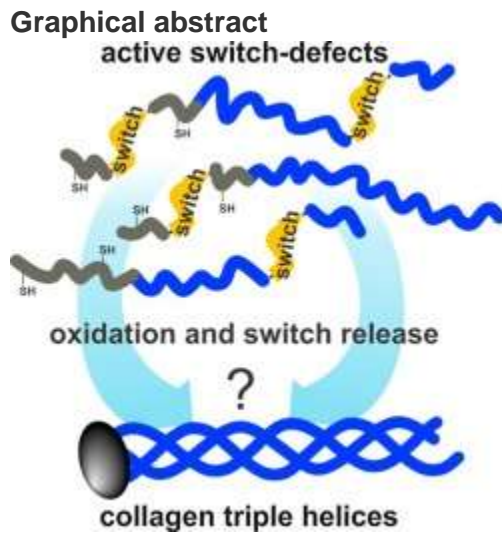
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Ville Hynninen, Pezhman Mohammadi, Wolfgang Wagermaier, Sami Hietala, ... Nonappa

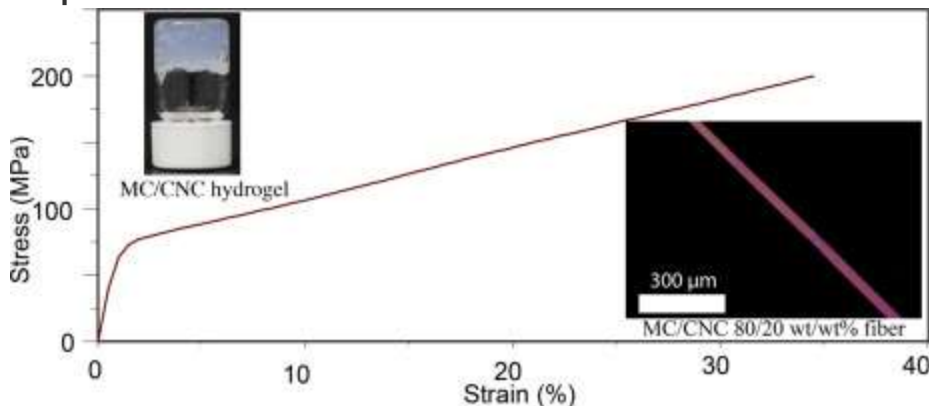
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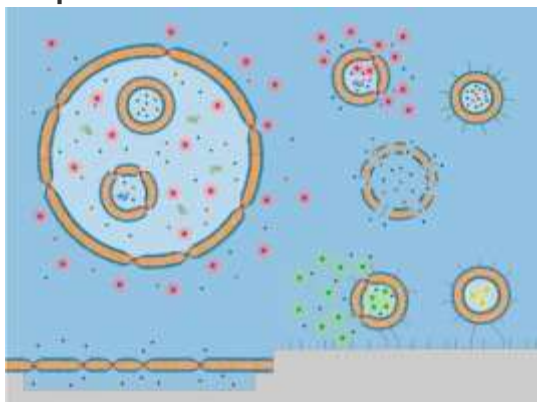
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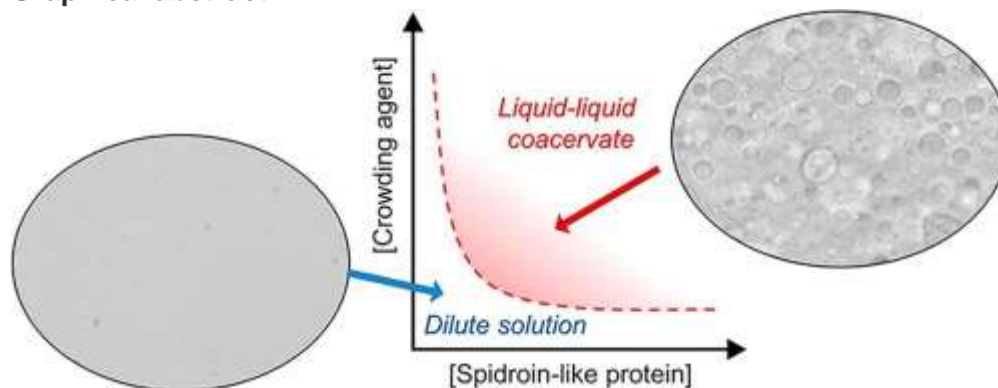
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Juliana Anggono, Ágnes Elvira Farkas, András Bartos, János Móczó, ... Béla Pukánszky

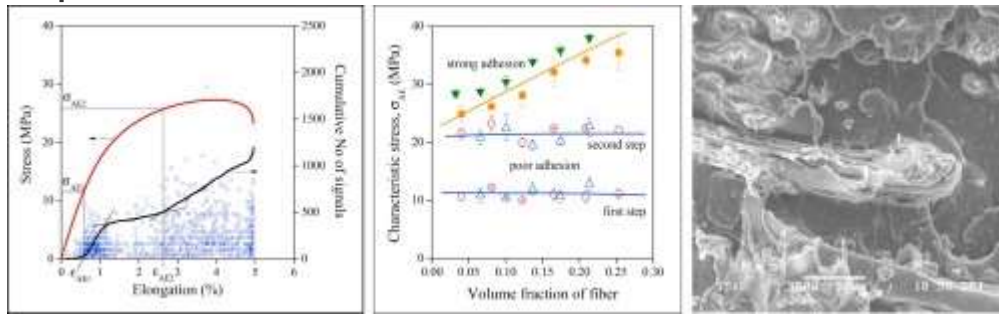
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Deformation and failure of sugarcane bagasse reinforced PP

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ARTICLE INFO

Keywords:

Natural fiber reinforcement
Mechanical properties
Fracture resistance
Instrumented impact testing
Interfacial adhesion
Local deformation processes

ABSTRACT

Polypropylene composites were prepared from sugarcane bagasse fibers by extrusion and injection molding. Wood flour was used as reference filler in the study. The fiber content of the composites changed between 0 and 30 wt% in 5 wt% steps. Maleated polypropylene was used as coupling agent to improve interfacial adhesion. Mechanical properties were characterized by tensile and fracture testing, while local deformation processes were followed by acoustic emission and instrumented impact testing, as well as by the analysis of scanning electron micrographs. The results showed that sugarcane bagasse fibers reinforce polypropylene similarly to other natural fibers. They increase stiffness, but decrease tensile yield stress, tensile strength and deformability. Increased interfacial adhesion leads to the considerable improvement of reinforcement. Bagasse fiber and wood flour filled composites have very similar properties. The impact resistance of the composites increased in the presence of both fibers compared to the neat matrix. Debonding is the dominating process in the absence of the coupling agent, while mainly fiber fracture occurs in its presence. Increased plastic deformation after debonding results in slightly improved impact resistance.

1. Introduction

The use of natural resources increases continuously in all areas of our life. The number of possible raw materials produced by nature is enormous and we use only a small fraction presently. The increase of interest in natural materials is driven by the improving environmental awareness of the public, but also by other factors. Natural fibers are extensively used in the automotive and building industry already now and further increase is expected in the future [1–9]. Natural fibers have many advantages, such as abundant source, low price, but these fibers are also light, thus their use reduces the weight of the vehicles [4–6,10–12]. Reduced weight results in decreased fuel consumption and smaller emission [6,10–13]. The fibers used in the largest quantity are flax, hemp and kenaf, but a number of other fibers like bamboo, ramie, sisal, coir and wood flour are also applied for various purposes such as inner door panel, under body cover, seat backs, ceiling liner, etc. [4,5,11,12,14–18]. Natural fibers have numerous advantages, but also a few drawbacks like sensitivity to moisture [11,12,16], small transverse strength, variability in properties, etc. [19].

The properties of heterogeneous polymers including fiber-reinforced composites are determined by four factors, by component properties, composition, structure and interfacial interactions [20]. In the case of wood flour and other natural fibers, the main factor proved to be the size and aspect ratio of the particles [21]. Larger aspect ratio improves stress transfer and reinforcement, but it makes processing more difficult [21]. The surface energy of natural fibers is small, thus their adhesion to the polymer matrix is weak, especially in polyolefins, which do not contain any polar functional groups [16,22,23]. Interfacial interactions may be stronger if the polymer contains groups capable of forming specific interactions, e.g. hydrogen bonds, like in poly(lactic acid) (PLA), for example [24]. In the case of large particles, the transverse strength, i.e. the strength of the fiber vertically to its axis, proved to be small, which led to small tensile strength and impact resistance [21]. Various fibers coming from a variety of sources can have a wide range of characteristics and thus the properties of the composites prepared from them can vary considerably [16,25].

One of the advantages of natural fibers is that they are cheap, especially if they are obtained from local resources very often as waste

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[14,26–31], which further decreases their price. Using local resources is extremely important in developing societies in which the value added application of cheap natural resources can improve economy considerably [14]. Indonesia is an agricultural country producing considerable amounts of coconut, rubber, coffee, tea, tobacco, but also sugar. The fibers from the sugarcane bagasse form a waste, which is burnt to produce energy for the production of the sugar. With the intensification and modernization of the processes, this energy source becomes superfluous and the bagasse generates waste, which must be handled in a different, but environmentally friendly and economically advantageous way. A possible approach for the value added application of fibers from sugarcane bagasse is their use as reinforcements in polymer composites.

Accordingly, the goal of the present project was to explore the possibility of using sugarcane bagasse fibers as reinforcement for polypropylene. We prepared composites with various fiber contents in order to determine the effect of composition on composite properties. PP/wood composites were also prepared to use them as reference. In the study, we focused on the analysis of deformation processes and the mechanism of failure in order to find ways to improve properties, if necessary. The potentials of the fibers for practical applications are also considered briefly in the final part of the paper.

2. Experimental

2.1. Materials

The polypropylene used as matrix for the composites was the Tipplon H 649 FH grade homopolymer produced by the MOL Group Ltd., Hungary. The polymer has a nominal density of 0.9 g/cm^3 and a melt flow rate of 2.5 g/10 min at 230°C and 2.16 kg load. The bagasse fibers were obtained directly from the sugar mill. They were cleaned, dried, cut up and sieved. Two fractions were obtained a fibrous and a powdery. The fibrous fraction was used in the present experiments. The average particle size of the fibers was determined from scanning electron micrographs. The average length of the fibers was $4560 \pm 1870 \mu\text{m}$, while their average diameter was $340 \pm 156 \mu\text{m}$. The wood flour used as reference was the Filtracell EFC 1000 grade produced by Rettenmaier and Söhne GmbH, Germany. The average length of the fibers was $363 \pm 136 \mu\text{m}$, while their average diameter was $64 \pm 11 \mu\text{m}$. A polypropylene functionalized with maleic anhydride was used as coupling agent. The Scona TPPP 2112 FA grade maleated PP (MAPP) was supplied by Byk-Chemie GmbH, Germany, and it had a melt flow rate of $2\text{--}7 \text{ g/10 min}$ at 190°C and 2.16 kg , and a maleic anhydride content of $0.9\text{--}1.2\%$ according to the data sheet of the producer. The fiber content of the composites changed from 0 to 30 wt % in 5 wt% steps. The ratio of MAPP/fiber was 0.1 in all composites.

2.2. Sample preparation

The fibers and the polymer were homogenized in a twin-screw compounder (Brabender DSK 42/7, Brabender, Germany) at set temperatures of $170\text{--}180\text{--}185\text{--}190^\circ\text{C}$ and 40 rpm. The fibers were dried before extrusion at 105°C for 4 h. Extrusion was repeated twice in order to increase homogeneity. The granulated composites were injection molded into standard (ISO 527 1A) tensile bars of 4 mm thickness using a Demag IntElect 50/330-100 machine. Processing parameters were $40\text{--}170\text{--}180\text{--}185\text{--}190^\circ\text{C}$ set temperatures, 300–700 bar injection pressure, 50 bar back pressure, 50 mm/s injection speed, 25 s holding time, and 30 s cooling time. The specimens were stored at ambient temperature (25°C , 50% RH) for a week before further testing.

2.3. Characterization, measurements

The mechanical properties were characterized by tensile and impact testing. Tensile tests were carried out using an Instron 5566 universal

testing machine with a gauge length of 115 mm and 5 mm/min cross-head speed. Modulus, yield properties (yield stress and yield strain), tensile strength and elongation-at-break were derived from recorded stress vs. strain traces. Local deformation processes were followed by acoustic emission testing. Acoustic emission (AE) signals were recorded with a Sensophone AED 404 apparatus. A single a11 resonance detector with the resonance frequency of 150 kHz was attached to the center of the specimen. The threshold level of detection was set to 23 dB. Impact resistance was characterized by the notched Charpy impact strength, which was determined according to the ISO 179 standard at 23°C with 2 mm notch depth. Instrumented impact testing was carried out using a Ceast Resil 5.5 instrument (CEAST spa, Pianezza, Italy) with a 4 J hammer. The particle characteristics of the fibers as well as the appearance of broken surfaces were studied by scanning electron microscopy (Jeol JSM 6380 LA, Jeol Ltd., Tokyo, Japan). Micrographs were recorded on fracture surfaces created during tensile and fracture testing, respectively.

3. Results and discussion

Fiber reinforced composites are used as structural materials. Their most important properties are stiffness, strength and impact resistance. Overall mechanical properties of composites are determined by local deformation processes. Accordingly, we discuss tensile properties and reinforcement in the first two sections of the paper. Subsequently we focus on fracture behavior and the analysis of local processes in the next two. Finally, structure-property correlations are discussed in the last section of the paper with some reference to practical consequences.

3.1. Tensile properties

The main role of reinforcing fibers is to increase the stiffness and the strength of the polymer used as matrix. The Young's modulus of polypropylene reinforced with the two types of fibers is plotted against fiber content in Fig. 1. Previous experience indicates that stiffness does not depend on fiber characteristics and adhesion very much, but mainly on the amount of fiber added to the matrix [21,32]. The presence of MAPP does not influence stiffness indeed, but fiber characteristics seem to have an effect [32]; the modulus of composites containing the bagasse fibers is smaller than that prepared with wood flour. Only one plausible explanation exist for this phenomenon, the bagasse fibers with their extremely large size debond from the matrix already at the very small

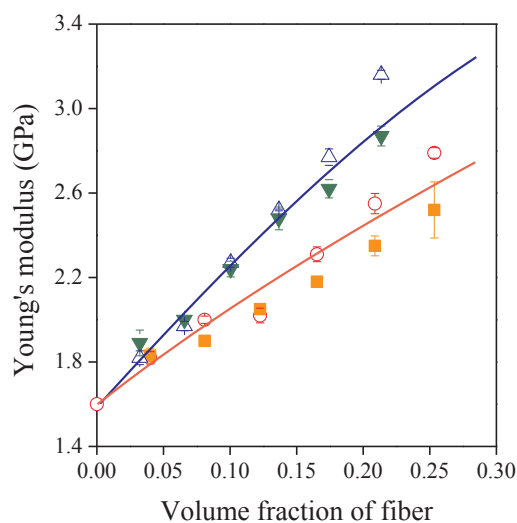


Fig. 1. Composition dependence of the stiffness of PP/natural fiber composites prepared with bagasse fibers and wood flour as reference. Symbols: (○) bagasse, (□) bagasse, MAPP, (△) wood flour, (▽) wood flour, MAPP.

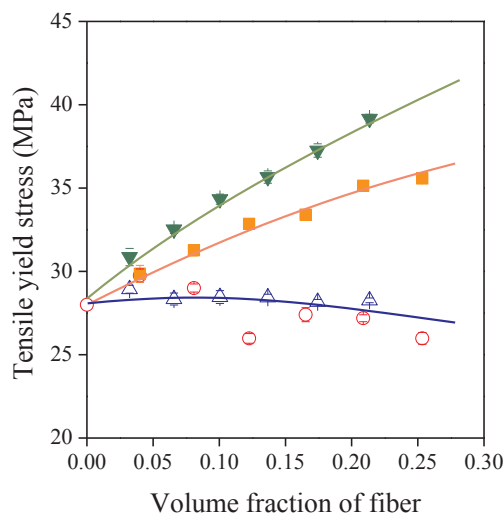


Fig. 2. Effect of fiber content on the tensile yield stress of PP/fiber composites. Influence of interfacial adhesion. Symbols are the same as in Fig. 1.

deformations of the modulus determination, voids form, which decrease modulus. We must also note that the gradient of the modulus vs. fiber content correlations decrease with increasing fiber loadings. This effect indicates the presence of some structural factor, either the fibers abut each other forming associations [33] or their average orientation decreases with increasing fiber content. Such a change in orientation with filler content was observed earlier [34].

Tensile yield stress is plotted against fiber content in Fig. 2. The difference in the reinforcing effect of the two fibers, bagasse and wood, remained the same, but the influence of interfacial adhesion is much larger than in the case of stiffness. Several studies proved earlier that tensile characteristics determined at larger deformations depend much more on interfacial adhesion than stiffness [21,32,33]. It is interesting to note, that the effect of different particle characteristics does not appear in yield stress at poor adhesion, possibly because of the large size of the two fibers. Although wood is much smaller than the bagasse fiber, but 210 μm is still much larger than the usual size of mineral fillers, which is in the micron range. The structural effect mentioned above affects properties also in this case and the effect can be seen in the composition dependence of yield stress. We much emphasize here, however, that both wood and bagasse reinforce PP at good adhesion.

The tensile strength of the composites is presented as a function of fiber content in Fig. 3. Quite surprisingly, the differences in particle characteristics are even less visible than in the case of tensile yield stress. One reason might be the attrition of long fibers, but more probably the extensive debonding of large particles that dominates local deformation. On the other hand, the effect of adhesion on reinforcement is significant in this case; strength almost doubles in the composition range studied.

One of the major drawbacks of wood and natural fiber reinforced composites is their limited deformability, which results in very rigid materials with small impact resistance. As shown by Fig. 4, the elongation-at-break values of the composites decrease considerably with increasing fiber content to very small values. Hardly any difference can be made among the composites in this respect, composites containing wood might have slightly larger deformability, and adhesion seems to decrease elongation, but the differences are very small. The results presented above clearly show that the fibers applied in this study can be used in practice only when a coupling agent is added to improve adhesion and that the deformability of the composites is small.

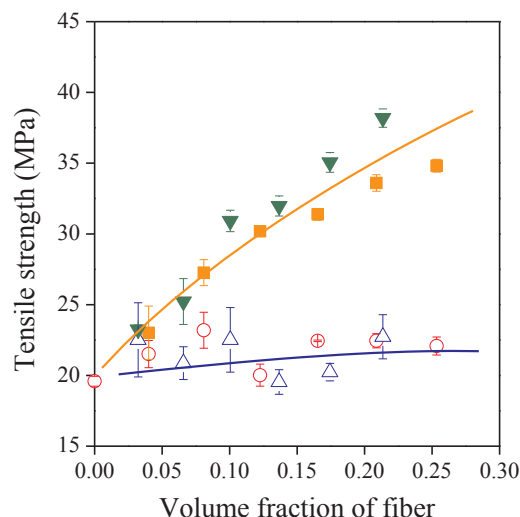


Fig. 3. Tensile strength of PP/lignocellulosic fiber composites plotted against fiber content. Symbols are the same as in Fig. 1.

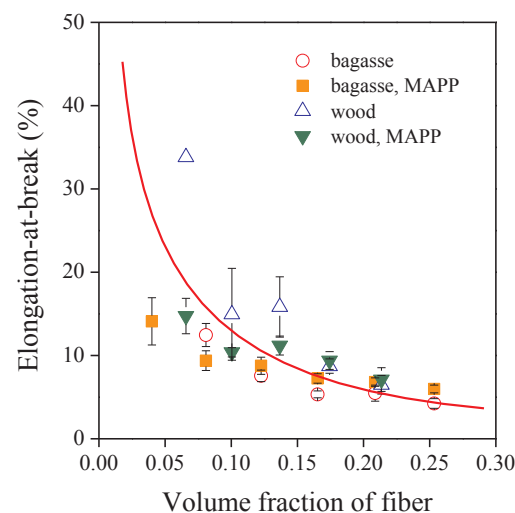


Fig. 4. Decreasing elongation-at-break values of PP/natural fiber composites with increasing fiber content. Symbols are the same as in Fig. 1.

3.2. Reinforcement

A general, qualitative idea can be obtained about the reinforcing effect of the two fibers from Figs. 2 and 3 presented above. However, it is very difficult to draw conclusions from those figures about reinforcement and it is impossible to estimate it quantitatively. A model is needed in order to determine the reinforcing effect of fibers more accurately. Such a model was developed earlier for the description of the tensile and impact characteristics of heterogeneous materials [35]. Eq. (1) describes the composition dependence of tensile strength in the following way

$$\sigma_T = \sigma_{T0} \lambda^n \frac{1 - \varphi_f}{1 + 1.5\varphi_f} \exp(B\varphi_f) \quad (1)$$

where σ_T and σ_{T0} are the true tensile strength of the composite and the matrix, respectively, φ_f is the volume fraction of the fiber in the composite, B expresses the load bearing capacity of the fiber and it depends on interfacial adhesion. In the equation true tensile strength ($\sigma_T = \sigma/\lambda$, $\lambda = L/L_0$, relative elongation) accounts for the change in specimen cross-section and λ^n for strain hardening occurring with increasing elongation. n characterizes the strain hardening tendency of the

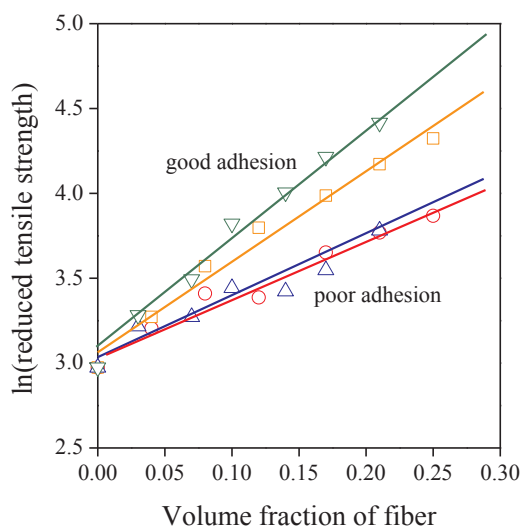


Fig. 5. Tensile strength of PP composites reinforced with natural fibers plotted against fiber content in the linear representation of Eq. (2). Slopes express the load bearing capacity of the fibers. Symbols are the same as in Fig. 1.

polymer and can be determined from matrix properties. The rearrangement of the equation leads to the reduced tensile strength

$$\sigma_{Tred} = \frac{\sigma_T}{\lambda^n} \frac{1 + 2.5\varphi_f}{1 - \varphi_f} = \sigma_{T0} \exp(B\varphi_f) \quad (2)$$

and if we plot its natural logarithm against composition, we should obtain straight lines, the slope of which expresses the reinforcing effect of the fibers quantitatively.

The tensile strength of the four sets of composites is plotted in the way dictated by Eq. (2) in Fig. 5. Straight lines are obtained indeed with smaller or larger deviations from the line. Fiber characteristics do not seem to influence reinforcement much, the points for the two fillers fall on the same line, but interfacial adhesion does. The addition of the coupling agent increased the slope of the lines, i.e. reinforcing effect, considerably. The parameters of the correlations are collected in Table 1.

The conclusions drawn from the direct observation of Fig. 5 are expressed quantitatively by the numbers in the table. Small differences can be seen in the slope of the lines for the composites prepared with the different fibers, but much larger as an effect of improved adhesion. Fig. 5 calls attention to another fact. The model applied assumes the homogeneous distribution of the heterogeneous phase in a matrix. If structural phenomena occur (changing orientation, aggregation) in the composites, the points deviate from the straight line. On closer scrutiny only slight deviation from linearity can be seen for the composites with good adhesion, i.e. which contain MAPP, thus our earlier assumption about the development of a special structure (fiber association) or the change of some structural factor (orientation) is not fully justified. Even if such phenomena exist, their effect on properties is small.

Table 1

Reinforcing effect (parameter B) of the studied fibers calculated from the tensile strength of the composites (see Eqs. (1) and (2)) at good and poor adhesion.

Fiber	Matrix strength, σ_0 (MPa)	Parameter B	R^{2a}
Bagasse	20.9	3.44	0.9668
Wood	20.9	3.64	0.9681
Bagasse, MAPP	21.5	5.30	0.9795
Wood, MAPP	22.0	5.89	0.9880

^a Determination coefficient indicating the accuracy of the fit.

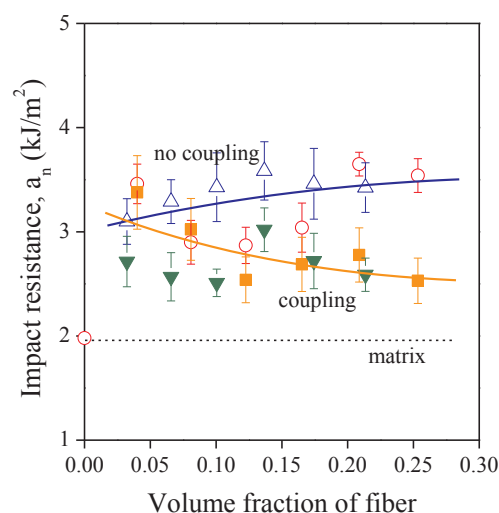


Fig. 6. Effect of fiber content on the Charpy notched impact strength of PP/natural fiber composites. Symbols are the same as in Fig. 1.

3.3. Fracture resistance

Impact strength is often a very important property for materials used in structural applications. Because of the dynamic conditions of testing, its composition dependence often differs considerably from that of tensile properties. The impact resistance of the composites is plotted against fiber content in Fig. 6. The standard deviation of the measurement is quite large, but some conclusion can be drawn from the data quite unambiguously. First of all, the impact strength of all composites is larger than that of the matrix. One of the major problems of wood reinforced composites is their limited impact strength, which cannot be improved in any way [36]. The only reasonable explanation for the phenomena is that local deformation processes occurring around the fibers during fracture absorb some energy, which increases impact strength. The other observation, which can be made, is that impact resistance increases slightly in the absence of the coupling agent, i.e. in the case of poor adhesion, while it decreases when the coupling agent is present. Obviously, the deformation process resulting in the absorption of energy is hindered by the presence of the coupling agent, by strong adhesion. It must be emphasized here, though, that although the fibers increased fracture resistance compared to the matrix, the absolute value of impact strength is still small, the largest values are around 3.5 kJ/m². At least 15 kJ/m² impact strength is expected from structural materials used in the automotive industry.

Instrumented impact testing was carried out on the composites in the hope of obtaining more information about the fracture process. The force vs. time traces of selected composites are presented in Fig. 7. All specimens fail by brittle fracture. The largest difference can be seen in the maximum force, which is related to fracture initiation stress. All composites seem to have similar maximum loads and the addition of MAPP decreases it somewhat. It is very difficult to tell anything about the area under the traces, which is related to fracture energy, by the simple visual observation of the fractograms, but a more detailed analysis indicated that it changes similarly to the impact resistance values presented in Fig. 6. Accordingly, the fibers improved the impact resistance of polypropylene both by increasing fracture initiation stress and fracture energy due to a local process or processes, which consume surplus energy during fracture, compared to the neat polymer.

3.4. Local processes, deformation mechanism

The previous sections clearly proved that local processes taking place around the reinforcing particles play a role in the determination of impact resistance and generally properties. The study of wood

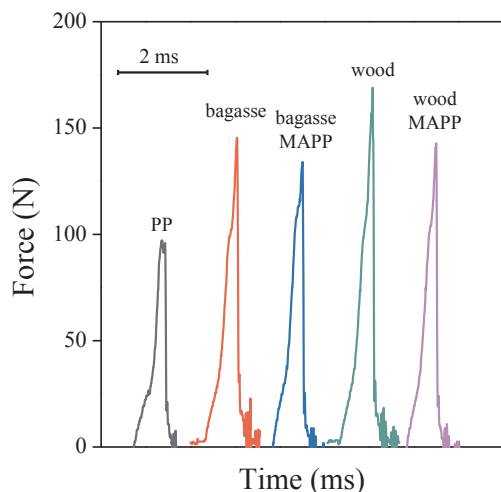


Fig. 7. Instrumented impact traces (force vs. time) recorded on selected PP/natural fiber composites. Fiber content: 20 wt%.

reinforced composites showed that several local processes can take place during deformation, the shear yielding of the matrix, its cavitation, debonding, i.e. the separation of the interface between the filler or fiber and the matrix, fiber pull-out, or fiber fracture [21,32,33]. These processes are competitive and they can take place simultaneously or consecutively. Usually one of the processes dominates during deformation and fracture, but the occurrence of the others cannot be excluded either. Some of the local processes generate elastic waves within the material, which can be detected by piezoelectric sensors thus acoustic emission testing gives information about the local processes.

The result of such an acoustic emission measurement is presented in Fig. 8. Small circles indicate individual events occurring within the material. The stress vs. strain trace of the composite is also plotted for reference (left axis). The number of signals is not very large and they can be divided into two groups. Events start to appear above a certain deformation and signals stop to develop at larger elongations; further signals appear again later until the specimen breaks. The evaluation of individual signals is difficult, but their evolution, the cumulative number of signals, offers more information about the deformation process. The cumulative number of signals is also plotted in Fig. 8 (right hand axis). The correlation clearly shows the occurrence of two processes during the testing of this composite reinforced with 20 wt%

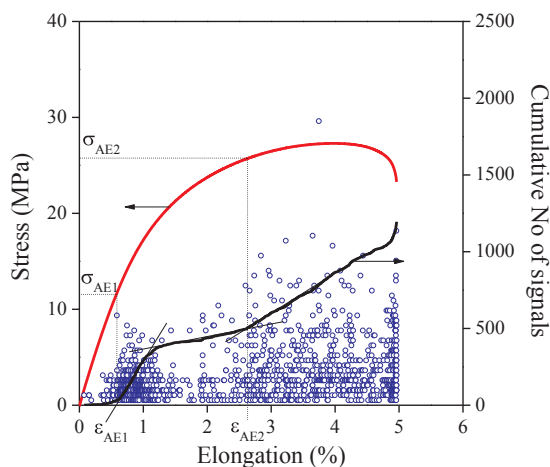


Fig. 8. Results of the acoustic emission testing of a PP/bagasse composite. 20 wt% fiber, poor adhesion (no MAPP). Symbols: (○) individual signals, — cumulative number of signals (right axis) and stress vs. elongation trace (left axis).

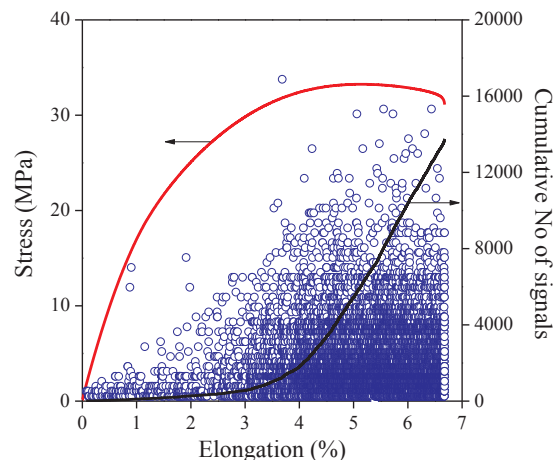


Fig. 9. Increased number of signals during the acoustic emission testing of a PP/bagasse composite containing 20 wt% fiber and MAPP. Good adhesion. Symbols are the same as in Fig. 8.

bagasse fibers not containing the coupling agent. Based on previous experience [21,32,33] we can assume that these two processes are debonding and the pullout or fracture of the fibers. The addition of the coupling agent, i.e. MAPP changes both the number of signals and the shape of the cumulative number of signal trace (Fig. 9).

Initiation starts at larger deformation than in the previous case and the number of signals is ten times larger. The cumulative number of signal trace increases rather steeply and only one process can be distinguished in this case. The changing shape of the trace indicates a different deformation mechanism, which earlier was identified as the fracture of the fibers [21,32,33]. In previous sections, we saw that the use of the coupling agent had a profound effect on the properties of the composites, and the results presented here indicate that the changes are caused by the modification of local processes.

Further analysis of local processes is possible, if we determine the characteristic stress values at which the local processes are initiated. The procedure is demonstrated in Fig. 8. At poor adhesion, two characteristic values can be determined (σ_{AE1} , σ_{AE2}), while only one in the presence of MAPP. The composition dependence of the characteristic values is presented in Fig. 10. The first process is initiated at very small stresses and it does not depend on composition. The process must be the debonding of large particles from the matrix. The second process is

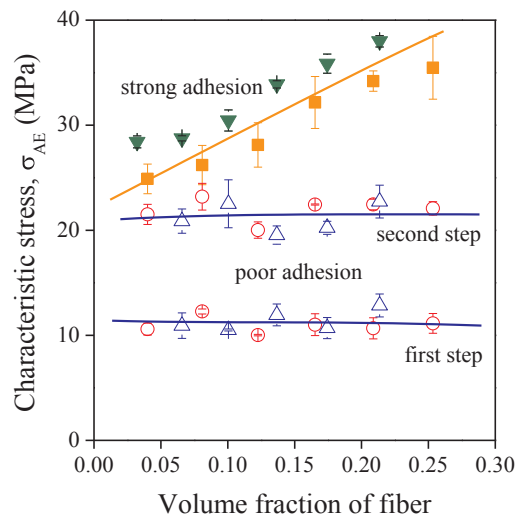


Fig. 10. Dependence of characteristic stresses (σ_{AE1} and σ_{AE2}) on fiber content. Different local processes and mechanisms. Symbols are the same as in Fig. 1.

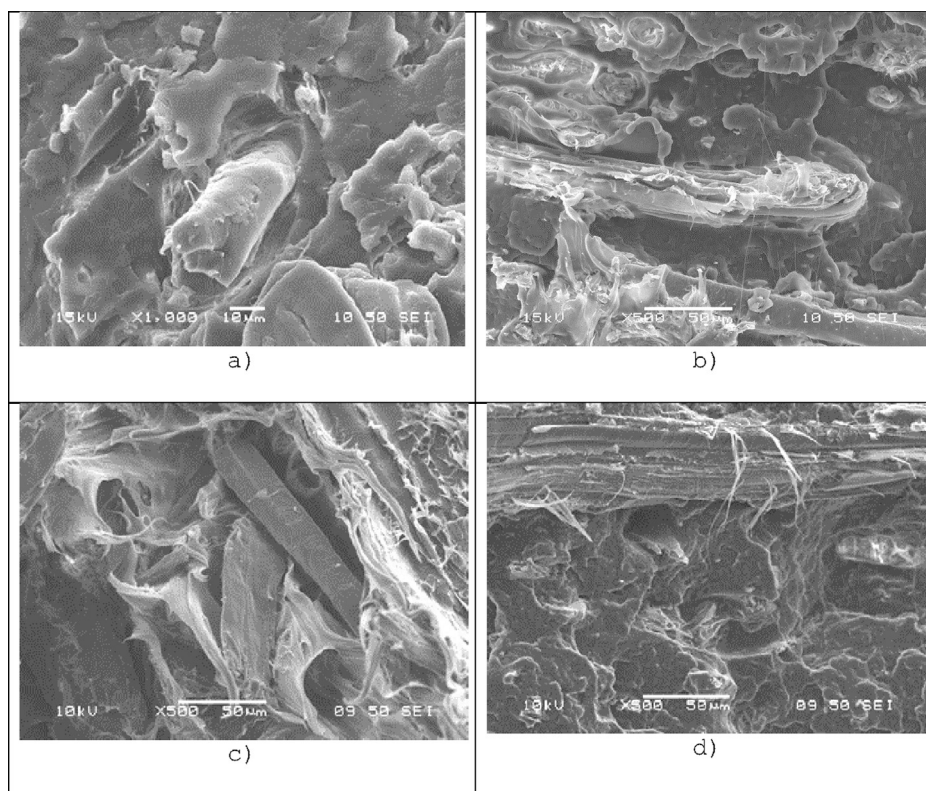


Fig. 11. SEM micrographs recorded on the fracture surface of selected PP/natural fiber composites. The surfaces were created in tensile testing. Fiber content is 20 wt %. (a) Bagasse, (b) bagasse MAPP, (c) wood, (d) wood, MAPP.

more difficult to identify, but in all probability, it is the pullout of the fibers. The fracture of the fibers occurs at larger stresses as shown by the case of strong adhesion, at which the single process occurring is initiated at larger stress. The different mechanism is shown also by the dissimilar composition dependence. Earlier this process was identified unambiguously as the fracture of the fibers [21,32,33]. Although we may have some ideas about the local processes emitting the signals, we need further proof for their verification.

Further evidence might be supplied by SEM micrographs. Typical micrographs recorded on fracture surfaces generated in the tensile test are presented in Fig. 11. All the composites contained 20 wt% fibers. Fig. 11a recorded on a composite reinforced with bagasse fibers shows the debonding and pullout of a fiber from PP. Debonding can be seen also in the presence of MAPP (Fig. 11b), but the fracture of some of the fibers occurs as well. Practically the same picture is conveyed by the micrographs recorded on composites containing the wood fibers. Debonding of large particles is shown in Fig. 11c, but the micrograph offers further information. It shows that fibers abut each other, which may explain the slight structural effect mentioned before. Moreover, strong plastic deformation is seen around debonded particles, which may account for the increased impact resistance of the composites (see Fig. 6), especially in the case of poor adhesion. A large broken fiber can be seen in Fig. 11d confirming our tentative explanation that fiber fracture occurs in the case of good adhesion and that it is the dominating deformation process in composites containing MAPP.

3.5. Discussion

The results presented in the previous sections answered a number of questions emerged in the study. The analysis of local processes confirmed our tentative assumption about the larger impact resistance of the composites compared to the matrix by showing that after the debonding of large particles plastic deformation might take place, which consumes energy. It also explained the larger reinforcing effect of the

fibers in the presence of the coupling agent. At poor adhesion, the debonding of the fibers may result in slightly improved impact resistance, but only fibers adhering strongly to the matrix carry considerable load.

Earlier we claimed that local deformation processes are important in the determination of composite properties. The tensile strength of the composites is plotted against the initiation stress of the various local processes in Fig. 12. According to the correlation, the initiation of the local process leads to immediate failure in the case of strong adhesion, i.e. the local process determines strength. Although not immediately, but failure occurs soon after the start of the second process also in the case of poor adhesion. On the other hand, debonding does not

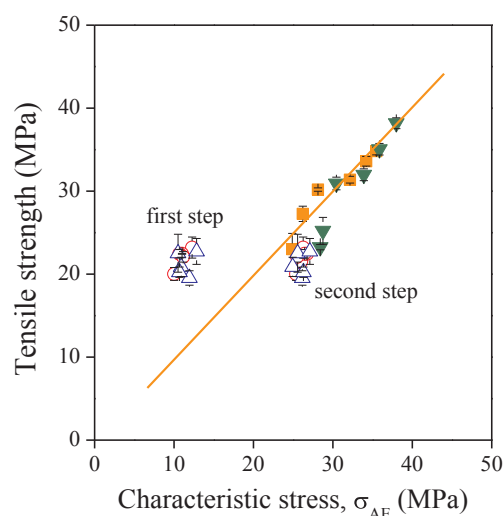


Fig. 12. Correlation between the tensile strength of the composites and the characteristic stresses determined by acoustic emission testing. Symbols are the same as in Fig. 1.

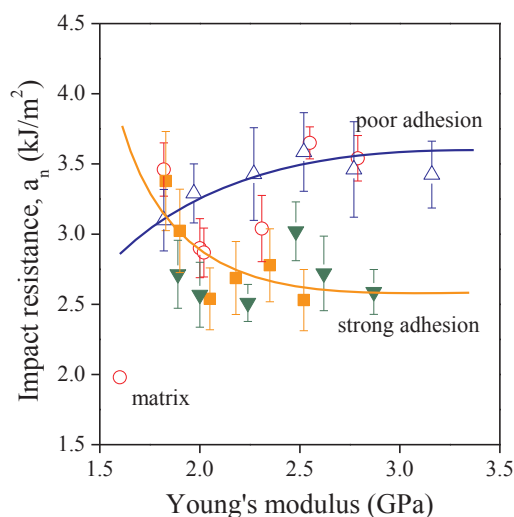


Fig. 13. Correlation between the impact resistance and stiffness of PP/natural fiber composites. Symbols are the same as in Fig. 1.

necessarily leads to failure; some plastic deformation takes place after its initiation. The analysis and especially the control of local processes offer a possibility to improve the properties of the composites.

In the case of structural materials, especially those used in the automotive industry, an important question is the balance of stiffness and impact resistance. Fracture resistance is plotted against stiffness in Fig. 13. The matrix has a small value in the lower left corner of the plot. All composites have larger stiffness, but somewhat surprisingly also larger impact resistance. Increasing adhesion leads to decreasing impact strength, but larger moduli are accompanied by larger impact strength in the case of poor adhesion. We explained the observed changes of properties with the occurrence of various local process, but the unusual correlations need further study and explanation. Nevertheless, the applied combination of fiber characteristics and adhesion offers some advantages for practical applications. However, it is clear that in spite of the somewhat larger impact resistance compared to the matrix, only composites with proper adhesion can be used in practice.

4. Conclusions

Sugarcane bagasse fibers reinforce polypropylene similarly to other natural fibers. They increase stiffness, but decrease tensile yield stress, tensile strength and deformability. Increasing interfacial adhesion achieved with the application of a coupling agent results in the considerable improvement of reinforcement. Composite strength increases with increasing fiber content, but deformability decreases even further. Although the very large bagasse fibers debond more easily from polypropylene than the smaller wood fibers used as reference, most properties are very similar in the two types of composites. The analysis of the composition dependence of properties indicated the presence of a slight structural effect, either the aggregation of fibers or the change of orientation with increasing fiber content. The impact resistance of the composites increased in the presence of both fibers compared to the neat matrix. The analysis of local deformation processes indicated that debonding is the dominating process in the absence of the coupling agent, while mainly fracture occurs in its presence. Increased plastic deformation after debonding results in slightly improved impact resistance. Although bagasse fibers can be used for the reinforcement of PP, fiber extraction and handling must be improved to obtain smaller fibers with a better size distribution. A coupling agent must be used in all cases to obtain reasonable properties.

Acknowledgements

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