S-1054 2017 Annual Report

Project Title: Biobased Fibrous Materials and Cleaner Technologies for a Sustainable and Environmentally Responsible Textile Industry

Duration: 1/1/2013–9/30/2018

About the S-1054 Project

This multi-state research project addresses the nation's research priority in bioenergy and biobased products by developing renewable fibrous materials and innovative technologies for eco-friendly and sustainable textile products that have an impact on improving the environment and quality of living. Four research objectives are defined: (1) to develop novel biobased polymeric materials; (2) to develop and evaluate biobased fibrous products for eco-friendly crop protection; (3) to develop and evaluate biobased products for health and safety applications; and (4) to develop and evaluate methods to remove dyes and finishing chemicals from textile waste water. The research progress is made through cooperation among the participants from 11 universities in the states of CA, CO, GA, IA, MT, NE, NY, TN, TX, WA, and WI.

Progress

Objective 1 To develop novel biobased polymeric materials

CA: At the University of California, Davis, scientists have continued to design and develop sustainable processes to efficiently convert biopolymers, e.g., proteins, cellulose, lignin, etc., into novel nanomaterials and functional products. Specific progress has been made in novel structure and performance develop of nanocellulose products based on prior accomplishment in isolating cellulose from various agricultural residues and food/beverage by-products such as grape and tomato pomance, cotton linter and rice straw and optimizing the derivation of nanocelluloses in varied geometries and surface chemistries.

A streamlined alkali process (4 % NaOH, 70°C, 5 min, twice) has been shown to be effective in removing most hemicelluloses, lignin and silica from rice straw to give ca. 10% higher yield of cellulose-rich product that led to alkaline cellulose nanofibrils (ACNFs) at ca. 7% higher yield than CNFs from purified cellulose under the same optimal TEMPO oxidation and mechanical defibrillation process. ACNFs were similar in lateral dimensions (1.25 ± 0.47 nm) and crystallinity (68 %), but longer and less surface oxidized (65 %) than CNFs and HCNFs (1.55 ± 0.54 and 1.36 ± 0.62 nm, 69 and 68 % CrI, 85 and 69 % surface oxidization, respectively). These ACNFs were also more thermal stabile and self-assembled into finer fibers (94-197 nm) than CNFs (497 nm). This facile alkali pretreatment is not only highly efficient in generating cellulose for preparing ACNFs with attributes similar to CNFs and HCNFs, but, like HCNFs due to their less pristine nature, also present some unique properties that are promising for advanced applications.

CNFs from rice straw have also been assembled into hierarchically macroporous (several hundred micrometer) honeycomb cellular structure surrounded with mesoporous (8-60 nm) thin walls. The high specific surface (193 m2/g) and surface carboxyl content (1.29 mmol/g) of these aerogels were demonstrated to be highly capable of removing cationic malachite green (MG) dye from aqueous media. The rapid MG adsorption was driven by electrostatic interactions and followed a pseudo-second-order adsorption kinetic and monolayer Langmuir adsorption isotherm. The excellent dye removal efficiency was demonstrated by 92 % dye removal in a single batch at 10:5 mg/mL aerogel/MG ratio and 100 mg/L dye concentration and 100 % dye removal through four repetitive adsorptions at a low 1:5 mg/mL aerogel/MG ratio and 10 mg/L dye concentration. The adsorbed MG in aerogels could be desorbed in aqueous media with increasing ionic strength, demonstrating facile recovery of the dye as well as the aerogel for repetitive applications.

A facile gelation-crosslinking approach has been devised to fabricate meso- and macro-porous CNF aerogels with multiple improved properties. CNF hydrogels from freezing-thawing were solvent exchanged with acetone then crosslinked with methylene diphenyl diisocyanate (MDI) to produce aerogels with significantly improved compressive Young's modulus, yield stress and ultimate stress with impressive 1.69, 2.49 and 1.43 scaling factors, respectively. The optimally crosslinked aerogels had nearly tripled specific surface (228 m^2/g) and doubled pore volume (1 m^3/g) from numerous new 9-12 nm wide mesopores as well as significantly improved thermal stability (43% char residue at 500 C vs. 9.1% for uncrosslinked aerogel). Crosslinking also turned the amphiphilic CNF aerogel to be highly hydrophobic, capable of completely separating chloroform from water via simple filtration. These nanocellulose aerogels show great promise for efficient and continuous separation of oils and hydrophobic liquids from water.

CO: At Colorado State University, PLGA-gentamicin nanoparticles were made using a water-oil method. The nanoparticles were characterized using SEM, TEM, and Nano-Sizer. Molecular acceptors were also synthesized using a typical culture method. The molecular acceptor was grafted to the nanoparticles. The nanoparticles with the acceptor were mixed in a polyethylene oxide solution. The solution was used to develop Nanofibers via a home-built eletrospinning apparatus. One research grant ($25,000) was received from the research council of the College of Veterinary Medicine & Biomedical Sciences at Colorado State University. The grant was to support to develop PLGA-gentamicin encapsulated Nanofibers for controlled drug delivery in wound healing

IA: Iowa State University continued on developing biodegradable nanofibers from fermented tea and biobased materials for textiles and composites. The scientists have worked on development of bacterial cellulose nanocomposites from with enhanced mechanical strength by incorporating electrspun poly(lactic acid) (PLA) nanofibers. The resulted bacterial cellulose with PLA nanocomposites showed improved mechanical properties and lower water absorption, which are the key parameters for textile materials used for regular daily wear.

NE: The University of Nebraska-Lincoln continued its development of biofibers from agricultural by-products, co-products and wastes and biobased materials from bio-polymers. Our main focus this year is on translational and pilot scale formation of biobased materials with excellent properties and low costs for future industrial productions. The scientists continued their research on keratin and soy protein manipulations for various applications focusing on continuous production of 100% protein fibers, and on reuse waste carpets as composites materials. The scientists have worked on development of fabrics and garments from natural cellulosic fibers from cotton stalk blended with cotton. They have made a garment from cotton stalk fibers, blended with cotton and have demonstrated that the materials from cotton stalk fibers have excellent performance properties.

***NY*:** Cornell University has continued to develop biodegradable 'green' resins and composites. The primary focus has been to develop self-healing protein and starch based resins for composite applications as well as self-healing green composites.

In the first research self-healing soy protein isolate (SPI) based 'green' thermoset resin was developed using SPI encapsulated poly(D,L-lactide-*co*-glycolide)(PLGA) microcapsules (SPI-PLGA-MCs). In this system, SPI, when released from the microcapsules, acts as the healant. In these studies SPI resin was crosslinked to improve its mechanical properties. SPI-PLGA-MCs were obtained using the water-in-oil-in-water emulsification technique. Effects of various microencapsulation formulation and processing parameters were investigated on size, size distribution, protein loading, encapsulation efficiency, and morphology of the microcapsules as well as the overall self-healing efficiency. Results of these studies showed that SPI-PLGA-MCs with diameters in the range of 0.8 to 1.5 μm resulted in the highest self-healing efficiency. Also, when the microcapsules contained subcapsules within themselves, the self-healing efficiency was reduced. Microcapsules produced using slower homogenization speed of 1,000 rpm were larger with an average diameter of 9.1 μm and contained diverse size of subcapsules inside. These did not result in high self-healing efficiency. Varying PVA concentration showed no significant effect on the SPI-PLGA-MCs size. However, at higher PVA concentration, microcapsules aggregated because the excess PVA on the microcapsule surface acted as glue. One of the reasons for using PVA was to be able to bond the microcapsules to resin which would assure the fracture of the microcapsules in the path of the microcracks. This was indeed the case and resulted in higher self-healing efficiency. The self-healing efficiency at room temperature (RT) for various formulations studied varied between 29% and 53%. The results indicated that the highest self-healing efficiency of 53% was obtained by SPI-PLGA-MCs prepared using 1% PLGA, 5% PVA and homogenization speed of 10,000 rpm.

In the second research area, self-healing green thermoset resin was developed using waxy maize starch (WMS). In this case, self-healing was achieved using waxy maize starch-loaded poly(d,l-lactide-co-glycolide) microcapsules (WMS-PLGA-MCs). The WMS resin was crosslinked using 1,2,3,4-butanetetracarboxylic acid (BTCA). A similar water-in-oil-in-water emulsification technique was used to obtain WMS-PLGA-MCs. Hydroxyl groups on WMS released from WMS-PLGA-MCs can react with the excess BTCA in the WMS resin and effectively bridge the microcrack surfaces, thus healing the crack. Highest self-healing efficiency in fracture stress of up to 51% and fracture toughness of approximately 66%, after 24 h of healing at RT, was achieved by adding 20% WMS-PLGA-MCs by weight. Self-healing starch-based resin developed in this study is not only green and sustainable but the fabrication processes including microencapsulation are water-based and can be easily scaled up. The nontoxic starch based green resin can be useful for fabricating green composites in many indoor applications such as automotive, aerospace and packaging, to replace currently used petroleum-derived composites.

In the third area, self-healing soy protein-microfibrillated cellulose (MFC) reinforced, SPI resin based green (MFC-SPI) composites were developed. In this case a green solvent, ethyl acetate, was used to produce SPI-PLGA-MCs. This process resulted in high protein loading of over 50%. Self-healing MFC-SPI composites with uniformly dispersed MFC (10wt%) and SPI-PLGA-MCs (15wt%) resulted in Young's modulus of about 1 GPa and strength of 15.2 MPa whereas SPI composites with only 10wt% of MFC showed Young's modulus of 1.4 GPa and strength of 24.5 MPa. Both these properties were significantly higher compared to pure SPI resin due to the inherent high tensile properties of MFC and its excellent hydrogen bonding with SPI resin. Self-healing mechanism, i.e., bridging of fracture surfaces of the microcracks by the healing agent (SPI), was observed through SEM imaging. Composites with no SPI-PLGA-MCs showed no self-healing as expected. However, self-healing SPI composites showed 27% healing efficiency after 24 h of healing. This self-healing efficiency is much lowered compared to that obtained for the resin (over 50%) for the reason that while the resin can be self-healed fractured fibers, the reinforcing component, cannot.

In the fourth area, a new 1-step process was developed for making green resins based on plant proteins tougher. In this case epoxidized natural rubber (ENR) fibers (ENRFs) were electrospun with diameters ranging from a few hundred nm to a few µm by changing the concentration of ENR solution. A simple 1-step process was developed to directly blend wet electrospun ENRFs into the SPI resin. Surface topography of ENRFs changed from irregular to somewhat bumpy as the ENR concentration increased from 0.1% to 5%. The average diameter of ENRFs also increased from 250 nm to 17 µm with increased concentration. The results indicated that the ENRF (electrospun from 3% concentration) loading from 0 to 20% had a significant increase in the fracture strain of the SPI resin, from 1.7 to 18.8%, over 10 times. This also resulted in increased toughness by a factor of 10. Importantly, tensile strength and Young's modulus remained almost unchanged. Crosslinking between the epoxy groups in ENR and amine and/or carboxylic groups in SPI and the high aspect ratio of the ENRFs seem to contribute to increased toughness of the SPI resin.

TX: At University of Texas at Austin, research efforts were continuously focused on the development of advanced textile materials using lignocellulose biomass, with specific end uses in energy and healthcare industries. A cellulose-based flexible yarn supercapacitor was produced. Two methods of fabricating complex yarn structure for the supercapacitors were developed. Electrochemical properties of the yarn supercapacitors, in terms of cyclic voltammetry (CV), galvanostatic charge/discharge (GC), electrical impedance spectroscopy (EIS), and capacitance, were measured and analyzed. The research revealed that the unique yarn linear structure could enable to integrate the yarn supercapacitor into various industrial and consumer products such as apparel products, outdoor and sports wears, camp/hike equipment, and specialty rope/cable products.

Research progress was also made in the formation and application of a biobased fibrous membrane with micro- and nano-fiber web structure as a drug delivery carrier. Regenerated cellulose micro-/nano- fiber (CMF) webs were fabricated by dry-wet electrospinning. Ibuprofen (IBU) was used as a model drug loaded on the CMF webs using a simple immersing method. The IBU-loaded CMF biomaterials were characterized in terms of polymeric structure, surface morphology, thermal stability, tribological property, and surface tension. The drug release mechanism was modeled numerically.

Objective 2: to develop and evaluate biobased fibrous products for eco-friendly crop protection

TN: Through a major USDA Specialty Crop Research Initiative (SCRI) grant received by (Project Director) Hayes, Wadsworth, Belasco, and collaborators at the University of Tennessee, Washington State University, and Montana State University, the long-term implications of deploying on soil quality, the soil microbial community, specialty crop production, pests and diseases, and consumers will be investigated via a transdisciplinary approach (http://biodebradablemulch.org). We have investigated the effect of field weathering and simulated weathering of commercially available and experimentally derived biodegradable plastic mulch films, and are currently completing the physicochemical analysis of the mulches. We also further analyzed data (and collected additional data) for a soil burial study of nonwoven fully biobased mulches that provided the change of physicochemical parameters during the time course of biodegradation during a 40 week period.

Objective 3: to develop and evaluate biobased products for health and safety applications

CA: Research conducted at the University of California, Davis, has demonstrated cellulose microfibers to be effective templates to immobilize bacteriophages to broaden their applications in targeting bacterial pathogens in foods and medicine. This study evaluated physical adsorption, protein-ligand binding and electrostatic interactions bound mechanisms so not to chemically nor genetically modifying the phages to enable effective translation of naturally occurring phages and their cocktails for antimicrobial applications. The immobilization approaches were characterized by phage loading efficiency, phage distribution, and phage release from fibers. Overall, the electrostatic immobilization approach bound more active phages than physical adsorption and protein-ligand binding and thus may be considered the optimal approach to immobilizing phages onto biomaterial surfaces.

NE: The University of Nebraska-Lincoln continued its development of biofibers from agricultural by-products, co-products and wastes and biobased materials from bio-polymers for textiles, composites and medical applications.

Objective 4: to develop and evaluate methods to remove dyes and finishing chemicals from textile waste water

NE: The University of Nebraska-Lincoln continued on developing environmentally responsible sizing/slashing agent from soyprotein isolates and soymeal to substitute PVA, which is a major problem for high COD in textile effluent, and on developing novel dyeing systems for cotton, and wool to decrease and eliminate dyeing effluents. NE scientists have focused on utilization of sorghum byproducts and coproducts, mainly husks and distillers grains for textile dyes and protein extractions, and have developed an excellent natural dye from sorghum husk and the best extraction method of proteins from sorghum distillers. They have made major success in extracting dyes from sorghum husks, and dyed wool with excellent properties, including depth of shades, colorfastness. NE scientists also found that the dyes have excellent fluorescent properties, and UV protections.

Milestones

CA: CA researchers have established streamlined processes to isolate cellulose from agricultural crop residues and food/beverage processing waste and develop coupled chemical-mechanical methods to produce varied nanocelluloses, many in near full yields. Unique dimensional attributes and surface chemical and charged characteristics can be targeted by selecting feedstock sources, e.g., cotton linter, rice straw, grape and tomato pomace, etc. as well as specific methods of derivation. These nanocelluloses have shown to be amphiphic, surface-active and capable of self-assembling into thin fibers, films, porous membranes, hydrogels and aerogels, etc. Developing potential applications of these diverse highly crystalline cellulose structures have generated two provisional patents.

NE: First time in the world, NE scientists have had a breakthrough in their polylactide research, i.e., have made 100% stereo-complexed crystals for PLA fibers with molecular weight up to $6x10^5$. The stereo-complexed structure substantially improved the resistance of PLA plastics against hydrolysis and increased softening points of PLA up to 60C. Such two major improvements provided PLA its possibility to be an excellent engineering plastics for the use at high temperature environments, and for the use in textiles. NE scientists have made major success in extracting dyes from sorghum husks, and dyed wool with excellent properties, including depth of shades, colorfastness. They also found that the dyes have excellent fluorescent properties, and UV protections. NE scientists have made a garment from cotton stalk fibers, blended with cotton and have demonstrated that the materials from cotton stalk fibers have excellent performance properties. A novel green process for hair perming and straightening using environmentally responsible and non-toxic chemical systems is fully developed and ready for industrial utilizations.

NY: NY research group is the first ever to successfully achieve both self-healing green resins based on plant proteins and starches as well as green composites. Self-healing characteristic can extend their useful life and make it easier for them to replace conventional composites derived from petroleum. SPI resin is brittle, but SPI/ENR green resin with higher toughness could be easily used as fully biodegradable thermoset resin in many applications including green composites. The self-healing technique has been further extended to obtain starch based resins that self-heal and provide significant benefits. Similarly the 1-step process for adding electrospun fibers for resin toughening can also be extended to other resins.

TN: TN scientists will complete data analysis of investigating the effect of weathering on physicochemical properties of biodegradable plastic mulches by Fall, 2018. The biodegradability of biodegradable plastic mulches in ambient soil and industrial composting (standardized) conditions will be determined by December, 2018.

Impact

Currently, most of the US cellulose biomass is used for bioenergy conversion. To improve economic performance of the bioenergy production, new technologies for producing biobased materials from bioenergy byproducts are critical. The U.S. apparel retailing industry has a market of $225B. Because the viscose rayon fiber manufacture no longer exists in the U.S. due to its pollution, the development of new echo-friendly rayon technology using the ionic liquid systems would benefit the U.S. agricultural and textile manufacturers in the product innovation and enhancement of competitiveness in the global marketplace. The variety of research projects associated in the multistate research group have made significant impact and milestones summarized as below.

In CA, Research progress at the University of California, Davis has advanced knowledge on biopolymer utilization from waste and by-products in our agricultural and food systems and created new processes in converting these biopolymers to nanomaterials and performance products. Specifically, cellulose has been efficiently isolated from several major crop residues including rice straw, graph and tomato pomace, cotton linter, and converted to nanocelluloses of nanoscale lateral and up to micro-scale length dimensions and charged or uncharged surfaces. Furthermore, various forms of fibers, films, hydrogels and aerogels have been assembled from these nanocelluloses to exhibit properties potentially useful for separation, catalysis, nanoparticle synthesis and molecular sensing, to name a few.

In NE, The scientists have reported our findings 3 times at major national and international conferences, and 3 time to local, and regional audiences. We have published 15 refereed journal articles. The findings continue to provide important information to researchers and industries for selecting the appropriate renewable resources and application conditions for the development of fibrous materials for textiles and composites industries. NE scientists' researches on the biobased materials, including fibers and chemicals, provide opportunities for Nebraska to add benefits and jobs to its economy. Their researches on zero discharge in dyeing, soymeal sizes, natural dyes from sorghum husks, and biofibers provide opportunities for the textile and materials industries to decrease their dependence on petroleum, and increase their sustainability. Their researches attract industries to contact UNL's Office of Technology Development for technology transfers. NE scientists' researches have been reported by organizations throughout the world.

NE scientists' work on fully stereo-complexed PLA fibers attracted much attention throughout the world due to its potential for large scale production of high quality PLA materials.

1. NE scientists' research on bioplastics/polymers were selected to report in the **State of the University 2017** document. http://www.unl.edu/chancellor/state-of-the-university-address-2017 (42-46 seconds).
2. Heating promises better bioplastics. By Amanda Joshi. ***Chemical Processing***. Sept. 25, 2017. http://www.chemicalprocessing.com/articles/2017/heating-promises-better-bioplastics/
3. **Budget-friendly bioplastic. NIFA (USDA National Institute of Food and Agriculture) Impact Feature**, Sept. 15, 2017. https://nifa.usda.gov/announcement/budget-friendly-bioplastic
4. Is There a Rise in Biodegradable Plastic Production Coming? **Trend in Tech**. By Katherine

Tanner. September 11, 2017. http://trendintech.com/2017/09/11/is-there-a-rise-in-biodegradable-plastic-production-coming/

5. UNL professor Yiqi Yang's research leads to discovery of eco-friendly polylactide plastic. **The Daily Nebraskan**. By Zoe De Grande. Sept. 8, 2017. http://www.dailynebraskan.com/news/unl-professor-yiqi-yang-s-research-leads-to-discovery-of/article_9fa8d2d6-9440-11e7-a271-67148d0ae638.html
6. New Technique Could Ramp Up Mass Biodegradable Plastic Production. **Engineering 360 by IEEE**. By Siobhan Treacy. August 31, 2017. http://insights.globalspec.com/article/6382/new-technique-could-ramp-up-mass-biodegradable-plastic-production
7. The Making of Biodegradable Plastic Could Take Off With This New Technique**. Seeker**. by Molly Fosco**.**. Sept. 5, 2017**. https://www.seeker.com/tech/materials/the-making-of-biodegradable-plastic-could-take-off-with-this-new-technique**
8. New breakthrough technique could revolutionise biodegradable plastic. Aristos Georgiou, **International Business Times**. By Aristos Georgiou. Sept 1, 2017. http://www.ibtimes.co.uk/new-breakthrough-technique-could-revolutionise-biodegradable-plastic-1637618
9. Mass production of biodegradable plastic. **ScienceDaily.** Aug. 31, 2017. https://www.sciencedaily.com/releases/2017/08/170831091454.htm
10. GOEDKOPE PRODUCTIEMETHODE VOOR BIOPLASTIC**. Techiek Maakt Je Wereld.** Aug. 31, 2017. https://www.deingenieur.nl/artikel/goedkope-productiemethode-voor-bioplastic
11. UNL researchers are working on corn starch bioplastic to reduce waste. **The Daily Nebraskan**. Sept. 1, 2017.http://www.dailynebraskan.com/news/unl-researchers-are-working-on-corn-starch-bioplastic-to-reduce/article_3ff67e84-8ebd-11e7-9e3e-833de7460b69.html
12. **Huskers bring the heat to improve biodegradable plastics.** Scott Schrage. ***Nebraska Today.*** August 31, 2017. http://news.unl.edu/newsrooms/today/article/huskers-bring-the-heat-to-improve-biodegradable-plastics/
13. UNL professor Yiqi Yang's research leads to discovery of eco-friendly polylactide plastic. **Polyestertime.** Sept. 11, 2017. http://www.polyestertime.com/unl-yiqi-yang-eco-friendly-polylactide-plastic/
14. Technique could aid mass production of biodegradable plastic **Biofueldaily.** Aug. 31, 2017. http://www.biofueldaily.com/reports/Technique_could_aid_mass_production_of_biodegradable_plastic_999.html
15. Technique could aid mass production of biodegradable plastic **ScienceCodex.** Aug. 31, 2017. http://www.sciencecodex.com/technique-could-aid-mass-production-biodegradable-plastic-614105
16. New Technology capable of improving properties of bio-thermoplastics. **Chinese Academy of Science.** http://www.cas.cn/kj/201709/t20170907_4613578.shtml
17. The research on bioplastics from PLA is also reported by:

a. **Morning AgClips**. https://www.morningagclips.com/mass-production-of-biodegradable-plastic/
b. **Materialsgate.** https://www.materialsgate.de/en/mnews/76006/Huskers+bring+the+heat+to+improve+biodegradable+plastics.html

c. **Product design and development**. https://www.pddnet.com/news/2017/08/technique-could-aid-mass-production-biodegradable-plastic
d. **R&D Magazine.** https://www.rdmag.com/news/2017/09/technique-could-aid-mass-production-biodegradable-plastic
e. **Science Magazine.** https://scienmag.com/technique-could-aid-mass-production-of-biodegradable-plastic/
f. **RurekAlert.** https://eurekalert.org/pub_releases/2017-08/uon-tca083017.php
g. **ChemInfo.** https://www.chem.info/news/2017/08/technique-could-aid-mass-production-biodegradable-plastic
h. **Physical Organization.** https://phys.org/news/2017-08-technique-aid-mass-production-biodegradable.html

NE scientists' research on natural dyes and their unique functions attracted much attention internationally and was reported worldwide.

1. Sorghum shows potential as fabric dye. Gina Incontro. ***Nebraska Today.*** August 7, 2017. http://news.unl.edu/newsrooms/today/article/sorghum-shows-potential-as-fabric-dye/
2. Nebraska researcher using sorghum for textile dye. Gina Incontro. ***IANR News***. July 31, 2017. http://ianrnews.unl.edu/nebraska-researcher-using-sorghum-textile-dye
3. Success Story. Sorghum: health food, sweetener and now, clothing dye. NIFA (USDA National Institute of Food and Agriculture) Update, May 31, 2017. https://content.govdelivery.com/accounts/USDANIFA/bulletins/19e8ba8
4. Sorghum Grain Alternative Uses: Healthy Popcorn, Gluten-Free Food, Clothing Dye & More. Gutlerrez, N., may 25, 2017. ***The Science Times.*** http://www.sciencetimes.com/articles/16036/20170525/sorghum-grain-alternative-uses-healthy-popcorn-gluten-free-food-clothing-dye-more.htm
5. Sorghum: health food, sweetener and now, clothing dye. **ACS (American Chemical Society) News Service Weekly PressPac (**press package**). May 24, 2017.** *ACS Sustainable Chemistry & Engineering.*

Only 200 out of a total of 100,000 researches were selected for this report annually. https://www.acs.org/content/acs/en/pressroom/presspacs/2017/acs-presspac-may-24-2017/sorghum-health-food-sweetener-and-now-clothing-dye.html

NE scientists' work on utilization of feathers was reported by media: Chicken feathers — poultry's diamond in the rough. By Katie Keiger. Poultry Times Aug 16, 2017. http://www.poultrytimes.com/poultry_today/article_e81e9b2c-8207-11e7-b16d-6370e4ed90d8.html

NE scientists work on utilizing corn for textiles and biomedical industry was reported by media.

Nebraska Corn Production Fuels Research and Innovation**.** by Jessica Walker Boehm ***Nebraska Agriculture and You 2017*. pp45-47**. *Nebraska Agriculture and You* is an annual magazine published in partnership with the Nebraska Dept. of Agriculture. http://www.farmflavor.com/nebraska/nebraska-agriculture-2017/

In NY, the research directly relates to the nation's efforts in reducing the wastes from agricultural and food processing and creating value-added products that can be easily disposed of without harming nature. Utilizing biomass and processing wastes to create high-performance renewable resins and composites materials that are also fully biodegradable and compostable. Using such green polymers and composites to replace currently available petroleum based polymers and composites would support the Government's 'Bio-preferred' program. In this research we have shown that the useful life of soy protein isolate (SPI) based resin can be increased 1) by using SPI filled microcapsules to achieve self-healing mechanism and 2) by toughening through the addition of electrospun natural rubber (ENR) nanofibers in a facile 1-step process. The self-healing mechanism was extended to microfibrillated cellulose (MFC) reinforced SPI composites. Our research group is the first ever to successfully achieve self-healing green resins and composites. Self-healing characteristic can extend their useful life and make it easier for them to replace conventional composites derived from petroleum. SPI resin is brittle, but SPI/ENR green resin with higher toughness could be easily used as fully biodegradable thermoset resin in many applications including green composites. The self-healing technique was further extended to obtain starch based resins that self-heal and provide significant benefits. Similarly the simple 1-step process developed for blending electrospun fibers for resin toughening can also be extended to other resins. This research opens up new possibilities of using fully green and toughened SPI resins in many applications including green composites.

In CO, PLGA-gentamicin nanoparticles can be synthesized.

In IA, the work addresses the challenges faced in the textiles and apparel industry. Sustainability is a technical challenge on many different levels. The researchers are the first to incorporate electrospun biobased nanofiber mats to the bacterial cellulose growing culture media during the growing to improve the mechanical properties and decrease the moisture regain of the materials.

In TN, during biodegradation of nonwoven fully biobased PLA+PHA plastic mulches in ambient soil, microorganisms induce an opening up of the supramolecular structure during the first 4 weeks. Subsequently, the microorganisms utilize the more readily available biopolymeric component (PHA in the case of PLA+PHA mulches; PLA of amorphous morphology for 100% PLA mulches) during the first 20 weeks. Subsequently, the biopolymers undergo slow, and steady depolymerization.

In TX, New technologies for converting lignocellulose biomass into functional high-end textile materials are critical for the enhancement of sustainability of textile and apparel industries. Market demands for biodegradable, biocompatible, and bioactive novel fiber and fabric products keep increasing steadily. The accomplished work helps promote a vision of the cellulose-derived fiber materials for future energy storing and tissue engineering applications. The research progress has been disseminated through publications in peer-reviewed journals.

Publications

Peer-reviewed Journal Papers

1. Vonasek, E., N. Nitin, Y.-L. Hsieh, Bacteriophages immobilized on electrospun cellulose microfibers by non-specific adsorption, protein-ligand binding and electrostatic interactions, *Cellulose*, 24:4581-4589 (2017).
2. Jiang, F., D.M. Dinh, Y.-L. Hsieh, Adsorption and desorption of cationic malachite green dye on cellulose nanofibril aerogels, *Carbohydrate Polymers*, 173: 286-294 (2017).
3. Jiang, F., Y.-L. Hsieh, Cellulose nanofibril aerogels: synergistic improvement of hydrophobicity, strength, thermal stability via crosslinking with diisocyanate, *ACS Applied Materials & Interfaces*, *9* (3), 2825–2834 (2017).
4. Gu, Jin and Y.-L. Hsieh, Alkaline cellulose nanofibrils from streamlined alkali treated rice straw, *ACS Sustainable Chemistry & Engineering*, 5: 1730-1737 (2017).
5. Yapor, J. P., Alharby, A., Gentry-Weeks, C., Reynolds, M., Alam, A. K. M. M., & Li, Y. V., Polydiacetylene Nanofiber Composites as a Colorimetric Sensor Responding To Escherichia coli and pH. ACS Omega, 2(10), 7334-7342 (2017).
6. Xiang, C., Acevedo, N., In Situ Self-Assembled Nanocomposites from Bacterial Cellulose Reinforced with Electrospun Poly(lactic acid)/Lipids Nanofibers, *Polymers*, 9(5),179 (2017).
7. Pan, G.W., Xu, H.L., Mu, B.N., Ma, B.M., Yang, J., and Yang, Y.Q. Complete stereo-complexation of enantiomeric polylactides for scalable continuous production, *Chemical Engineering Journal*. 328. 759-767 (2017).
8. Song, K.L., Xu, H.L., Xie, K.L., and Yang, Y.Q., Keratin-based biocomposites reinforced and crosslinked with dual-functional cellulose nanocrystals, *ACS Sustainable Chemistry & Engineering*. 5(7), 5669-5678(2017).
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Books and Book Chapters

Yang, Y.Q., Yu, J.Y., Xu, H.L., and Sun, B.Z. edited book. **Porous Lightweight Composites Reinforced with Fibrous Structures**. 368 pp. 4 parts, 13 Chapters. 140 Figures and 39 Tebles. Published by Springer-Verlag Berlin Heidelberg, Germany. (Heidelberger Platz 3, 14197 Berlin, Germany). ISBN 978-3-662-53802-9; ISBN 978-3-662-53804-3 (eBook). DOI 10.1007/978-3-662-53804-3. Library of Congress Control Number 2016962702. Copyright Springer-Verlag GmbH Germany 2017.
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Conference Presentations/Abstracts/Posters

1. Xiang, C., Acevedo, N.C., "Biodegradable Bacterial Cellulose Nanocomposites Reinforced with Electrospun Poly(lactic acid)/Lipids Nanofibers". The Fiber Society 2017 Fall Meeting. Athens, GA, November, 2017.
2. Mu, B.N., Xu, H.L., and Yang*, Y.Q. Accelerated Hydrolysis of Cellulosics after Reactive Dyeing. The Fiber Society's Fall 2017 Technical Meeting and Conference and International Symposium on Materials from Renewables (Advanced, Smart, and Sustainable Polymers, Fibers, and Textiles). November 8-10, 2017. Athens, Georgia, USA.
3. Yang*, Y.Q., Pan, G.W., Xu, H.L., Ma, B.M., Qian, Z.L., and Lao, H.Z. Melt-Spun PLLA-PDLA Fibers with Completely Stereo-Complexed Crystallites. 8th International Conference on Advanced Fibers and Polymer Materials. (ICAFPM 2017 Next-Generation Fibers: Changing Our Life), Session H: Natural Fibers and Biomimetic Polymers. Keynote Speech. Shanghai, China. October 8-10, 2017.
4. Xu, H.L., Palakurthi, M., Xu, L., and Yang*, Y.Q. Compression molded composites from waste polyester and cotton textiles. Session of Processing & Properties of Biobased Composites & Blends. 253rd ACS National Meeting & Exposition, San Francisco, CA, United States, April 2-6, 2017, CELL-309. (April 4, 1:55-2:20 pm).
5. Yang, Y.Q., Hou, X.L., Fang, F.F., Guo, X.L., Wizi, J., Ma, B.M., and Tao, Y.Y. Textiles Dyed with Sorghum Husks. The Nebraska Grain Sorghum Board Meeting. Board Room, Nebraska Innovation Campus, 2021 Transformation Drive, Lincoln, NE. November 14, 2017.

6. Yang, Y.Q. Future of Textiles. Junior and senior students from Marian High School. UNL. Nov. 7, 2017.
7. Yang, Y.Q. Agricultural Byproducts for a Sustainable Textile Industry. Nantong University, Nantong, Jiangsu, China, May 26, 2017.
8. Netravali, A. N., (Invited Research Seminar), Advanced Green Composites, Sukant Tripathy Memorial Symposium, December 1, 2017, Lowell, MA.
9. Netravali, A. N., (Invited Presentation), Green Materials: From Sports Gear to Ballistic Application and From Housing to Nanofibers, American Society of Interior Designers (ASID), November, 3, 2017, Ithaca, NY.
10. Netravali, A. N., (Invited Research Seminar), Advanced Green Composites, Åbo Akademi University, August 10, 2017, Turku, FINLAND.
11. Netravali, A. N., (Invited Panel presentation), Hemp: From Textiles to Packaging & Composites to Housing, Hemp Summit, April 18, 2017, Ithaca, NY.
12. Netravali, A. N., (Invited Research Seminar), Self-Healing Green Composites, Ohio State University, April 4, 2017, Wooster, OH
13. Netravali, A. N., (Invited Presentation), Green Composites for Architectural Applications, 'Matter Design Computation: The Art of Building from Nano to Macro' Symposium, Preston Thomas Lecture Series, January 10-11, 2017, AAP, Cornell University, Ithaca, NY 14853.
14. Netravali, A. N., (Plenary Address), 'Advanced Green Composites', 25th International Conference on Processing and Fabrication of Advanced Materials, January 22-25, 2017, Auckland, NEW ZEALAND.

Fact Sheet

S. Ghimire, D.G. Hayes, J. Cowan, D. Inglis, L.W. DeVetter, and C. Miles, 2017, Biodegradable Plastic Mulch and Suitability for Sustainable and Organic Agriculture", Washington State University Factsheet FS103E (2017-2093), in press.