BioBased Technologies Available for Licensing

Status:

All Technologies in this catalog are patent pending or issued and are available for licensing/ partnering opportunities.

For more information on many of these technologies please visit our website: www.ndsureserchfoundation.org

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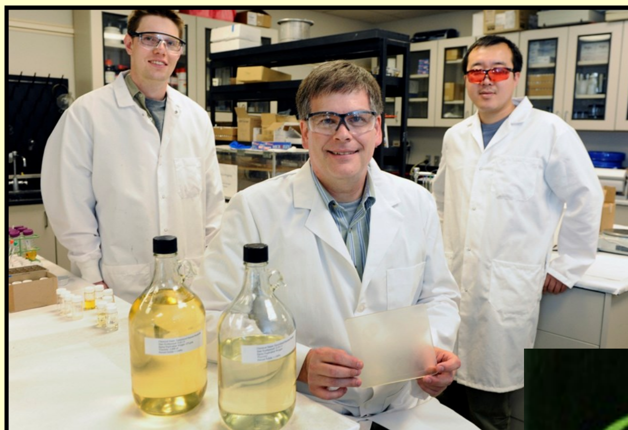

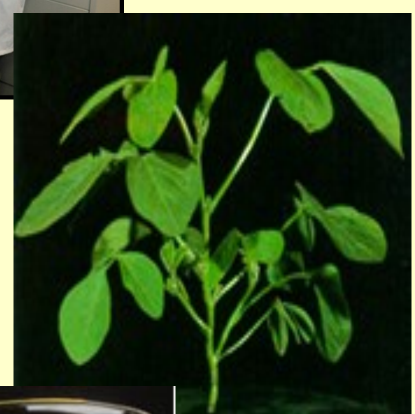

BioBased Technologies by Application

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Tech. No.	Technology Title
RFT-530	**Biomass Derived Photoinitiators for the Synthesis of Broad Spectrum of Polymers UV and/or Visible Light** Due to the desire for sustainable methods and materials, photochemical methods of fabrication are of great commercial interest. Photoinitiators are used for free radical and acid/base polymerization with numerous applications but are currently derived from fossil fuels. Sivaguru et al have developed biomass-derived Types 1, 2, and 3 photoinitiators from various sources with the use of UV and/or visible light. These photoinitiators require simple transformations of biomass, are efficient in promoting polymerization, and use sustainable strategies which minimize the dependence on fossil fuels for high performance materials.
RFT-529	**Renewable and Sustainable Biomass Derived Photodegradable Polymers** Worldwide efforts have been devoted to converting biomass into chemicals due to the high abundance, low cost, and renewability. Carbohydrates are of particular interest as one of its derivatives, FDCA, is one of the top 14 bio-based chemicals that can be used as a replacement in the synthesis of polyethylene terephthalate (PET). Though made from renewable resources, recyclability of the polymers has remained an issue. Sivaguru et al addressed this through the use of a nitrobenzyl phototrigger unit backbone which allows for controlled photodegradation, via UV irradiation, of biomass-derived polymers.
RFT-520	**Vanillin: A Bio-based Crosslinker for Melamine-Formaldehyde Coatings** n an effort to improve environmental bio-compatibility, bio-based materials have been explored as alternatives to petrochemical-based composites. Specifically, there is currently an unmet need in the field for bio-based aromatic compounds. Lignin is the most abundant aromatic biopolymer with excellent thermal and mechanical properties. One of its degradation products, vanillin, is considered a waste product in pulp and paper industries making it cost-effective as a building block for polymers. Webster et al have synthesized a novel phenolc resin based on vanillin and then crosslinked the resin with melamine-formaldehyde (MF) resins which have numerous applications such as laminate flooring, cabinetry, surface coatings, textile finishes, and paper processing. They developed a novel synthetic approach resulting in various resins and coating compositions in which vanillin significantly increased impact, hardness, and solvent resistance.
RFT-512 **RFT-513**	**Modified Soybean Oil Derivatives as Processing Oils for Rubber Compounds** There has been growing commercial and industrial interest in biodegradable and renewable materials over petroleum-based materials. Particularly, soybean oil is widely used due to its availability and low cost. Chisholm et al have determined that appropriate modification of soybean oil results in materials for use as a processing oil for rubber compounds. They show, through numerous examples, that the use of unmodified soybean oil reduces key mechanical properties, such as moduli and tensile strength when compared to conventional petroleum-based processing oils. However, rheological and mechanical properties can be substantially improved by 1) styrenating the soybean oil or 2) producing a higher molecular weight liquid from soybean oil (ex: sucrose soyate and soy-based oligomer). Thus, soybean oil can be used as the basis for a bio-based and green alternative to petroleum-based oils for rubber compounds.
RFT-503	**Advanced Bio-Based Composites Using Methacrylated Epoxidized Sucrose Soyate (MAESS)** Bio-based polymers have gained significant traction due to growing concern for the environment and depletion of petroleum-based resources. Plant-based polymers have shown the greatest promise, but have still faced issues such as low glass transition temperature, modulus, and hardness. Ulven et al. have developed a composite of methacrylated epoxidized sucrose soyate (MAESS) derived from vegetable oil and fiberglass fabric which addresses these issues for improved mechanical properties over current bio- and petroleum-based composites.

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RFT-502 RFT-521	**Hard and Flexible, Degradable Thermosets from Renewable Bioresources with the Assistance of Water and Ethanol** Thermosets are widely used in industry due to their superior dimensional stability, good processing ability, and high formulation flexibility for tailoring the desired properties such as high modulus, strength, durability, and thermal and chemical resistance. However, they may release VOCs, cannot be reprocessed by heat or solvent, and depend on non-renewable resources. To address these issues, Webster et al. developed degradable bio-based thermosets. These novel thermosets achieve high hardness while maintaining excellent flexibility as well as outstanding adhesion and solvent resistance, which is unprecedented in the field. Further, they degrade rapidly in aqueous base conditions in addition to being thermally degradable.
RFT-499	**Polymers Derived from Bio-diesel Waste for Road Dust Control** Scientists at NDSU have developed a new material that can be applied to gravel roads for suppression of road dust. The material is made from the huge waste stream that is generated during the production of biodiesel which is primarily glycerol and biodegradable or bio-derived fatty acid esters. The new material is made up of mono- and di-gylcerides that are synthesized from a combination of waste glycerol and soybean oil triglycerides. Upon application to the road surface, the glycerides undergo crosslinking reactions to form a larger, more stable molecule.
RFT-490	**Acetoacetylated Lignin Thermosets** Lignin is a key component of woody plants, the most abundant aromatic bio-polymer in nature, and is made up of a mixture of aromatic alcohols, the monolignols, as opposed to carbohydrate monomers. Commercially, lignin is sourced from wood products and is a direct byproduct of the pulping process to convert wood into wood pulp and extract cellulose. However, it is currently treated as a waste product which limits its use. Webster et al have identified another use through the acetoacetylation of lignin to develop bio-based resins. The lignin can be used directly from the pulping process or be depolymerized first and is an excellent source of terrestrial carbon that can be developed into thermoplastic and thermosetting polymers. Acetoacetylation of lignin results in a resinous liquid.
RFT-488	**Bio-based Cyclic Carbonate Functional Resins and Polyurethane Thermosets** There has been growing interest in bio-based resins due to the foreseeable limit of fossil feedstocks and increasing environmental concern. Additionally, polyurethanes are widely used commercially but rely on petroleum-based materials and utilize isocyanate, which is hazardous. Webster et al. have developed a novel bio-based material that can be reacted with amines to form polyurethanes using a non-isocyanate route, and thus are safer than current systems. Specifically, the resins contain a high number of cyclic carbonate groups synthesized from the reaction of epoxidized sucrose fatty acid ester resin with carbon dioxide. Further, these resins are prepared from epoxidized sucrose fatty acid esters from different vegetable oils and can be fully or partially carbonylated.
RFT-487	**Epoxy Resin Thermosets Derived from Vanillin** Thermosetting polymers and composites are widely used in industry due to their low density, good mechanical properties, low cost, and dimensional stability. However, most resins are synthesized primarily using petroleum-based chemicals. Due to current environmental concerns and the limit of fossil feedstocks, the industry is suffering from increasing costs and environmental regulations. Webster et al. have developed novel epoxy resins synthesized from the reaction between vanillin and diamines to form a Schiff base. Vanillin can also be glycidated to form another bio-based resin. Vanillin is derived from the depolymerization of lignin, an abundant aromatic bio-polymer currently treated as a waste product in pulp and paper industries, and therefore expands the use of traditionally wasted materials.

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RFT-478	**Novel Monomers from Biomass** The majority of biomass polymers, when broken down into their constituents, consist of cellulose derived sugars of 5 or 6 carbon atoms and lignin-derived aromatic building blocks. These building blocks are relatively highly oxidized and thus, without further chemical conversion, are not well-suited for fuels and chemicals. Scientists at NDSU have recently invented novel methods for the conversion of renewable resources to feedstock chemicals. The lignin and cellulose degradation products are converted to higher quality monomers through certain chemical reactions for use in polymer synthesis.
RFT-477	**Novel Photodegradable Polymers** Building Blocks for polymers are mainly derived from fossil fuels. Though synthetic polymers play vital roles in daily life, their non/poor degradability increases concerns regarding their impact on the environment. To address the above issues of degradability and sustainability, NDSU researchers have developed polymer building blocks from renewable resources with built-in photocleavable unit(s) to obtain photodegradable polymers that can be pre-programed for degradation with light. These materials were synthesized and evaluated for degradation under irradiation of UV light. Complete decomposition of the polymeric materials was observed with recovery of the monomer that was used to resynthesize the polymers.
RFT-462	**Acrylic Monomers Derived from Plant Oils - Synthesis and Use in High Value Polymers** Scientists at NDSU have developed a one-step method to convert plant oil into acrylic monomers that substitute for petroleum-based monomers in the production of acrylic polymers. This method can use essentially any plant oil, animal fat, or other fatty esters as the raw material. The output is a combination of (meth) acrylic fatty monomers that can be used directly in the production of latexes, adhesives, surfactants, sizing agents, resins, binders, and other products that utilize acrylic polymers. Additionally, the NDSU monomers contain two types of double bonds. The one within the acrylic group is reactive in conventional addition free radical polymerization, which allows formation of linear polymers. The double bonds within the fatty chain remain unaffected during free radical polymerization, so remain available for oxidative cross-linking and additional tuning of the polymer performance characteristics. This is in contrast to existing plant oil based monomers, which produce non-linear branched and cross-linked polymers (because their fatty chain double bonds participate in the polymerization) The performance attributes of the linear structure derived from the NDSU monomers provide significant benefits as compared with competing plant oil based polymers, with far more options for tuning their functionality and controlling their performance because of their great versatility in macromolecular configuration and chemical composition.
RFT-459 RFT-489	**Bio-Based Highly (Meth)Acrylated Resins and Thermosets** Thermosetting polymers and composites are widely used in industry due to their many desirable characteristics, such as low density and cost, dimensional stability, and good mechanical properties. However, most of these resins are petroleum-based raising environmental concerns and potentially increasing cost and regulations. Thus, there is a demand for novel resins and composites synthesized from renewable materials, such as plant oils. Webster et al. answer that need with a novel bio-based resin containing a large number of unsaturated vinyl groups. Specifically, they have developed a polyfunctional bio-based oligomer synthesized from an epoxidized sucrose fatty acid ester resin and an ethylenically unsaturated ester (RFT-459). More recent modifications by the group (RFT-489) have added an acid anhydride leading to a vinyl functionalized resin with a lower viscosity. The resins can then be cured using free radical initiators to form highly crosslinked thermosets with numerous applications. These systems use significantly lower amounts of styrene than petrochemical
RFT-458	**Composites from Flax Fibers and Glass Fibers in a Bio-Based Resin** The use of bio-based resins and/or natural fibers in composites has emerged due to the need for improved chemical sustainability and environmental impact. There is growing interest in polyurethanes as they are durable and cost effective. However, they are traditionally made from petroleum based polyols and isocyanates. Ulven et al answer the need for sustainable materials with the development of structural biocomposites comprising cellulose-based bast natural fibers and/or glass fibers and bio-based polyurethanes. Specifically, bio-based polyols are reacted with polyisocyanates to generate bio-based polyurethanes. These materials have a higher modulus, hardness, and Tg than other bio-based and petroleum-based polyols.

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RFT-368 RFT-452	**High Performance, Bio-based Polyamides for Injection Moldable Products** Scientists working at NDSU have discovered a method for making thermoplastics for injection molding that are based, in part, on renewable resources. Unlike other bio-based polyamides, these possess the high melting temperatures, fast crystallization rates, low moisture uptake, and good mechanical properties associated with engineering thermoplastics. These polymers can be used to replace the petroleum-based nylon 6,6 and nylon 6 for high end injection molding applications such as the electronic and automotive parts.
RFT-438	**Plant Oil-Based Reactive Diluents for Coating and Composite Applications** NDSU scientists have developed plant oil-based reactive diluents for coating and composite applications that possess both low viscosity and high reactive functionality. With these improved characteristics, these plant oil-based materials eliminate or reduce the need to be blended with petrochemicals thereby increasing the bio-based content of the product, which is environmentally more desirable. The fundamental aspect of the invention involves transesterification of a plant oil triglyceride with an alcohol that also contains at least one double bond. By completely replacing the glycerol component of the plant oil triglyceride with three equivalents of the unsaturated alcohol, fatty acids esters are produced containing at least one double bond that is not derived from the parent plant oil. Depending on the application requirements, a low-cost, biobased unsaturated alcohol can be used to produce the reactive diluents of the invention.
RFT-423	**Novel Polymers and Polymeric Materials Based on the Renewable Compounds, Eugenol and Iso-Eugenol** Due to the finite supply of fossil resources and the growing environmental concern, there is a major need for chemicals and materials derived from renewable resources. Aromatic building blocks, such as phenols, are particularly important and can be derived from renewable sources. Chisholm et al are the first to convert eugenol and iso-eugenol into vinyl ether monomers via reaction of the hydroxyl group. The result is soluble, processable linear polymers that retain the allyl group for crosslinking reactions and incorporation of other functional groups.
RFT-422	**Blocked Bio-Based Carboxylic Acids and Their Use in Thermosetting Materials** Scientists working at NDSU have discovered a way to make vinyl-block bio-based carboxylic acid crosslinkers for epoxy resins that are particularly useful for vegetable oil based epoxy resins. The resulting coatings have an excellent combination of hardness, flexibility, adhesion, and solvent resistance.
RFT-413	**Vegetable Oil-Based Polymers for Nanoparticle Surface Modification** The extremely high surface area of nanoparticles provides many advantages over conventional particles with dimensions in the micron scale. For a variety of applications, it is necessary to suspend the nanoparticles in a liquid medium. Researchers at NDSU have developed a new plant-oil-based polymer technology focused on the application of nanoparticle suspension in water. One primary example of this technology's application is its use as a protectant, while dispersing and suspending FeNPs in decontamination efforts involving chlorinated hydrocarbons, such as tetrachloroethylene. The copolymers described herein are not only high effective with respect to suspending nanoparticles in water, but also exhibit high biodegradability. Biodegradability is important for environmental applications because the polymer is typically not recovered after treatment of a ground water contaminant plume. In addition, compared to other approaches, this copolymer technology enables compositions to be highly tailored or optimized for a given nanoparticle and application.

Tech. No.	Technology Title
RFT-365	**Bio-based Branched and Hyper-branched UV Curable Oligomers** This invention revolves around the synthesis of novel high bio-renewable content oligomers based on soybean oil and cashew nutshell oil. These oligomers can be either UV or thermally cured to produce thermoset polymer materials such as coatings. Because of the more rigid structure of these novel oligomers as imparted by the cashew nutshell oil, the cured materials containing these oligomers possess much improved material properties than current biobased materials and in some cases even their petro-based counterparts.
RFT-349	**Soybean Oil Based UV Curable Coatings with High Bio-renewable Content** The invention revolves around a UV curable coating that is based on acrylated soybean oil, hyperbranched acrylates, adhesion promoter, and a renewable reactive diluent that showed good coating properties, good anti-stain and anti-corrosion performance directly on aluminum after prolonged (nearly 2000 hours) salt spray test.
RFT-335	**Bio-Based Coatings Based on Monomer-Grafted Alkyd Ester Resins** Scientists at NDSU have synthesized monomer-grafted sucrose ester resins by polymerizing styrene in the presence of the sucrose ester resins. At a composition of 50% styrene-50% sucrose ester, coatings had extremely fast track free drying times, similar to a commercial styrenated alkyd resin. However, the styrenated sucrose ester resin had a much lower viscosity than the commercial resin, meaning that higher solids coatings can be prepared. In addition, water dispersible resins were prepared by grafting a mixture of styrene and acrylic acid with the sucrose ester resin. These could be cross-linked with a melamine-formaldehyde resin to yield coatings that had good hardness, adhesion, and flexibility.
RFT-318	**Polymers Derived from Plant Oil Exhibit Increased Crosslink Density, Superior Properties** This proprietary technology platform involves the conversion of plant oil triglycerides to polymerizable monomers that are subsequently used to produce a wide variety of bio-based polymers, tailored for specific applications in multiple industries. There are four major attributes of the proprietary polymerization process that set this technology apart from all other previously developed plant oil-based technologies developed to date. These key features also allow major material performance advantages that enable this renewable polymer technology to successfully compete with petroleum-based polymer materials.
RFT-314	**Bio-Based Functional Resins and Thermoset Materials with Excellent Mechanical Properties** The technologies included in this portfolio lead to the production of bio-based chemical feedstocks that yield high performance bio-based thermoset materials (materials that strengthen when heat is applied). All of these high-functioning bio-based thermosets have been tested and show excellent hardness, solvent resistance, and gloss, as well as higher degrees of crosslinking and higher glass transition temperatures than currently available bio-based technologies with properties comparable to petrochemical-based materials. Due to the variety of crosslinking chemistries (methods for linking polymer chains) and the ability to “tune” these systems, these materials have potential in a number of applications in the fields of coatings, adhesives, composites, and inks.
RFT-310	**Novel Acetoacetoxy and Enamine Compounds and Coatings Therefrom** Researchers in the NDSU Department of Coatings and Polymeric Materials (CPM) have discovered enamine resins which are the reaction products of an acetoacetatylated resin, and a C1-C20 alkyl amine or a mixture of C1-C20 alkyl amines. The acetoacetylated resin is the reaction product of a polyol having 4 or more hydroxyl groups; and at least one acetoacetate. The invention also relates to an acetoacetylated resin which is the reaction product of a polyol having 4 or more hydroxyl groups and at least one acetoacetate, where a portion of the hydroxyl groups of the polyol are replaced by acetoacetate groups and the remaining hydroxyl groups are replaced by a saturated monofunctional carboxylic acid ester, unsaturated monofunctional carboxylic acid ester, or a mixture thereof; as well as to enamine resins prepared from these acetoacetylated resins.

For Further Information visit our website:

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