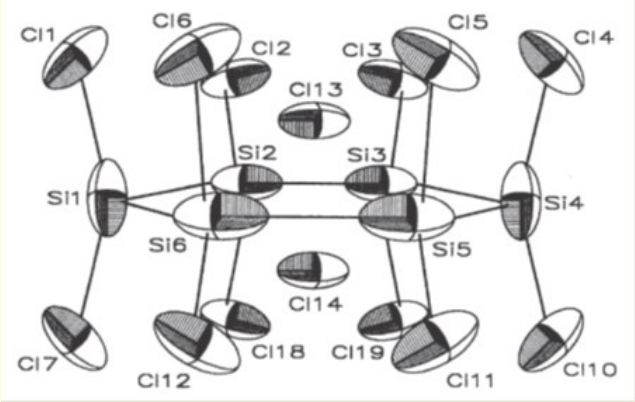
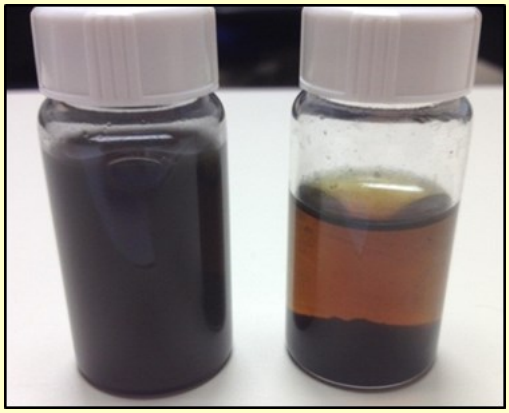
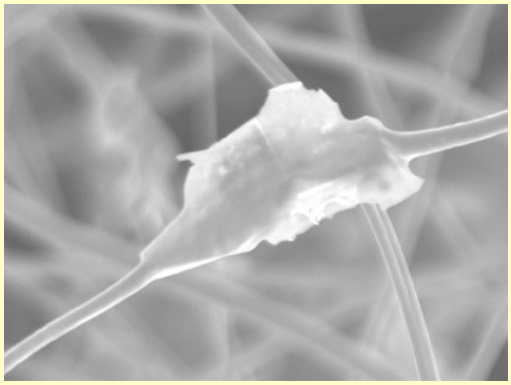
NDSU | RESEARCH FOUNDATION

Chemistry and Materials Technologies Available for Licensing



Chemistry





Materials

All Technologies Available for Licensing

Tech No.	Chemistry and Materials
RFT-533	Block-Scaffolds for Bone Regeneration using Nanoclay-Polycaprolactone Scaffolds with Supplements
RFT-530	Photoinitiators that Trigger Extremely Rapid and Efficient Polymer Synthesis using UV or Visible Light
RFT-529	Renewable and Sustainable Biomass Derived Photodegradable Polymers
RFT-520	Vanillin: A Bio-based Crosslinker for Melamine-Formaldehyde Coatings
RFT-517	Novel Non-Isocyanate Siloxane-Polyurethane Coatings
RFT-514	Metal-Free Synthesis of N-Containing Compounds Using Stabilized Photoreactive Hydrazide Scaffolds
RFT-512, RFT-513	Modified Soybean Oil Derivatives as Processing Oils for Rubber Compounds
RFT-509	Smart Coating for Corrosion Mitigation in Metallic Structures
RFT-505	Devices and Methods for Producing Synthetic Silk with Superior Characteristics
RFT-502, RFT-521	Hard and Flexible, Degradable Thermosets From Renewable Bio-resources with the Assistance of Water and Ethanol
RFT-499	Polymers Derived from Bio-Diesel Waste for Road Dust Control
RFT-490	Acetoacetylated Lignin Thermosets
RFT-488	Bio-based Cyclic Carbonate Functional Resins and Polyurethane Thermosets
RFT-487	Epoxy Resin Thermosets Derived from Vanillin
RFT-478	Novel Monomers from Biomass
RFT-477	Photodegradable Polymers Enable Recovery of High Value Components from Electronics and Composites
RFT-462	Acrylic Monomers Derived from Plant Oils—Synthesis and Use in High Value Polymers
RFT-459, RFT-489	Bio-based Highly (Meth)Acrylated Resins and Thermosets
RFT-458	Composites from Flax Fibers and Glass Fibers in a Bio-Based Resin
RFT-454	Continuous Synthesis of Si Nano-Crystals Using Liquid Silanes
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RFT-430/431	Removal and Recovery of Phosphate, Selenium, and Arsenic from Water, w/ Potential Reuse as Fertilizers
RFT-423	Novel Polymers and Polymeric Materials Based on the Renewable Compounds, Eugenol and Iso-Eugenol
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RFT-413	Vegetable Oil-Based Polymers for Nanoparticle Surface Modification
RFT-380	Novel PEGylated Compounds and Process for Making Antifouling/Biocompatible Materials
RFT-368, RFT-452	High Performance, Bio-Based Polyamides for Injection Moldable Products

All Technologies Available for Licensing

Tech No.	Chemistry and Materials
RFT-324	Efficient Processes to Produce Polyalkylated Oligo-ethyl-polyamines
RFT-318	Polymers Derived from Plant Oil Exhibit Increased Crosslink Density, Superior Properties
RFT-311	Unique Electrospinning Process and Compositions for High-Volume Silicon Nanowire Production
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Tech. No.	Technology Title
RFT-533	**Block-Scaffolds for Bone Regeneration using Nanoclay-Polycaprolactone Scaffolds with Supplements** Scientists at NDSU have developed a flexible, modular, bone scaffold for filling large bone gaps and accelerating bone growth with various additives, such as nutrients, cytokines, therapeutics and minerals incorporated into the scaffold. The scaffold is made of a clay and a polymer. Large bone defect scenarios exist that currently do not have satisfactory solution. These range from nonunion of fractures, excessive fractures with associated bone loss, revision total joint arthroplasty and others. This invention addresses all of these situations by enabling a customized block based nanoclay bone-mimetic scaffold. A defect site of an injured bone can be filled with a scaffold comprising one or more blocks that may be interconnected. The blocks can be designed in a variety of shapes and sizes and can be prefabricated. The large bone defect space can be treated with bone morphogenetic protein (BMP-2) for example that is incorporated into the scaffold matrix.
RFT-530	**Photoinitiators that Trigger Extremely Rapid and Efficient Polymer Synthesis using UV or Visible Light** NDSU researchers have developed a range of Type I, Type II, and acidic photoinitiators, which provide polymerization of polyacrylate with good efficiency at low concentrations. The synthesis of photoinitiators is efficient using routine chemistry, and their structures are easily manipulated to tune for low energy (including visible) light wavelengths. These photoinitiators are each triggered by a very narrow and easily defined wavelength, making timing of polymerization easy to control (and avoiding inadvertent triggering of the reaction). The photoinitiators may be produced from either bio-based or petroleum-based starting materials, including such readily available materials as vanillin.

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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** In an effort to improve environmental bio-compatibility, bio-based materials have been explored as alternatives to petro-chemical-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-517	**Novel Non-Isocyanate Siloxane-Polyurethane Coatings** Glycidyl carbamate (GC) functional resins are used due to their high mechanical strength, toughness and abrasion and chemical resistance associated with polyurethanes as well as the convenience of epoxy-amine chemistry. Webster et al. have combined these resins with polydimethylsiloxane to develop self-stratified coatings that yield coatings hav ing low surface energy as well as reduce the hazards of isocyanates.
RFT-514	**Metal-Free Synthesis of N-Containing Compounds Using Stabilized Photoreactive Hydrazide Scaffolds** NDSU Scientists have developed highly stable hydrazide-based scaffolds that use visible light and a metal-free process to produce molecules and polymers that contain nitrogen (positioned singly or as a pair of adjacent nitrogen atoms). This scaffold begins with a N-N bond that can be used as a catalyst to make anything from drug and specialty molecules to complex polymers. The N-N moiety allows creation of unique N-containing molecules, using visible light rather than higher energy UV. The unique approach is possible because the NDSU team as developed handling procedures that stabilize the hydrazide scaffold until a light sensitizer (such as thioxanthone) is added. The scaffold utilizes photoinduced excited state chemistry rather than ground state redox chemistry, providing substantially different end products and performance attributes as compared with compounds derived from redox chemistry.
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.

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RFT-509	**Smart Coating for Corrosion Mitigation in Metallic Structures** Though corrosion is well understood in terms of mechanisms and methods of control, it still accounts for a notable number of failures in pipelines buried or on the ground. This is due to a large number of potential complications such as varying soil properties along the pipeline and over time, local cracks on the soft coating surface, separation of coating from the pipeline surface, and corrosive environments. To address this, Azarmi et al developed smart coatings which can both prevent and monitor corrosion of steel through the use of a hard coating deposited by thermal spraying with embedded Fiber Bragg Grating (FBG) sensors.
RFT-505	**Devices and Methods for Producing Synthetic Silk with Superior Characteristics** Scientists at NDSU have developed a device and methods to produce spider silk that has the ability to produce silk similar to the silk produced by a spider pasting. Our device mimics the pH and ionic gradients found in the natural gland, but also pulls the fiber from the device as opposed to extruding it via pushing. This replicates native shear forces that are important for proper alignment of silk proteins. The result is a solid silk fiber that integrates the natural elements of fiber production (i.e. pressure, pH, and ionic gradients) to more accurately replicate the spider's ability to produce silk. Additionally, application of an electric field to the microfluidic device is a unique combination of microfuidic spinning and electrospinning to create a better fiber.
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.

Tech. No.	Technology Title
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.
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	**Photodegradable Polymers Enable Recovery of High Value Components from Electronics and Composites** In the U.S., only about 10% of post-consumer plastic is recycled. This leads to incredible waste of both plastic and valuable materials embedded in plastic. NDSU researchers have developed a photodedgradable polymer technology to improve value-added recovery of materials from plastics, as well as recycling of the plastics themselves. Recovery of valuable components represents a huge and poorly tapped opportunity for reuse, with electronic devices and carbon fiber composites being two examples. With respect to carbon fiber products, more than 30% of carbon fiber ends up discarded as waste. Electronics have an even worse recycling story. Almost 90% of electronic waste is disposed without recycling, even though it is a gold mine … one ton of circuit boards contains 40 – 800 times more gold than a ton of ore. There is also a tremendous amount of copper, silver, and palladium that is discarded rather than recovered. One way to radically decrease this waste is to make recovery and sorting of the valuable components easier and less expensive. The NDSU technology enables this recovery, using polymers (optionally bio-based) with built-in photocleavable unit(s). The resulting photodegradable polymers can be designed for degradation with specific wavelengths of UV and/or visible light by selecting the appropriate photocleavable unit(s). Use of these photodegradable polymers in circuit boards and in carbon fiber composites would enable them to be recycled far easier than today. They could be collected, exposed to the specific wavelength needed to degrade the ‘plastic’ structural or connecting material(s), which releases the high value metals and carbon fiber for collection, recycling, and reuse. Additionally, the photodegraded remnants of the polymers can themselves be collected and used to produce a new plastic product.

Tech. No.	Technology Title
RFT-462	**Acrylic Monomers Derived from Plant Oils - Synthesis and Use in High Value Polymers** Scientists at NDSU have developed an efficient and cost-effective one-step method to convert plant oils 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 may react during the polymerization reaction).
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 vinyl ester resins.
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.
RFT-454	**Continuous Synthesis of Si Nano-Crystals Using Liquid Silanes** Tunable band-gap of silicon nano-crystals (Si-NCs) presents applications such as light emitting diodes, broad-band absorber in solar cells and many more. By engineering the size, crystallinity, surface state (functionalized group) the properties of Si-NCs can be designed to offer variety of opto-electronic properties. Syntheses of freestanding Si-NCs adopt either a low-pressure plasma process with mono-silane or cumbersome chemical reduction processes; these have limited throughput and require additional processing to make them stable. Injection of liquid hydrosilane composition and subsequent pyrolysis allows continuous synthesis of few nm to sub-micron sized particles, with the ability to design the morphology (amorphous, intermediate to crystalline) and surface chemistry (passivation). In addition, by sequential injection of the liquid hydrosilane composition synthesis of core-shell nanoparticles of Si is possible. Synthesis of organic-inorganic photoluminescent hybrid nanomaterials with tunable emission is feasible with this technology. **Status: Optioned Exclusively in all Fields of Use and in all Territories**

Tech. No.	Technology Title
RFT-449	**Silicon Thin films with Embedded Heteroatoms** Scientists at NDSU have discovered methods for forming silicon thin films and structures with incorporated metals, non-metals, and combinations thereof. The precursor compositions useful in such methods are generally liquid at ambient temperature and are comprised of liquid silane(s) and metal and/or non-metal source(s). The compositions may be processed by printing, coating, or spraying onto a substrate and subjected to UV, thermal, IR, and/or laser treatment to form silicon films or structures with embedded heteroatom(s). These compositions allow for the control of dopant level prior to film processing allowing for very high doping levels with minimal out-diffusion. The available dopants are not highly toxic (as is the case for phosphine and diborane) and provide a means for film deposition without the use of expensive vacuum chambers. **Status: Optioned Exclusively in all Fields of Use and in all Territories**
RFT-447	**Roll-to-Roll Synthesis of Silicon Thin Films from Liquid Silanes** Silicon thin films are fundamental in solar and microelectronic industries, and are presently obtained using expensive low-pressure plasma enhanced chemical vapor deposition (PECVD) using gaseous silanes despite of its low precursor utilization efficiency. Instability and low vapor-pressure of liquid hydrosilanes have limited their use in the semiconductor industries for longtime. Researchers at NDSU have developed a process to synthesis silicon thin films from liquid hydrosilane (Si_6H_{12}) at ambient pressure in a roll-to-roll method using atmospheric pressure aerosol assisted chemical vapor deposition (AA-APCVD) that has higher deposition rates compared to the state-of-the-art PECVD. Solubility of solid dopants in the liquid hydrosilane facilitate the deposition of degenerately doped (n & p –type) Si thin films opposed to compressed toxic phosphine and borane gases used in other techniques. Low decomposition temperature (higher activation energy) of cyclohexasilane (Si_6H_{12}), a liquid hydrosilane, benefits for a new plasma-free process for the synthesis of silicon nitride films and Si nanowires (with suitable catalyst) at temperatures as low as 350 degrees C using the AA-APCVD, readily adoptable for large-scale roll-to-roll continuous manufacturing. Liquid hydrosilane compositions consisting of nanomaterials enable hybrid Si films with embedded nanomaterials that have applications in energy harvesting and light emitting devices. **Status: Optioned Exclusively in all Fields of Use and in all Territories**
RFT-444	**Artificial Bone Forms and Compositions for Approximating Bone** Scientists at NDSU have developed a platform combining engineered materials with a specialized additive manufacturing (3D printing) process to produce the most realistic alternative to human bone available. High resolution manufacturing precisely reproduces every detail of the desired bone, including the contour of cortical ‘hard’ bone and intricate structure of trabecular ‘spongy’ bone.
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.

Tech. No.	Technology Title
RFT-430/431	**Removal and Recovery of Phosphate, Selenium, and Arsenic from Water, w/ Potential Reuse as Fertilizers** Scientists at NDSU have developed a technology that removes selenium, arsenic, trichloroethylene and phosphorus from water using beads containing reactive nano zero valent iron (nZVI) particles encapsulated in calcium alginate beads. When charged with phosphorus or selenium, these beads can be beneficially reused to provide phosphate and/ or micronutrient fertilization. Therefore, the technology provides dual benefits of cleaning eutrophic and contaminated water bodies and waste streams, while collecting some of the contaminants (selenium and phosphate) with the potential of reuse in a form that facilitates this reuse.
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-419	**Removal and Recovery of Phosphate from Water Bodies and Reuse as a Fertilizer** Scientists at NDSU have developed biodegradable iron-containing alginate beads that remove phosphorus from water, and can then be beneficially reused to provide Phosphate fertilization. As a result, this dual-use technology can be used to clean water bodies that are eutrophic due to excess phosphorous, then use the phosphorous for fertilization in agricultural, nursery, and greenhouse settings where phosphorus is a limiting nutrient.
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.
RFT-380	**Novel PEGylated Compounds and Process for Making Antifouling/Biocompatible Materials** Surfaces having non-fouling characteristics are of great interest for the development of advanced materials in many different applications. In medical device applications, protein attachment can cause any number of unwanted immune reactions when exogenous materials are implanted into biological systems. Materials developed with polyethylene glycols, often referred to as PEGylated materials, are of great interest due to their protein resistance and nontoxic properties. One of the most widely used biomaterials is Polyurethane, due to its biocompatibility and its mechanical properties. Researchers at NDSU have developed a new class of PEGylated polyurethane materials using a novel process which is much more effective than traditional procedures. The resulting compounds are novel siloxane-PEG copolymers having terminal amine functionality and a backbone of siloxane having a varied number of pendant hydrophilic PEG chains. The low surface energy siloxane can aid in bringing PEG chains to the surface, and the terminal amine functionality can be bound into the polyurethane by reaction with isocyanate. Therefore, the surface of the material will be amphiphilic while the underlying polyurethane bulk will give toughness to the system. This approach allows for precise control over the number of hydrophobic PEG chains, siloxane and PEG chain lengths, and terminal amine functionality.

Tech. No.	Technology Title
RFT-368 RFT-452	**High Performance, Bio-based Polyamides for Injection Moldable Products** Scientists at NDSU have discovered a method for making a family of 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, and other semi-crystalline engineering thermoplastics, for high end injection molding applications such as the electronic and automotive parts where heat tolerance is needed.
RFT-325	**Routes for Superior Synthesis of Cyclohexasilane** Tetradecachlorocyclohexasilane dianion (YSi_6Cl_{14} :Y=counter ion), is an important intermediate in the production of cyclohexasilane (Si_6H_{12}, CHS). CHS is a liquid precursor for electronics grade silicon materials and devices. CHS is also a more benign liquid phase alternative to gaseous SiH4 and corrosive $HSiCl_3$ in the various procedures and technologies adopted in silicon based electronic processes. The existing method to produce YSi6Cl14 salt is low and yields up to 9-11%. This invention teaches a method to produce yields that are significantly improved to approximately 80-90% for the YSi6Cl14 salt. **Status: Licensed Exclusively in all Fields of Use and in all Territories**
RFT-324	**Efficient Processes to Produce Polyalkylated Oligo-ethyl-polyamines** Certain Polyalkylated Oligo-ethyl-polyamines such as TMEDA, TEEDA and PEDETA are useful intermediates in organic synthesis and analytical chemistry and used extensively in inorganic chemistry as ligands for a variety of metal complexes. In spite of high demands, PEDETA (penta-ethyl-di-ethylene-triamne) has not been available in industrial scales due to the difficulty in the realization of complete alkylation of the starting material using conventional methods. This novel method describes a process of obtaining PEDETA that is pure and without any side or incomplete alkylated product. The process involves no work-up and is thus environmentally friendly. In addition, the reaction time and work-up process is drastically reduced from the conventional synthesis method. **Status: Licensed Exclusively in all Fields of Use and in all Territories**
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-311	**Unique Electrospinning Process and Compositions for High-Volume Silicon Nanowire Production** North Dakota State University (NDSU) has developed unique synthetic routes to a novel liquid silicon precursor, cyclohexasilane (Si6H12), which is converted to silicon nanowires by electrospinning. Readily purified by distillation, the liquid nature of Si6H12 allows the development of a high-volume electrospinning route for silicon nanowire production. Because the spun wires convert to amorphous silicon at relatively low temperatures, formation of excessive surface oxide and carbide phases can be avoided which would otherwise negatively affect capacity and rate capabilities. The technology can be used in the development of anodes for use in next-generation lithium ion batteries, in which the traditional carbon-based anode is replaced with a silicon-based anode for a dramatic increase in capacity (theoretically over 1100% increase in capacity). **Status: Licensed Exclusively in all Fields of Use and in all Territories**

Tech. No.	Technology Title
RFT-278	**The Use of Fibers from Agricultural Waste Streams as a Reinforcing Agent in Commodity Thermoplastics** This invention describes a process wherein lignocellulosic fibers recovered from various agricultural waste streams (such as crop waste otherwise discarded by ethanol plants) are combined with commodity thermoplastics as a means of reinforcing and strengthening the plastics. This method works with commodity thermoplastics and recycled plastics where other fiber reinforcing processes have not succeeded. **Status: Licensed Exclusively in all Fields of Use and in all Territories**
RFT-265	**Composition and Method of Forming Functionalized Cyclohexasilanes** This invention pertains to a composition of matter derived from cyclohexasilane. The compound has unique physical properties and can exist in a liquid state at standard temperature and pressure - a characteristic that renders them appropriate for applications in novel deposition routes including high-speed printing and direct-write. The invention has applications in the manufacture of silicon-bassed solar cell in the photovoltaic industry. **Status: Licensed Exclusively in all Fields of Use and in all Territories**
RFT-237	**Low Band Gap Polymers** This invention describes the preparation of a new low band-gap (~0.5eV) conjugated polymer, accomplished via the electro-polymerization of Acenophto[1,2-b]thieno[3,4-e]pyrazines. This polymer has an application in light emitting-diodes (LEDs),photovoltaic devices, sensors, electrochromic devices, and field effect transistors (FET). The advantage of utilizing conjugated polymers in such applications is the ability to tune the properties of such materials at the molecular level. Control of polymer band gap is an important property in the production of technologically useful materials.
RFT-226	**Modified Glycidyl Carbamate Resins Exhibiting Superior Mechanical Properties** This invention pertains to novel glycidyl carbamate resins that have been modified with alkyl or ether alkyl groups. These resins have improved properties such as lower viscosity, which makes them good candidates for commercialization in the paint industry. In particular, it has potential for application as a coating on aircrafts.
RFT-225/240	**Unique Sol-Gel Hybrid Coatings with Superior Properties for a Wide Range of Industrial Applications** This invention pertains to the preparation of two-component polyurethane coating formulation comprising: an epoxy functional binder, and a blended curing component (having one sol-gel and one amine cross-linker.

Tech. No.	Technology Title
RFT-219	**Novel Polyurethane/Epoxy Hybrid Coatings** This invention involves the preparation of a novel coating composition comprising a glycidyl carbamate functional resin, an aromatic epoxy resin, and a polyamine cross-linker. This coating formulation with the aromatic epoxy resin has improved corrosion resistance over coatings that do not contain the aromatic epoxy resin.
RFT-160/161	**Chromophore and Polymer Capable Of Detecting the Presence of Various Neurotoxins** This is a dual-use technology that was initially reported under the spin electronics program funded by Department of Defense. The "spintronics" polymer is being tested for use in applications such as increased electronic or computer memory. However, this same material was also used by CNSE in sensor tests. The material provides an optical alert when it comes in contact with metallic poison such as insecticides that are in the same family as nerve gas and neurotoxins.
RFT-72	**Novel Chemotherapeutic Agents for Anti-Tumor and Anti-Cancer Drugs** This invention relates to novel, substituted (functionalized) polysiloxane compositions (and methods for synthesis of same) that may be useful as antineoplastics (chemotherapeutics) or other therapeutic agents. Since compositions of this type can transverse cellular membranes, they may also serve as delivery vehicles for other agents with biological activities in both animals and plants (e.g., drugs, herbicides, fungicides, anti-microbials, etc.).
RFT-71	**Multi-use Aminofunctional Alkoxy Polysiloxanes** Linear and cyclic polysiloxanes functionalized with amine moieties have been synthesized utilizing aminoalcohols. The reaction is cost effective and a one-pot process with minimal purification of end product required. A diverse and versatile array of amino-silicone products are possible due to the variety of aminoalcohols commercially available. Potential market applications include coatings, adhesives, sealants, rubbers, elastomers, catalyst supports, sol-gel/ceramic precursers, and ionically conductive materials.
RFT-65	**A Method of Using Organometallic Single Source Precursors to Make Aluminum Oxide or Other Inorganic Coatings** A new family of organometallic compounds was developed. These compounds contain a metal such as aluminum and a group 16 element such as oxygen in a stoichiometric ratio of 2:3 and can be decomposed to produce an inorganic compound such as A1203 (aluminum oxide), eliminating the organic portion of the original compound. Aluminum oxide is the only material developed to date under this program, although it may be expanded to other very useful compounds. This technology has completed initial laboratory testing. Scale-up is required, but no difficulties are foreseen. The advantages of the invention include the relatively innocuous nature of the precursor compound and the effluent organic compounds generated during decomposition and the low temperature of decomposition (less than 100°C).

Tech. No.	Technology Title
RFT-39	**Advances in the Deposition of Amorphous Silicon Films and Printed, Flexible Electronic Circuits** This technology involves a process of producing compounds containing a tetra-dedachloro-cyclohexa-silane dianion. They are prepared by contacting trichlorosilane with a reagent composition comprising a tertiary polyamine. The resulting tetradecachlorocyclohexasilane dianion can be chemically reduced to cyclohexasilane, a compound useful in the deposition of amorphous silicon films. One potential application involves use as a feedstock material for semiconductor wafers and photovoltaics. **Status: Licensed Exclusively in all Fields of Use and in all Territories**

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Revised 2/27/17