Nanotechnology-Related Technology Available for Licensing

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Novel Procedure for Creating Nano-Laminated Edible Films
UMA 05-27; McClements and Decker (Patent process initiated)

- Description: Edible films or coatings can be used to prevent food exposure to a host of conditions that can cause changes in food quality and safety. Current edible films have limited uses because of their physical characteristics. For example, lipid-based films have good moisture barriers but contain no mechanical strength. This invention overcomes these shortcomings by engineering edible films with multiple functional layers. The novel aspect of this invention is that it would be possible to engineer the properties of edible films and coatings in a much more controlled fashion than is possible using conventional technologies. In particular, by controlling the chemical composition, thickness, number and order of the various thin films used to make the laminate, it is possible to control the rheology, permeability, and stability of the overall film. In addition, it is possible to engineer unique functional attributes into the film by incorporating active agents, such as anti-microbials, anti-browning agents, anti-oxidants, enzymes, flavors, colors, etc.

- Applications: Food coatings, films, protectants, enhancements.

- Advantages: This invention has several key advantages over existing edible film technologies: (1) It permits the physical properties and functional attributes of edible films and coatings to be engineered using nano-scale and/or micro-scale techniques; (2) It is independent of any specific material, allowing the invention to leverage new materials advances; and (3) It uses all food-grade materials (GRAS) and existing inexpensive production techniques.

Novel Procedure for Improving Encapsulation of Particulate Materials
UMA 05-22; McClements and Decker (Patent process initiated)

- Description: Many industries use micro-encapsulation to convert liquid oil-in-water emulsions into powders containing particles that consist of oil droplets embedded in a solid wall material. The most common industrial technique used to accomplish this conversion is spray drying. The efficient production of high quality spray dried product depends on selection of the most appropriate spray drier design, operating conditions, and feed material. This invention improves the composition of the feed material used in spray drying, by improving the final properties of the powders produced and/or reducing the amount of solids required in the materials. This novel invention improves the feed material by covering each individual oil droplet (or other type of particle) with a multilayer biopolymer membrane that is relatively thick and resistant to rupture prior to carrying out the drying process. These interfacial membranes can be designed to improve the economic, physicochemical and functional properties of the spray dried material.

- Applications: Industries such as drug, food, beverage, supplement, and personal care report problems associated with micro-encapsulation of functional ingredients, e.g., poor dispersibility, chemical degradation of functional ingredients, high product losses during production.

- Advantages: Several features of this invention improve upon conventional spray dried material: (1) Reduces the amount of wall material required to create stable systems, which reduces the cost of the spray drying process; (2) Prevents destabilization of the material within the droplets during storage and application, e.g., lipid or flavor oxidation, which increases the shelf-life of the powder; (3) Prevents oil droplet aggregation before, during and after micro-encapsulation, which improves the quality of the powder; and (4) Improves dispersibility of the powders.

Patchy Surfaces for Selective Adhesion, Sensing and Separations
UMA 05-10; Santore (Patent process initiated)

- Description: This invention presents a new method of selective particle separation, sensing, and adhesion control, based on particle size, characteristic curvature, and surface chemistry, including lengthscales of heterogeneities in surface chemistry. The invention describes the preparation and use of detection / adhesion surfaces that contain nanoscale domains which are fundamentally adhesive while the rest of the surface is fundamentally repulsive to some portions of the surface of some external objects. These surface features can be recognized by external objects and molecules, the surface pattern being the sensing element. Patterns can adhere single molecules or objects up to at least one micron, and being a completely artificial construct, achieve selectivity without the use of fragile and costly biological molecules, if applying this method to analysis of biological materials.

- Applications: For the separation and / or sensing of molecules and particles from classical chemical separations to pharmaceutical and biomedical applications. Can be used to analyze very small volumes, as a substitute for,
or to enhance, chromatographic separation. Can be used in combination with other methods such as electrophoresis and flow field fractionation; can be used in linear flow chambers (on chips and sensors) and with gentle shearing flows; appropriate for biological cells to separate them from proteins, different types of cells or viruses.

- **Advantages:** This method follows the concept of biological pattern recognition, but on a scale of nanometers instead of angstroms, without the use of fragile biological molecules. The selective adhesion surface features can be economically applied to planar or other geometries such as fibers (for increased throughput).

**Geobacter sulfurreducens Conductive Pili as Biological Nanowires and Uses Thereof**
UMA 05-09; Lovley, Reguera, McCarthy, Tuominen (Patent process initiated)

- **Description:** The present invention reports the conductive properties of Geobacter sulfurreducens pili (geopili) and their use in nanotechnology applications. More specifically, the present invention provides methods for culturing cells of G. sulfurreducens to produce conductive pili, as well as methods for their isolation and for their modification in order to produce biological nanowires or biological/inorganic hybrid devices with different functionalities. The invention provides applications for cells expressing native or modified pili, as well as for the isolated native or modified pili.

- **Applications:** Geopili, the pili produced by Geobacter sulfurreducens, may be applied in any application where nanowires are required. These include but are not limited to nanowires with electronic properties ranging from metallic to semiconducting for use in control of electron charge in nanodevices, and electrically-based biological and chemical biosensors.

- **Advantages:** Geopili can easily be mass-produced and they are naturally conductive, thus reducing manufacturing costs, and they can be altered using common genetic manipulations to make nanowires with different functionalities.

**Amphiphilic Monomers and Polymers Derived Therefrom**
UMA 05-01; Thayumanavan (Patent process initiated)

- **Description:** The present invention demonstrates that incorporation of amphiphilic functionalities within the same monomer unit affords assemblies that are micelle-like or inverse micelle-like in solutions. The amphiphilic polymers exhibit very low critical micelle concentration (CMC), the assembly adapts itself to its environment (micelle-like in water, inverted micelle-like in apolar solvents), multiple functionalities could be directed in the interior of these nanoscale assemblies, and the invention offers the ability to compact incompatible functionalities by creating amphiphilicity using a third functionality.

- **Applications:** This invention may be applied to a variety of applications. This may include chemical decontamination of sensitive equipment, smart adhesive, controlled drug release, controlled release of pesticides or insecticides, targeted delivery to specific cell types, targeted gene delivery, and as compatibilizing agent for incompatible polymer blends.

- **Advantages:** It is an object of the present invention to provide a polymeric compound having invertible micellar capability at low critical micelle concentration, as compared to small molecule surfactants of prior art. The current amphiphilic polymers can be exemplified by the ability to perform phase transfer catalysis in fluorocarbon solvents. The polymer has the capability to sequester both lipophilic and hydrophilic compounds and confine them together in a nanoscale environment.

**Direct Surface Attachment Methods for the Preparation of Light Emitting Quantum Dot Nanoparticle – Poly(phenylene vinylene) Composite Materials**
UMA 04-24; Emrick (Patent process initiated)

- **Description:** The composite materials prepared in this unique approach allow the properties of quantum dots (CdSe nanocrystals) to be exploited in electronic polymer materials, using only a very low loading of quantum dots relative to conventional approaches. The effective dispersion of quantum dots within electronically active polymers, such as poly(phenylene), results in extensive interfacial contact between the quantum dots and polymer. This generates an efficient energy transfer between the two components that cannot be achieved in conventional blends, where quantum dot aggregation prevents such efficient transfer. Key to this invention is the strategic use of organic functionality in both the nanoparticle growth step and the subsequent polymerizations that provide the composite materials.

- **Applications:** Fabrication of light-emitting devices such as light-emitting diodes, solar cells, photon counters, sensor materials, materials for flat panel displays.

- **Advantages:** There are significant cost advantages, as well as environmental benefits, associated with the use of lower weight percentages of quantum dots in the composite materials.
Designing Stiff Hydrogels from Biodegradable and Biocompatible Polymers
UMA 04-18; Tew and Bhatia (Patent process initiated)

- **Description**: Triblock copolymers of poly (L-lactide) (PLLA) and poly (ethylene oxide) (PEO) have been processed to form stiff hydrogels which display elastic moduli in the range of 1000 – 18,300 Pa at ambient and physiological temperatures. These elastic moduli are in the same range as soft tissues (human and animal).
- **Applications**: Drug delivery systems; Drug eluding medical implants; Tissue engineering; Gels for rheological processing, cosmetics, etc.
- **Advantages**: Biodegradable and Biocompatible; Controlled Modulus.

Porous Hydroxyapatite Networks for Synthetic Bone Material by Spinodal Decomposition
UMA 04-14; Hyers (Patent process initiated)

- **Description**: A synthetic porous bone graft material produced through a spinodal decomposition process. The porosity can be varied by varying the initial composition, while the pore size can also be varied by varying the time-temperature history. The resorption rate may be controlled through solution treatment. Control of these process variables would allow the implant material to be tailored to the specific application.
- **Applications**: Bone grafts for human and animal use.
- **Advantages**: Costs less to produce than currently available materials. Is a resorbable, porous, biomaterial of calcium phosphate. The rate of resorption, pore size, and porosity can be tailored to each specific application (injury, etc.). Stronger than currently used materials. Can be made to match the natural elastic modulus of natural bone. Eliminates the need for surgery to remove bioinert materials. Eliminates the need for autograft or allograft natural bone and the associated complications.

Encapsulation of Oils Using Three-Layered Interfacial Membranes Produced from Emulsifiers and Biopolymers
UMA 04-12; McClements and Decker (Patent process initiated)

- **Description**: Oil-in-water emulsions containing droplets stabilized by three (or more) layers are formed using a multiple-stage process. The emulsifiers and biopolymers used can be food-grade phospholipids, small molecule surfactants, fatty acids, proteins, polysaccharides and biopolymer complexes. In this way food-grade emulsions can be produced containing droplets surrounded by layers of different substances, rather than the conventional one or two layers.
- **Applications**: (a) Encapsulation of oil-soluble food and non-food components inside oil droplets, such as vitamins, antioxidants, colorants, bioactive lipids, preservatives, or minerals. (b) Encapsulation and protection of water-soluble food and non-food components, such as those mentioned above. (c) Controlled release, and release in response to environmental changes, (pH, ionic strength, temperature), of both oil and water soluble ingredients. (d) Creation of low-calorie food products by using a non-digestible interfacial membrane – such as sauces, desserts, soups, beverages, creamers, meat products, pet food.
- **Advantages**: Three-layer interfacial membranes have advantages over conventional emulsions: (a) dramatically improved stability to freeze-thaw cycling; (b) improved stability to pH and salt concentration; (d) improved stability to thermal processing; and (d) can be produced economically using existing production technology. All ingredients can be food-grade, thus, no need for FDA approval

Rapid Production of Structured Materials
UMA 04-10; Watkins (Patent process initiated)

- **Description**: Structured metal oxides can be prepared by the condensation of metal alkoxides or other suitable precursors within patterned organic templates dilated with supercritical fluids. Templates can be rapidly prepared and patterned by appropriate techniques such as hot embossing, nano-imprint lithography, step and flash lithography, or by conventional photolithography. Complex three-dimensional structures can be prepared by two-photon lithography in a process called three-dimensional lithographic micro-fabrication. Supercritical fluid drying of MEMS (micro-electro-mechanical systems) is a common practice to prevent feature collapse and problems with stiction. This process offers a means to compress multiple process steps using equipment already familiar in the industry.
- **Applications**: Useful for a variety of applications. The metal oxide device structures can be dense or can exhibit well-defined mesoporosity. Enables rapid and economic production of structures for MEMS, NEMS (nano-electromechanical systems), microfluidic devices, devices for sensing and detection. Can be extended to a number of structural materials including various metal oxides. Possible extension to calcium carbonate mimics of bone, which would lead to net-shape medical implants.
- **Advantages**: A unique process which is rapid and efficient. Reduced number of process steps to achieve structures not possible through conventional processing (e.g., below 50 nm).
A Masking Method for Nanotemplated Surfaces
UMA 04-02; Santore (Patent process initiated)
- **Description**: A development of materials, surfaces and method for exclusion-masking technique at the nanometer or micron length scale, and for controlling the selective adhesion of materials, (such as proteins, bacteria, viruses, cells or particles and molecules of non-biological origin).
- **Applications**: Protein separations, biomaterials, tissue scaffolds, materials with controlled wetting and adhesive properties. Biological and non-biological adhesive preparations.
- **Advantages**: This method produces patterned surfaces with different chemical libraries available on the patterned areas. The pattern detail can range from 3 nm up to micron scale, with spacing as large as 1 pattern repeat (of a 3-nanometer-sized feature) per micron is possible, surpassing the range of spacing achievable by the phase separated polymer film method. The variation achievable in size and shape of the masking area is also greatly enhanced. The method could be applied on irregular objects and fibers.

Novel Polymer Capsules Prepared by Interfacial Crosslinking of Amphiphilic Graft Copolymers
UMA 03-25; Emrick (Patent pending)
- **Description**: A chemical crosslinking process is used to prepare capsules from PEGylated polyolefins using either oil-in-water (i.e., oil inside the capsule in a water-based system), or water-in-oil system. The covalent network structure of these capsules makes them more robust than many other systems under investigation in controlled-release. The unique nature of the crosslinking chemistry is such that the crosslinks can be made either hydrolytically stable or unstable. Those with hydrolytically stable crosslinks have longer carrier lifetimes, while those with hydrolytically unstable crosslinks will degrade over a time period that can be controlled by crosslink density and the type of crosslinker used.
- **Applications**: Capsules for controlled release in drug delivery. Release of flavors and scents.
- **Advantages**: A unique feature of this new approach is the ability to construct a “dual release” system in which molecules from both the capsule periphery and from its interior can be separately released in a controlled manner.

Process For Synthesis Of Oriented Molecular Sieve Membranes With Improved Separation Performance
UMA 03-11; Tsapatsis (Patent pending)
- **Description**: A modified seeded growth method was developed that allows the fabrication of zeolite MFI films that have straight 5.5Angstrom channels perpendicular to the membrane surface. The membranes show improved separation performance. For example, they have the highest permeance and selectivity reported up to now for xylene isomer separation.
- **Applications**: Separation of hydrocarbon mixtures, membrane reactors.
- **Advantages**: The membranes show highest flux and selectivity compared to those reported before. The membranes are potentially more resistant to cracking compared to those reported before.

Design of Polymer Surfaces With High Affinities Toward Biological Cells
UMA 03-04; Nuesslein (Patent pending)
- **Description**: This is a new method to sense microbial cell types at high levels of selectivity. The development of a bacteria-friendly surface is achieved through polymer imprinting, a process wherein monomers are polymerized around a target cell to retain a replica imprint. If this "mold" of the target cell is coupled to the surface of a vibrating detection device, bacterial cells can be detected selectively in less than a minute by the significant reduction in the vibration frequency of the detection device. The novel aspect of this invention is the ability to now sense microbial cells directly (on-line) in environmental samples, very quickly, selectively, and in real time through the cell-friendly man-made surfaces. Furthermore, one can fabricate bio-material surfaces for drug testing, or create attachment sites to support specific recognition and growth by human cells in medical prostheses.
- **Applications**: This invention may have great impact on health and welfare by supporting pharmaceutical and medical diagnostics, minimizing rejection of medical prostheses, as well as industrial process control, food and water processing. In addition, it could be useful in first-line-of-defense detection applications where quickness and selectivity are paramount, such as military situations, bioterrorist attacks, environmental contamination, and disease control.
- **Advantages**: This system senses different kinds of microorganisms selectively, quickly, directly, and at low concentrations. Currently the fastest sensing devices are indirect and need at least 15 minutes of sample processing time.
Novel Ligands and Functionalized Nanoparticle Compositions Compatible in Either Organic or Aqueous Solutions
UMA 02-31; Skaff & Emrick (Patent pending)
- **Description:** This invention provides a variety of nanoparticle-polymer composite materials, each such composite having a nanoparticle component, a polymeric component and a coupling component, each of which is dictated by the solvent system (either water or an organic solvent) in which the nanoparticle is to be dispersed, such that the nanoparticle-polymer composition retains the stability, photoluminescence and quantum yield properties of the nanoparticle. An example of this invention is a new class of ligands, specifically polyethylene glycols (PEGs) terminated with covalently bound pyridine groups, synthesized and used to prepare water and oil soluble CdSe nanoparticles. This scheme represents a novel route to water soluble nanoparticles, and the methodology allows one to prepare water soluble nanoparticles more quickly than previously. Water solubility does not depend on pH, due to the charge neutral PEG chains. A unique aspect of these nanoparticle materials is their amphiphilic nature, as the isolated PEG-covered nanoparticles are soluble in both water and organic solvents, and exhibit absorption, photoluminescence, and quantum yield properties.
- **Applications:** Nanoparticle bio-tags; medical uses such as biological detection agents.
- **Advantages:** The products are new materials, and the preparation method provides an easy, rapid synthesis of water-soluble nanoparticles, which is amenable to scale-up and mass production.

A Method of the Synthesis of a Novel Layered Silicate with Three-Dimensionally Microporous Layers
UMA 02-26; Tsapatsis (Patent pending)
- **Description:** The material is a three-dimensionally microporous layered silicate, and is obtained in a highly crystalline form, which remains crystalline up to 723 K with little lattice contraction. There are channels in the silicate layers, including pores perpendicular to the layers, the layers being bonded by cations. The structure may be altered by substituting alternative ions. Layers may be delaminated to produce single porous silicate layers. In another aspect, the material can include a polymer to produce a composite material.
- **Applications:** Layered silicates may be used in applications such as catalysis, adsorption, ion-exchange and separation; in nanocomposites with polymers as active filters like conventional layered silicates or clays. The 3-D porosity enables its use for membrane applications, such as gas separation applications: oxygen generation/enrichment from air streams, natural gas purification, and carbon dioxide recovery.
- **Advantages:** This layered silicate is the first with three-dimensional channels. It has a unique topology, it possesses thermal stability up to 500 degrees C, which is important for high temperature catalysis applications.

A Rapid Interfacial Route to Produce Water Dispersible Nanoparticles
UMA 02-12; Emrick (Patent pending)
- **Description:** This invention describes a simple direct route by which water-dispersed nano-particles can be prepared. Water-oil dispersions with nanoparticles, the elemental composition of which allows the attachment of oil-soluble ligands, are shown to undergo a process at the oil-water interface that imparts a water solubility to the particles. The nanoparticles are photoluminescent in both the oil-soluble and water soluble states.
- **Applications:** Nanoparticle-based materials, especially those with active electronic and luminescent properties, are attracting interest as components in biotechnology for use as fluorescent tags in diagnostics and detection of disease. Nanoparticles of different sizes differ in emission wavelength, opening opportunities to perform complex biological studies based on this precise detection mechanism.
- **Advantages:** Production of water-soluble nanoparticles by an interfacial process, which overcomes previous limitations that require multiple preparative steps to achieve water solubility.

Nanofabrication
UMA 01-26; Tuominen & Russell (Patent pending)
- **Description:** Multilevel 3D nanofabrication process using laterally-patterned block copolymer templates and nano wires to yield functionalized nanoscopic structures on various surfaces. Very cost effective method for manufacturing of nano scale structures.
- **Applications:** Electronic ﬁeld emission arrays for flat panel displays and spin polarized electron emitters. High density magnetic data storage devices in the 1000 Gbit/in² density range. Solid state thermoelectric cooling devices. Biomolecular diagnostic-sensor arrays. Magnetic electronic devices for magnetic sensing applications and for “spintronics” applications.
- **Advantages:** Cost effective, rapid fabrication of 3D multi-level nanostructures. Field emission arrays which have higher resolution, are less expensive to manufacture and can be thinner, more ﬂexible, and possibly brighter than those currently available. A simple process which allows for the patterning of the ordered arrays of cylinders which can then be ﬁlled with electro deposition of many types of metals or substances to accomplish active physical and chemical nano devices. Flexible, thin nanoscopic thermoelectric cooling devices can now be made
which may be very energy efficient and cost effective to manufacture. Simple, cost effective process for creating high density magnetic storage, smart media, microelectrodes and molecular electronics.

Classification, Separation, and Capture of Ultra-Fine Particles by Impact Separation
UMA 01-14A; Blake & Jakus (Patent pending)
- **Description:** A system for handling, collection and classification of ultra-fine and nano-scale particles is based on impact separation technology through control of the operating environment. The fractional efficiency for particle capture and the cut-diameter are affected by the geometry of the device, flow rate, and operating pressure, together with the particle characteristics.
- **Applications:** Classification of particles and removal of agglomerates. Separation of particles from carrier gas. Collection of powders.
- **Advantages:** Based on commercial embodiment with simple design. Ease of scale-up. Continuous operation. Readily integrated with synthesis processes or other collection devices.

Ultra-High-Density Magnetic Arrays
UMA 00-12; Tuominen & Russell (Patent pending)
- **Description:** A technology for manufacturing extremely dense magnetic arrays for next-generation data storage applications. Produced by a novel imaging technique and conventional manufacturing processes, this technology has the potential for storing very large volumes of data on the order of 200 gigabits per sq inch or more. Other applications include giant magnetoresistive (GMR) materials for disk drive read/write heads.
- **Applications:** Next-generation ultra-high-density magnetic data storage media. Patterned data storage media for smart cards or other microchip applications. High density GMR read heads and encoders.
- **Advantages:** Combines a novel imaging system with conventional manufacturing processes. Simple, fast, reproducible process. Scaleable and adaptable to a wide range of media geometries. Ultra-high-densities of 1.2 trillion+ magnetic images per sq inch. High thermal stability for long-term data integrity. Imaging technique allows for ultra-fine patterning. Low power consumption.

Functionalization of Surfaces by Surface-Initiated Graft Polymerization
UMA 00-08; Bianconi, Ingall. Shrout & Long (Patent pending)
- **Description:** This invention comprises a novel method for attaching polymer and copolymer films of desired thickness (nanometers to microns) to a variety of substrates. The invention provides strong surface attachment to silicon, glass, oxide ceramics, and all structural metals. The method makes possible this strong surface attachment of any desired polymer or copolymer layer; both polar and nonpolar monomers can be used. Surface interfaces can be specifically tailored for optimum chemical modification, chromatographic properties, lubricant and wetting properties, anti-fouling properties, and biocompatibility and biostealth properties. Photolithographically-patterned polymer features, useful for metallization, etch barriers, fabrication of nano-scale devices such as capacitors, and other functions in microelectronics, can be generated on any of the above-mentioned surfaces.
- **Applications:** Optimization of any coating for innovative biomaterials, microelectronics, and all structural materials. Novel properties that can be attained include: **Biomaterials:** Tethering of ligands, biomolecules, reporter groups to surfaces; Biological and chemical sensors; Reduction of nonspecific adsorption of proteins and cells (biostealth materials); Artificial membranes; **Microelectronics:** Metallization or other functionalization of nanoscale patterned polymer features; Chemically modified electrodes; Alternative method for production of nanoscale photolithographic features for semiconductor devices; **Structural materials:** Polymer to ceramics adhesion; Polymer to polymer adhesion; Anti-fouling coatings; Optimization of lubrication and wetting properties of ceramics and metals.
- **Advantages:** Specific tailoring of any surface for optimized chemical or physical properties. Substrates not limited to gold. Wide range of polymers, copolymers, and combinations. Polymerization site at the distal end of the polymer chain, allowing for unlimited polymer growth and selected functionalizations of the polymer film surfaces. Chemical attachment to surfaces by strong covalent bonds, instead of less robust physical adhesion. Readily adaptable process. Controllable for highly uniform, dense polymer coverage.

Formation of Submicron Patterns on Films
UMA 00-05; Russell, Thurn-Albrecht, Schaffer, Mlynek & Steiner (U.S. Patent 6,391,217)
- **Description:** This invention offers a novel but easily adapted approach to well defined and well organized hollow structures in polymers. Extremely dense submicron lithographic patterns in films have numerous applications in Microelectronics and data storage, medical and research biotechnologies, high-tech materials for insulators and adhesives. More generally, this invention is suitable for applications requiring well-defined submicron features.
• **Applications**: Ultra-high density lithographies on films for Computing (next generation data storage and microelectronics); Biotechnology (drug delivery systems and biomaterials); Applications also include insulating materials, ultra-thin laminations, filters, adhesives, and other uses requiring well-defined submicron features.

• **Advantages**: Novel and easily scaled patterning system makes use of conventional manufacturing processes. Simple, fast, reproducible process is inexpensive and adaptable to a wide range of polymers and geometries. Exceptionally high patterned densities. Environmentally sound.

**Benign Process for Creating Micro-Porous Polymer**  
UMA 99-36; Winter & Gappert (U.S. Patent 6,558,607)

• **Description**: A novel and environmentally benign process for creating open-pore structures in a variety of polymers. The zero-emission process is applied to create tailored pore size distributions during or after processing (extrusion, injection molding, blow molding) for a wide variety of geometries (film, fibers, molded parts) while preserving the overall shape of the polymer. The process is easily scaled-up.


• **Advantages**: Works with a variety of polymers including polyethylene and polypropylene. Processing allows control of pore size and distribution. Employs conventional equipment and techniques which are easily scaled-up. Sample geometry controlled by conventional shaping methods (extrusion, injection molding, blow molding, etc.). Microporosity induced either during or after shaping and composite fabrication. Environmental benefits – processing fluids are benign, recoverable, and reusable. Resultant porous polymers are exceptionally clean, and retain shape and structural integrity.

**A Method for Surface Functionalization of Titanium and Other Metals**  
UMA 99-23; McCarthy (Three patents issued; licensing available in all but one application)

• **Description**: An innovative process for altering titanium and a wide range of other metal surfaces to adapt a variety of functional characteristics. The process results in a thin, high strength coating on the metal surface. Functional characteristics achieved include improved adsorption, wetting and catalytic properties, improved adhesion, and selective adhesion to metal in silica-metal composites.

• **Applications**: Pigments for inkjets, paints, and plastics; Coatings for titanium, stainless steel, nickel and other metals; Reinforced structural and sheet polymers containing Ti fillers; Stronger polymer coatings; Functionalized titania surfaces for adsorbents, catalysts, and membranes; Chemically modified titania electrodes and sensors; Well-characterized, high density surface monolayers

• **Advantages**: Pigments: Functionalized Ti particles resist coagulation to stay evenly dispersed for smoother color quality; Enable Ti polymer or silica filler to act as reinforcement; Highest density surface coverage achievable with organosilanes; Selective modification of composite surfaces – e.g. modify titania exclusively in a silica-titania composite; Lower boiling points allow for vapor phase modification; Eco-Friendly: Method involves less toxic reagents and produces no corrosive byproducts; Stronger, corrosive resistant stronger more durable coatings.

**Reversible Hydrogels**  
UMA 97-22; Petka & Tirrell (U.S. Patent 6,090,911)

• **Description**: The invention is based on the discovery that a block copolymer that includes α-helical blocks, e.g. terminal blocks, which form intermolecular coiled-coil structures, and one or more random-coiled blocks, which link the α-helical blocks, can form suspensions that can reversibly gel to form monodisperse hydrogels. The transition between the gel and liquid phases depends on pH, temperature, concentration, and chemical structure. The copolymers can be synthesized biologically through genetic engineering.

• **Applications**: Bases for cosmetics. Wound dressings, using copolymers to produce a protective, medicated gel surrounding the wound and promoting healing. To encapsulate drug molecules for sustained delivery applications. Because the properties of the gels can be highly sensitive to physical conditions, the gels can find application in gel-based actuators, valves, sensors, motors, switches, artificial muscles, memory devices, optical shutters, filters, toys, paints, coatings, absorbants, bioreactors, micro-machines, display devices, and robotics.

• **Advantages**: Produces monodisperse gels with a uniform pore size. Precision control of structure, pore size, hydrophilicity or hydrophobicity. Gels can have a recognition or peptidic target sequence inserted into the integral block copolymers and can thus be used in affinity chromatography.