WiSys Ref: T100002/T120033

Compostable Thermoset Polymers

Background

Thermoset materials, such as cured rubber and phenolics, are stronger than traditional thermoplastics (such as Poly(lactic acid) – PLA)) due to their ability to cross-link and are also better suited to high-temperature applications. However, they are generally more brittle, are non-reformable and therefore are among the most difficult materials to recycle and reuse, thereby limiting their use. As a result there is a clear and unmet need for the development of polymer materials with improved properties over thermoplastics such as PLA that are able to readily degrade and and be reused.

Technology

Research from the Unviersity of Wisconsin-Stevens Point has resulted in the development of a series of cross-linkable, biodegradable thermoset polymers with reversible crosslinking from mercaptosuccinic and succinic acid. This novel series of polymers have utility for a broad range of applications including health care, durable goods and packaging.

Base monomers are polymerized or cross-linked without the need for protection and deprotection, allowing for the creation of a wide variety of di-functional and poly-functional monomers. These crosslinking reactions offer the unique feature of being readily reversible allowing for depolymerization to base monomers without degradation, offering recyclability for sustainable commodity applications, aka "green thermosets".

The polymers are biodegradable via hydrolysis in commercial compost conditions comparable to current bio-derived compostable polymers such as PLA. Properties such as duration of degradation in a compost setting, material pliability, toughness and optical clairty are controllable via the degree of polymer crosslinking. In addition, poly(lactic acid-co-pentylenemercaptocuccinate) and poly(lactic acid-co-butylenemercaptosuccinate) (PLA copolymer) films have been developed in an effort to improve the physical characteristics that keep biodegradable PLA from being more widely used.

Research and Development Status

Synthesis of the materials under both catalyzed and self-catalyzed conditions have been realized and preliminary laboratory-level processing has been completed demonstrating these novel polymers can be processed to form cross-linked thermosetting resins, that after processing, range from highly transparent to opaque films as well as neat resin samples and those with glass-like properties, depending on the composition of the polymers. Further characterization of these novel thermosetting resins is currently underway. Industry-standard material data sheets for lead resins are in preparation and further degradation analyses is currently being finalized.

Key Technical Features

T100002 and T120033 provide for fully sustainable polymers (renewable feedstocks and fully reversible chemistry) with an environmentally acceptable life cycle. <u>Key performance features of the polymers include</u>:

- Processing times and conditions are similar to available resins;
- Post-curing enhances the mechanical strength and glass transition temperature (Tg) with some-fully cured members of the series possessing a Tg at or above that of PLA (e.g. 75 +/- 3°C higher than PLA);
- Curing has been shown to occur in the absence of oxygen and there was no difference observed between curing under nitrogen or oxygen;
- Full cross-linking of the polymer series has produced polymers with high thermal stability at elevated temperatures imparted by cross-linking.
    - The modulus of the uncured sample was found to be 300 Pa at 200°C increasing to 10^7Pa, which is multiple orders of magnitude higher than that of PLA at the same temperature ($10^{3.5}$ Pa).
- A direct comparison of compostability has been made between these materials and PLA.

    - Polymers have been shown to degrade to a similar extent and timeframe as PLA and degradation time of film samples can be extended by increasing the crosslink density of the polymers;
- Cured crosslinked films are insoluble in organic solvents and infusible, but degrade readily under aqueous conditions when heated following parameters similar to those employed to reclaim PLA.
- Cured films have readily undergone hydrolysis to produce clear aqueous solutions in a pressure vessel at 170°C;
- Materials display high and controllable optical transparency (refractive index of 1.47 to 1.5 can be readily controlled) and possess strong adhesive properties on variable surfaces and materials.
- Materials show elastomeric properties similar to rubber however unlike traditional thermoset materials used in this industry, they are readily degraded at the end-of-life and can therefore be reclaimed and reused.

Commercial Applications

- Platform technology with utility across a broad range of applications including consumer, healthcare or technical products that are potentially bio-derived, recyclable or compostable following use. These include:
    - Biodegradable polymers for industrial applications such as injection molded products/films, durable goods, disposable food containers and utensils, as well as plastic bags;
    - Biodegradable polymers for packaging applications such as packaging with barrier properties (e.g. bottles, food packaging, films etc…); and
    - Bioresorbable polymers for medical applications including sutures, screws, suture anchors, support membranes, plates/mesh, and/or pins/rods.

Intellectual Property

WiSys holds rights to one issued U.S. patent (9,187,596) covering T100002 entitled: “Bis-(Hydroxyalkyl)Mercaptosccinates” as well as one pending U.S. application (US 2013/0289233A1) covering T120033 entitled: “Reversible Crosslinked Polymers”. For more information on partnering opportunities, please contact Jennifer Cook at jennifer@wisys.org or by phone at 608-316-4131.