Bio-Based Polymers and Composites

Dec 17, 2011

Dr Richard P. Wool

Professor of Chemical Engineering

Affordable Composites from Renewable Resources (ACRES)

Center for Composite Materials

Academy Street

University of Delaware

Newark DE 19716-3144

302-831-3312

wool@udel.edu

Requested Self-Nomination from Richard Engler

Contact Person same

Category-Academic

Bio-Based Polymers and Composites

1. **Most Recent Milestones and Dates**

Professor Richard Wool is considered to be a world leader in the development of new bio-based materials that are being used in support of the green energy infrastructure (wind, tidal, energy efficient housing, and hydrogen) and in advanced materials applications for electronics, automotive, aeronautical and civil infrastructure. Much of his work is detailed in a recent book coauthored with Dr Susan Sun, entitled *Bio-Based Polymers and Composites* (Elsevier). Some recent milestones include the following:

1. **Development of Biobased Foam as a replacement for Polyurethane and their toxic. Isocyanate groups used in MDI and TDI. (US patent submitted 2011). The foam is essentially 100% biobased and is derived from unique mixtures of fatty acids and triglycerides. The foam was developed in collaboration with Crey Bioresins Inc and is currently being explored by several packaging and automotive suppliers. The foam is also cytocompatible and supports the growth of human tissue.**
2. **Development of bio-based Composite resins in collaboration with Crey Bioresins Inc and Dixie Chemical TX. Worldwide distribution of these EPA approved resins has commenced (2011) with Dixie Chemical. RPW is the owner of the patent for the different green chemical reactions required to make the resins (Figure 1). Crey Bioresins uses RPWs inventions in green materials to make Composite resins, Pressure sensitive adhesives, foams and other green adhesives.**
3. **Agreements for commercial development of new bio-based materials using RPWs patented green chemicals have been signed (2010) with about 20 other corporations. For example, these include pressure sensitive adhesives from high oleic oils, which are both biodegradable and bio-compatible (DuPont), Green Epoxies (ITW), Urea Formaldehyde–free Insulation (MAI), Hurricane Resistant Energy Efficient Roof, Tidal Turbines (UEK) etc. These markets in sustainable materials will involve at least 100B lbs of plant oil based resins, lignins and natural fibers whose use will have significant impact on the environment.**
4. **Eco Leather: RPW has invented eco-leather which is made from natural fibers, including chicken feathers, flax and plant oils (2011). This breathable leather substitute can be used to replace 52 billion lbs of toxic waste currently generated by leather industry. Nike and Puma are currently exploring this technology.**

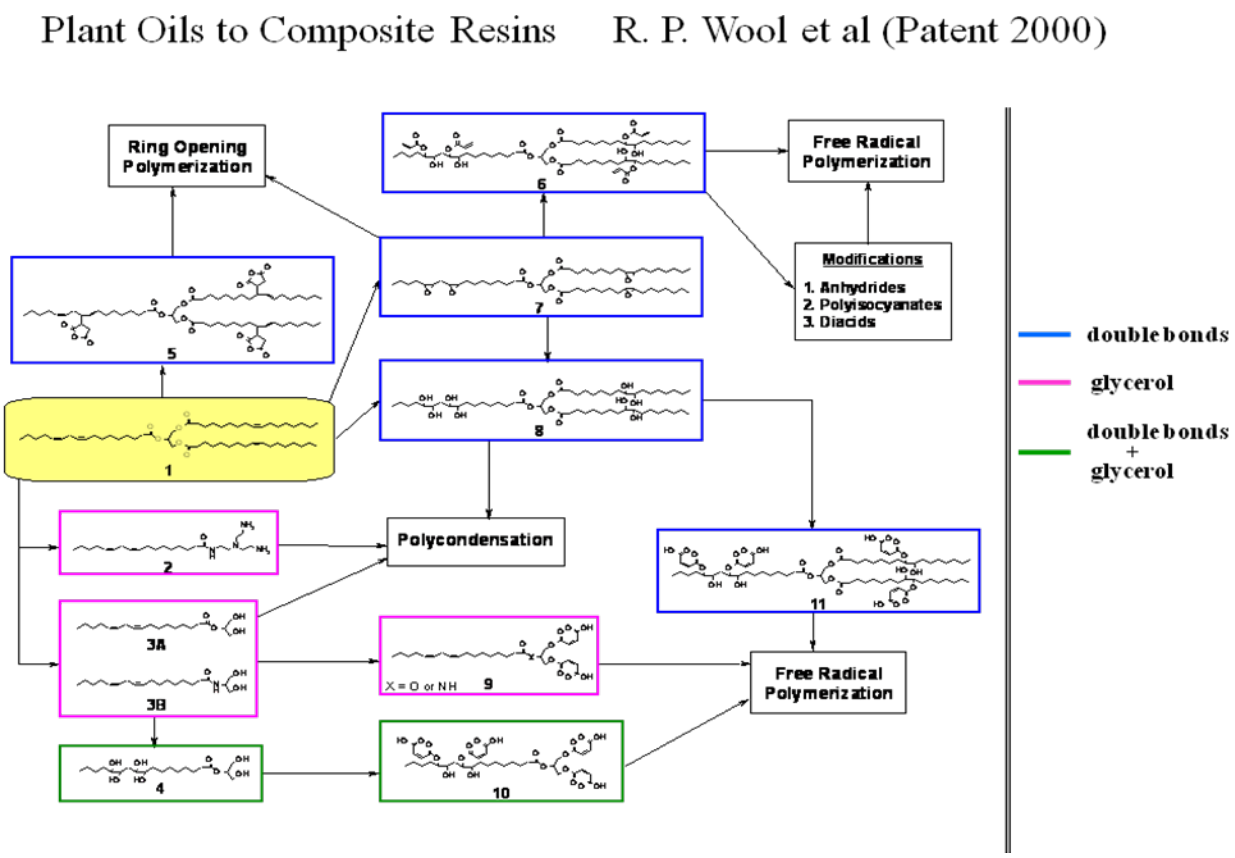

Fig 1: Typical triglyceride chemistry used by Prof Wool's group to make bio-based materials

5. **Significant Patents include the following:**

Wool R.P., Bio-based Foam from natural Oils, US Patent Application No 13168125 (2011)

Wool, R. P. Kusefoglu S., Zhao, R., Palmese, G., and Khot, S: (2000) US Patent No. 6,121,398, "High Modulus Polymers and Composites from Plant Oils"

Wool R. P. and Bunker S. P., Pressure Sensitive Adhesives from Plant Oils, (11/11/2003) US Patent No 6,646,033:

Wool R. P., Lu, J and Khot, S. N., Sheet Molding Compound from Plant Oils, US Patent No 6,900,261, Issued May 31 2005.

Wool, R. P., Schiltz, D.C. and Steiner, D. (1992, November 10). Injection Moldable Biodegradable Starch Polymer Composites. U. S. Patent No. 5,162,392.

Wool R.P. and Hong C.K., (2008) Low Dielectric Constant Materials from Plant Oils and Chicken Feathers, US Patent Serial Number, 60/396,319

2. **Academic Award Statement:**

Professor Richard Wool is being nominated for the Presidential Green Chemistry Award in the Academic Category for his contributions to the development of new sustainable bio-based materials. These include composite resins, pressure sensitive adhesives, foams and hurricane resistant energy efficient roofs made with recycled materials. His academic activities in the field of Green Chemistry and Engineering include the following:

1. **Professor Wool is the 2011 recipient of the Affordable Green Chemistry Award from the American Chemical Society. He also received the Lifetime Achievement Award from the Bioenvironmental Polymer Society and was the Xerox Distinguished Lecturer for New Materials from Nature (2009).**
2. **He directs the multidisciplinary ACRES Program which has developed the significant patents in the field of green bio-based materials now being licensed world-wide in the fields of composite resins, natural fibers, foams, pressure sensitive adhesives, elastomers and coatings.**
3. **He teaches Green Chemistry and Engineering at the University of Delaware and has appeared on Nova (Making Materials Greener), Sundance Channel and MSNBC for his work on hydrogen storage on chicken feathers.**
4. **He trains visiting scientist from all over the world in the synthesis, properties and manufacture of new green materials**
5. **He is a US Scientific Advisor to the South African Government in Pretoria in the field of Green Materials**
6. **He developed the new course on Bio-based Materials at the University of Delaware.**
7. **He gives plenary talks worldwide on Bio-based Materials, including the recent ACS Meeting In Anaheim (2011) which held a Symposium in his honor, Vienna BEPS plenary (2011), Xerox Lecture (2009), Green Chemistry Gordon Conference (2008), Montreal International Congress on Chemical Engineering (2009),and the Green Chemistry and Engineering Annual Meetings in DC (2005-2009), Beijing (2006), Brazil (2007) NIST (2008), Chemical Heritage Foundation (2008), AICHE (2008).**
8. **He was the Chairman of the ASTM committee that developed all the standards for Biodegradable Plastics in the Environmentally Degradable Plastics Committee.**
9. **He is the Chairman-Elect of the Gordon Research Conference on Composite Materials**
10. **He has over 150 publications, patents, book chapters and books which were cited over 3000 times. He is a Fellow of the American Physical Society and member of the American Chemical Society and the AICHE.**
11. **He is the president and founder of Crey Bioresins Inc which has commercialized his new bio-based materials.**

3. **Focus Area Statement: The Design of Greener Chemicals.**

Professor Richard Wool's materials are made primarily with chemically functionalized triglycerides, chemically modified Lignin and Natural fibers (Hemp, Jute, Leafs, Chicken Feathers, and Cellulose). His composite resins are typically made with a highly unsaturated plant oil (e.g. Soyoil and Linseed) while his pressure sensitive adhesives, coatings and elastomers are made from high oleic oils. The foams, depending on their required rigidity are made from mixtures of different oils in which the blowing agent for the foam is CO_2.

The EPA has issued a PMN for several bio-based resins and more are pending. Jim Willis of the Chemical Control Division of the Office of Pollution Prevention and Toxics sent a

note of congratulations on PMN PO7-0654, which under TSCA No 5, "may have particular merit for its potential to prevent pollution to the environment". This particular PMN for example will allow the replacement of highly toxic di-isocyanates in PU foams and petroleum based resins in composites, which overall will contribute to the removal of at least 100 billion lbs of CO_2 per year from the atmosphere.

One of the major problems in designing for green materials is the broad number of options in selecting both the chemistries and the base monomers—in other words, there are too many degrees of freedom which has requires too much trial and error to hit the sweet spot. This problem has now been solved: Professor Wool's major design tool for green monomers is his recently invented "Twinkling Fractal Theory (TFT) of the Glass Transition" (R.P. Wool, JPS/B 46, 2765 (2008). This theory combined with his broad slate of chemistries used to functionalize triglycerides (Figure 1) and lignin allows the precise determination and predictability of the material properties made from these monomers. The TFT also provides the solution to a long unsolved problem in solid state physics which has detracted from the use of bio-based materials in many potential applications.

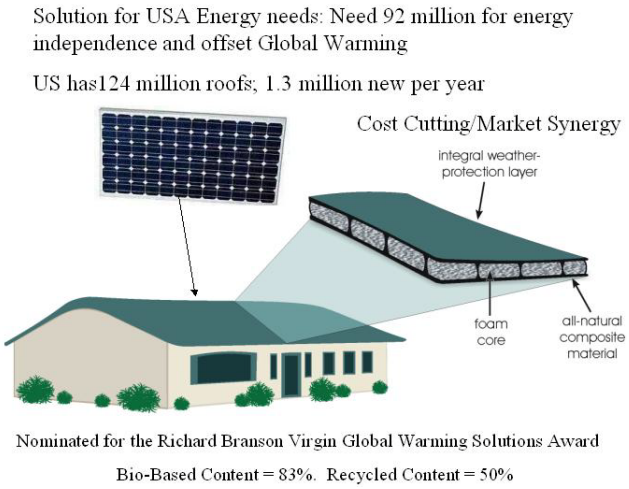

Figure 2. The solar energy integrated hurricane resistant, energy efficient roof designed by Prof Wool's group which was nominated for the Virgin Global Warming Solutions Award.

In his current research with his ACRES group, he is using the green chemistry design tools to provide the new bio-based materials for the emerging materials intensive Green Energy Infrastructure involving wind, tidal, solar, hydrogen and energy efficient housing. Professor Wool was nominated for the Richard Branson Global Warming Solutions Award (2008) for his design of Solar integrated Energy Efficient Housing made with bio-based materials, as shown in Figure 2

4. Abstract: Bio-Based Polymers and Composites

Professor Richard Wool's research has shown that recent advances in green chemistry, genetic engineering, composite science, and natural fiber development offer significant opportunities for new improved materials from renewable resources that are recyclable, biocompatible and biodegradable, thereby enhancing global sustainability. When such bio-based resins are combined with natural fibers (plant and poultry) starch and lignin, new low-cost composites, pressure sensitive adhesives, elastomers and foams are produced that are economical in many high-volume applications. These high performance composites are being designed for use in energy efficient solar integrated roofs, wind foil blades, hurricane resistant housing, sub-aqua hydro turbines and hydrogen storage, in addition to agricultural equipment, automotive sheet molding compounds, civil and rail infrastructures, marine applications, electronic materials, and sports equipment. The development of bio-based materials is consistent with the principles of Green Chemistry and Engineering, which pertain to the design, commercialization and use of processes and products that are technically and economically feasible while minimizing the generation of pollution and the risk to human health and the environment. As a world leader in applications of green chemistry to bio-based materials, Professor Wool is a worthy candidate to receive the Presidential Green Chemistry Award.