Nanoparticle-Anchored Plasticizers

TDA Research, Inc.
12345 W. 52nd Avenue
Wheat Ridge, CO 80033
Telephone: 303-422-7819
http://www.tda.com

Environmental Problem

Plasticizers are small, often volatile molecules added to hard, stiff plastics to make them softer and more flexible. Phthalate plasticizers are not directly bound to polymers such as polyvinyl chloride (PVC) and can leach out of the plasticized material. From environmental, health, and safety perspectives, the loss of plasticizers to the surrounding medium—whether air or soil in the environment, saliva in the mouth of an infant, or pharmaceutical solutions passing through intravenous tubing—is unacceptable and commercially undesirable. Due to their known toxicity, the European Union banned three phthalates and restricted three more from toys and other child care items. PVC is the second largest plastic sold, and plasticizers are the highest volume additive for PVC.

SBIR Technology Solution

With support from EPA's SBIR Program, TDA Research, Inc., developed a system that softens plastics by forming a polymer nanocomposite that does not become brittle and contaminate its surroundings by leaching its plasticizer. Polymer nanocomposites are a combination of a polymeric host matrix and additive particles that are smaller than 100 nm. Properly designed nanoparticles can be dispersed into a polymer, and the unusual behavior of the polymer at the nanoparticle surface can change the overall bulk physical properties of the composite. There is a synergistic effect of combining nano-particles with polymers that is well beyond the sum of the properties of both phases, and revolutionary improvements in the properties of the resulting composite materials can be achieved.

Plasticizers change the properties of a polymer by increasing the free volume between polymer chains, allowing more chain movement, which translates to more flexibility of the softened plastic. TDA has shown that plasticizers anchored to nanoparticles can soften PVC but cannot escape from the polymer. Although the nanoparticles resisted efforts to migrate out of the polymer, the nanocomposite PVC exhibited a lower glass transition temperature, tensile strength, and modulus, indications of the formation of a softer, more plasticized material. Both rigid and traditionally plasticized PVC formulations showed increased plasticization with the addition of TDA's nanoparticles.

The addition of TDA's nanoparticles resulted in the additional benefit of increased plasticizer permanence. In PVC formulations plasticized with dioctylphthlate, the addition of small (2-5%) amounts of TDA's nanoparticles significantly decreased the percent of plasticizer lost to air, activated carbon, and aqueous and organic solvents. This improved retention feature decreases the amount of phthalate leaching from plasticized materials and could increase the service lifetimes of soft PVC materials.

Commercialization Information

As a result of EPA's SBIR funding, TDA made significant advances in areas vital to commercializing hybrid nanoparticles. TDA's nanoparticles are designed to be inexpensive and attractive to the commodity polymer materials market. TDA scaled up production of nanoparticles from the gram to

Pictured above is the device used to synthesize TDA's nanoparticle-anchored plasticizers, which soften polyvinyl chloride (PVC), keep plastics soft longer, and do not escape.

the kilogram scale and developed preparative methods that are environmentally benign and can be carried out with simple "bucket chemistry" techniques. TDA established ongoing collaborations with several commercial partners and has extended this technology to other plastics. In addition to the anchored plasticizer nanoparticles developed for PVC, TDA also gained knowledge that allowed for the development of additional applications, such as impact modifiers and nanoparticles as carriers for colorants and antimicrobials.

Company History

TDA Research, Inc., was founded in 1987 and is located in Wheat Ridge, Colorado. The company carries out research and development for proprietary technology in advanced materials and chemical processes that it can either manufacture or license. TDA employs 65 individuals, nearly all with degrees in either chemistry or chemical and mechanical engineering (two-thirds of whom have advanced degrees). In the past 2 years, in partnerships with major companies that are leaders in their fields, TDA successfully commercialized the large-scale manufacture of fullerenes and a direct oxidation process that removes and recovers sulfur from natural gas. TDA also commercialized electronically conducting polymers that are made easier to process because they disperse in organic solvents.

SBIR Impact

- From environmental, health, and safety perspectives, the loss of plasticizers to the surrounding medium is unacceptable and commercially undesirable.
- TDA developed a system that softens plastics by forming a polymer nanocomposite that does not become brittle and contaminate its surrounding medium by leaching its plasticizer.
- TDA's nanoparticles are designed to be inexpensive and attractive to the commodity polymer materials market.
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