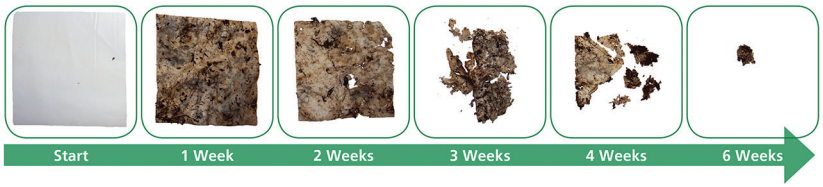
Greening the Packaging Industry

Globalization has changed the landscape of global manufacturing and supply chains, creating huge opportunities for more efficient production of goods and services, but also significant sustainability issues. One such challenge is the waste of packaging materials throughout the supply chain. Manufacturers have made progress toward end-of-life product strategies by developing biodegradable and compostable packaging materials. But what about the beginning-of-life strategies — designing packaging materials that start from plant-based feedstock rather than fossil carbon? In other words, can plant-based carbon sequestered from CO_2 in the environment be incorporated into packaging materials?

Northern Technologies International Corp. (NTIC), a small business headquartered in Circle Pines, MN, has developed biodegradable, compostable, and, for the first time, bio-based, polylactide (PLA) for blown plastic packaging films and end products.

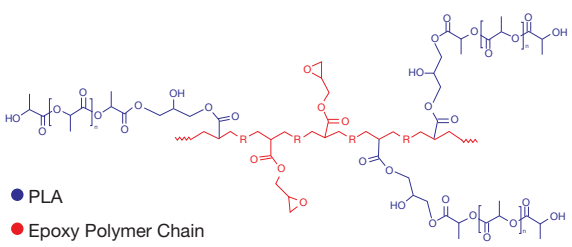
Conventional PLA resins have several drawbacks that have limited their commercial success. PLA is a brittle polymer with poor flexibility and impact properties. Its glass transition temperature is around 50°C, making it unsuitable for applications that require heat resistance (*e.g.*, disposable hot-food containers). Its crystallization rate is too slow and its cycle time too long for molding applications. And, because of its poor melt strength and integrity, it is difficult to form thin films out of PLA.



▲ When placed in a composting environment, a biodegradable-compostable bag made with the epoxy-modified PLA degrades in six weeks. Image courtesy of NTIC.

To address these issues, NTIC developed an innovative reactive-extrusion process to synthesize epoxy-modified PLA molecules through transesterification and coupling chemistries. The new epoxy-functionalized PLA molecule can be reactively blended with regular PLA resin and other biodegradable polyester resins, such as poly(butylene adipate-co-terephthalate) (PBAT), to achieve properties not found in traditional PLA resins — strain hardening properties for blown-film applications, as well as improved processability, heat resistance, and impact resistance.

The epoxy modification not only improves the rheology of the PLA resin, but also functions as a surfactant to aid in blending the PLA with other biodegradable polyesters, which would otherwise phase separate. The resin can also be blended with fillers, modifiers, and additives to confer additional desired properties.



▲ NTIC has designed new bio-based PLA resins that are modified with epoxy polymer chains. Depending on the application, the ratio of PLA to epoxy can be changed. The resin shown here is composed of one epoxy polymer chain for every three PLA chains. Image courtesy of NTIC.

NTIC developed the functionalized PLA technology in collaboration with Ramani Narayan's Biobased Materials Research Group at Michigan State Univ., with support from the Small Business Innovation Research Program of the National Science Foundation. The company has successfully commercialized its innovation in bio-based and biodegradable-compostable specialty packaging films, coated paper/paperboard products, and cutlery.

With its 100% bio-based carbon content, every kilogram of PLA effectively recycles 1.83 kg of CO_2 from the environment, *i.e.*, the CO_2 is incorporated into the polymer molecule through plant-biomass photosynthesis. The functionalized PLA products are completely biodegradable in industrial composting systems and offer an environmentally responsible end-of-life option; microorganisms present in the composting environment readily utilize PLA and completely remove it safely and efficaciously.

Building upon the initial commercial success of its injection-molded, bio-based and biodegradable-compostable cutlery, NTIC has now successfully introduced its sustainable packaging films into the marketplace. The company currently supplies biodegradable-compostable bags to global companies such as Levi Strauss & Co. About 76,000 m.t./yr of plastic packaging resins are used for packaging 5 billion garments in South Asia alone, translating to about $200 million in economic value.

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