Fraunhofer ICT

Development of stereocomplex PLA formulations

Temperature-resistant plastics based on sustainable raw materials

New bio-based polymer formulations have the potential to substitute established petro-based plastics in the medium and long term, and to counteract climate change due to their better CO_2 balance. The polymer of lactic acid (PLA) has by far the largest production capacities of any biopolymer, and is thus the most widely available. In addition, PLA is also produced in Europe, offering greater supply security when raw material availability is limited.

Challenge

PLA is of particular interest for use in technical components due to its good mechanical properties. However, its low temperature resistance is a major disadvantage and an obstacle to the development of new applications. To overcome this limitation, researchers at Fraunhofer ICT are developing new, tailored polymer formulations. Targeted stereocomplexation (crystallization between PLLA and PDLA molecular chains, so-called sc-PLA) is a proven and practical development route for increasing the temperature resistance of PLA (Fig. 1).

The generation of pure stereocomplex PLA crystals, and thus the avoidance of less temperature-stable alpha crystals, is technically very challenging. However, it is mandatory for achieving high temperature stability.

To solve this problem, Fraunhofer ICT is developing new concepts for the economical and scalable production of purely stereocomplex PLA formulations that meet the special requirements of the plastics processing industry.

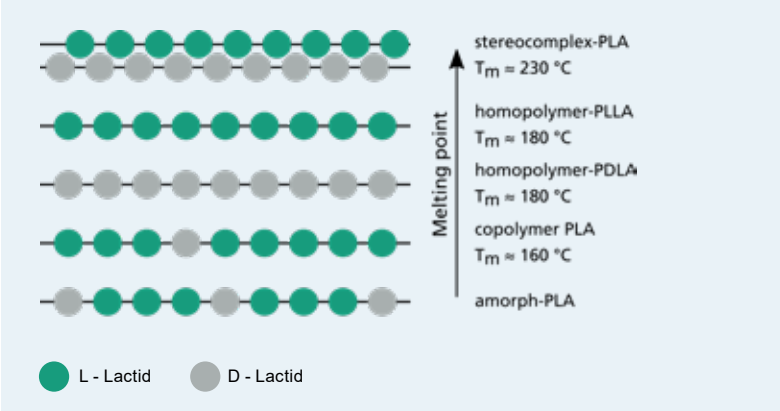

Fig. 1: Different PLA modifications

Our development approach

To ensure scalability and economical production, Fraunhofer ICT is developing new formulations based on polymer-specific nucleating agents.

These so-called selective nucleating agents particularly enhance stereocomplex crystallization, and thus allow the production of pure stereocomplex, high-temperature-resistant PLA materials by injection molding (Fig. 2).

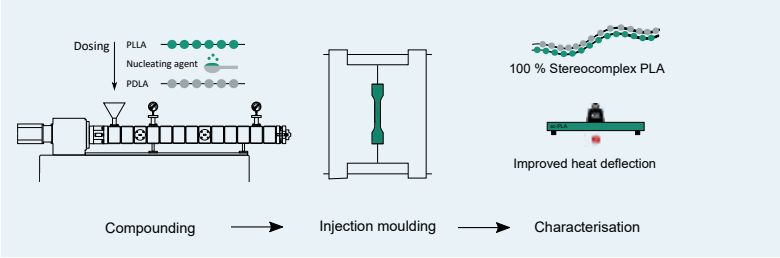

Fig.2: Manufacturing concept for pure sc-PLA at Fraunhofer ICT

Sample results

Figure 3 shows the analysis of the crystallization and melting behavior of various PLLA and PDLA compounds with special nucleating agents. This was carried out in the laboratory using low-cost screening experiments. Nucleating agents NA-5 and NA-6 (Fig. 3) show the desired melting behavior with a mono-modal melting peak at 220 °C. This indicates pure stereo-complexity (confirmed by X-ray diffraction). With the positive laboratory results, the production of sc-PLA was successfully scaled up to pilot-plant scale on twin-screw extruders and injection molding lines. Figure 4 shows the investigation of heat resistance using injection molded specimens. The crystallinity was influenced by different mold temperatures. With low mold temperatures (leading to low crystallinity), only poor temperatu-re resistance could be achieved, even with the NA-5 and NA-6 nucleating agents. However, temperature resistances greater than 160 °C were obtained with mold temperatures above 110 °C. For the highest mold temperature, temperature resistances of over 180 °C were measured.

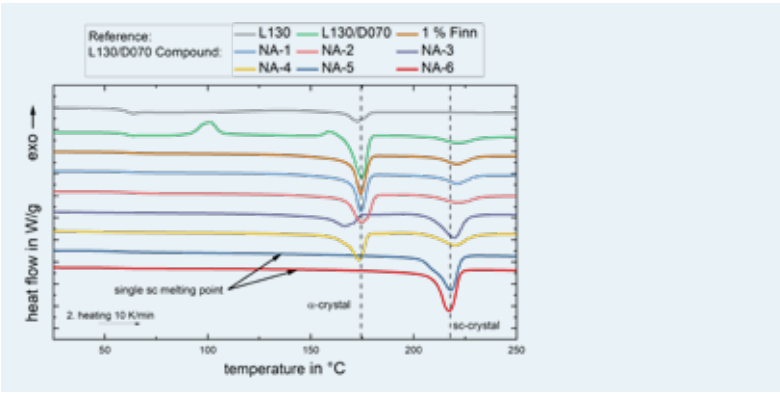

Fig. 3: DSC examination PLLA/PDLA compounds

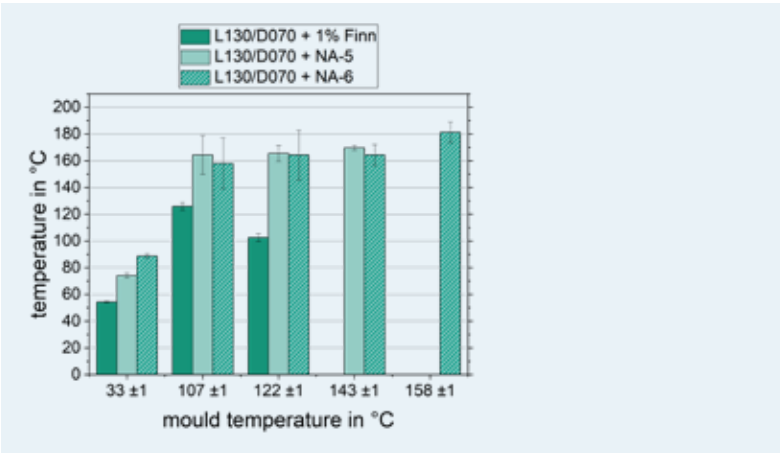

Fig. 4: HDT-B measurement on injection-molded test specimens

Our services

- Advice for individuals and companies on the possible applications of biopolymers
- Development of new tailor-made polymer formulations according to customer specifications
- Characterization and evaluation of the suitability of biopolymers for a specific field of application
- Sampling of biopolymer formulations in film extrusion, thermoforming, 3D printing and injection molding, to evaluate processing properties and component quality

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