Electron beam induced compatibilization of PLA/PBAT blends in presence of epoxidized soybean oil

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Polylactide acid (PLA) is a biobased and biodegradable polymer, which has sufficient mechanical properties to replace fossil-based polymers in many applications. Nevertheless, its brittleness still limits its utilization. It is part of recent studies to blend PLA with other biobased and/or biodegradable polymers to enhance its properties. [1] However, poor compatibility between different polymers in blends often limits mechanical and physical properties. Addressing this, reactive compatibilization techniques have been developed to enhance the interfacial adhesion between different polymers in blends. [1, 2]

Objective

- Enhancement of mechanical properties of PLA by
  - Blending with PBAT
  - Addition of ESBO
  - Reactive compatibilization by electron beam treatment
- Investigation of the effects of the combination of electron beam treatment with compatibilizing agents

Experimental

Blends of PLA were prepared in a lab-scale co-rotating twin screw extruder. Films thereof were prepared with a flat film extrusion line and subsequently treated with electron beams at different doses by Fraunhofer FEP. Samples consist of PLA as matrix polymer, poly(butylene adipate-co-terephthalate) (PBAT) as flexible polymer and epoxidized soybean oil (ESBO) as compatibilizer. The compatibilizing effect is analyzed by thermal and mechanical methods and visualized by scanning electron microscopy (SEM).

Results

It was shown that electron beam treatment and combination with ESBO leads to converging glass transition temperatures (T_g) of the two polymers, see figure 1. The T_g of PBAT increases with increased irradiation dose in contrast to a decreased T_g of PLA. The convergence of the two glass transition temperatures may be an indication of the compatibilization of the two phases. An increase in elongation at break occurs, shifting from around 3 % to 270 % in presence of ESBO, probably due to plasticizing effect. An additional electron beam treatment increases elongation at break even more to 340 % without decreasing Young's modulus, indicating a substantial improvement of the compatibility.

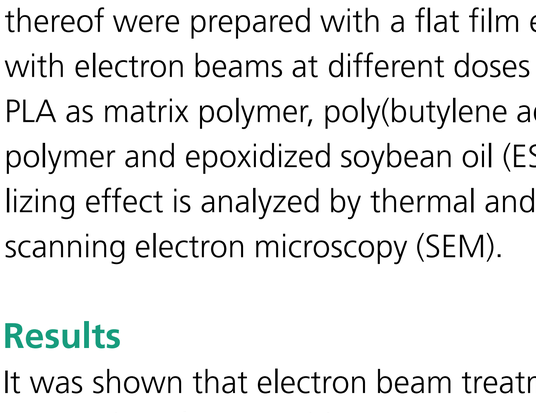

Figure 1: T_g of PBAT and PLA in presence of ESBO

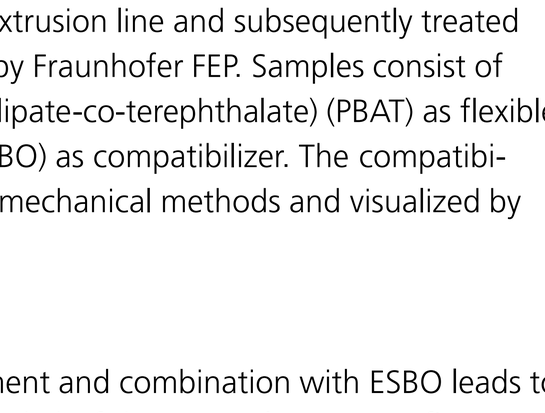

Figure 2: Nominal elongation at break and Young's Modulus of PLA/PBAT without and with ESBO

SEM images were taken of the films electron beam treated at 50 kGy which have been immersed in Tetrahydrofuran for 48 hours to extract PBAT. Cavities with a diameter of approximately 0.5 µm are formed in the sample without ESBO, see figure 3, which may indicate extracted PBAT fragments. In the sample with ESBO added cavities have a maximum size of 0.1 µm, slightly to be seen in figure 4. The reduced diameter suggests a reduced particle size, indicating a decreased interfacial tension between the two polymers.

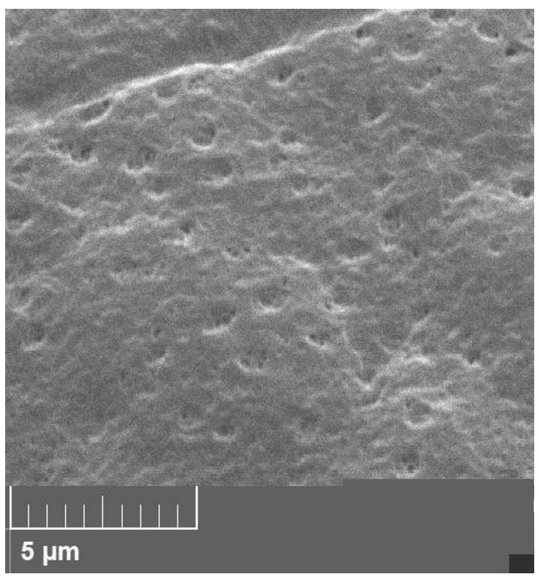

Figure 3: SEM image of PLA/PBAT irradiated with 50 kGy

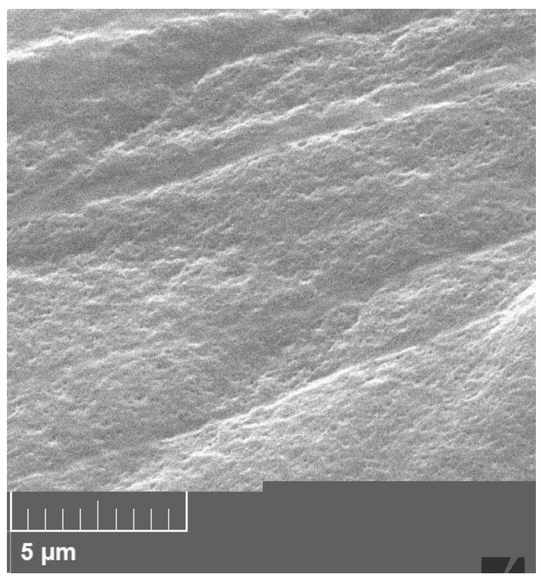

Figure 4: SEM image of PLA/PBAT/ESBO irradiated with 50 kGy

Presence of ESBO also leads to improved mobility of PLA molecules, leading to recrystallization processes. However, electron beam treatment suppresses this effect, which is an indication of a reaction between ESBO and the polymers. Preliminary results of contact angle measurements suggest that the reactive binding of the compatibilizer may as well result in decreased migration thereof.

Conclusion

The results show that electron beam treatment can significantly improve the compatibility between different polymers in blends, leading to enhanced mechanical and thermal properties. Moreover, the use of reactive compatibilizer further enhances the interfacial adhesion between different polymers in blends, see figure 5.

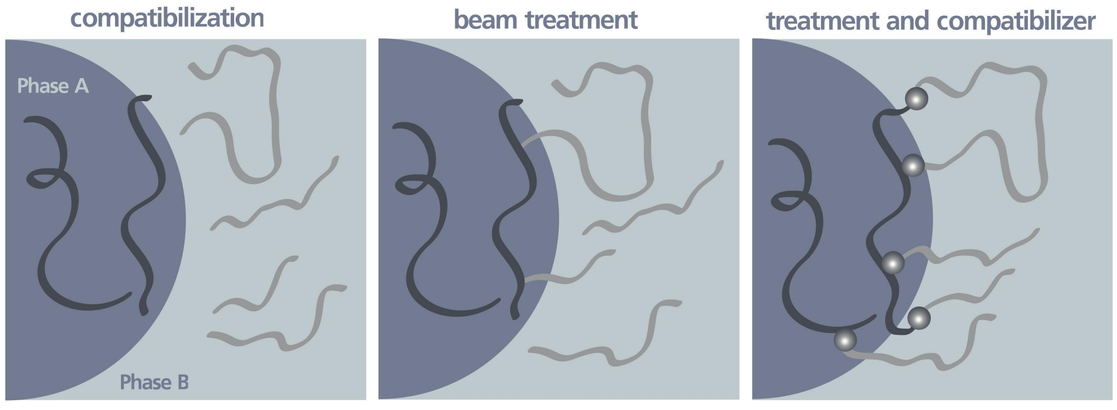

Figure 5: Schematic illustration of the proposed effects of the combination of compatibilizing agents with electron beam treatment

We would like to thank Fraunhofer FEP for their valuable support and contribution to this project.

1 Weidner, Eckhard; Kabasci, Stephan; Kopitzky, Rodion; Mörbitz, Philip (2020): Thermal and Morphological Properties of Poly(L-Lactic Acid)/Poly(D-Lactic Acid)-B-Polycaprolactone Diblock Copolymer Blends. In: Materials (Basel, Switzerland) 13 (11). DOI: 10.3390/ma13112550.
2 Carbonell-Verdu, A.; Ferri, J. M.; Dominici, F.; Boronat, T.; Sanchez-Nacher, L.; Balart, R.; Torre, L. (2018): Manufacturing and compatibilization of PLA/PBAT binary blends by cottonseed oil-based derivatives. In: Express Polym. Lett. 12 (9), S. 808–823. DOI: 10.3144/expresspolymlett.2018.69.

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