

Bio-based Polymers for Food Packaging Applications

C. Rader^{a,b}, Dr. Roger Marti^a, Dr. Ennio Vanoli^a, Dr. Christoph Weder^b

^aHaute école d'ingénierie et d'architecture de Fribourg, Bd de Pérolles 80, 1705 Fribourg, Switzerland

^bAdolphe Merkle Institute, Chemin des Verdiers 4, 1700 Fribourg, Switzerland

Goal: To introduce a bio-based polymer with lower environmental impact for packaging

Introduction and Scope

Close to all plastic manufactured has been made since 2000. Additionally, 40 percent, 161 millions of tons, of plastic produced is for packaging and used one time to be later discarded. Current polymers used in packaging are sourced from the petro industry. With global warming reaching record levels, this project focuses on developing novel polymers sourced from biomass, specifically cellulose, to introduce a greener plastic. Research into bio-based PE and PET exists, but the end life of the polymer is the same. Instead, the goal is to introduce a bio-based polymer that has a lesser environmental impact compared to bio-PE and bio-PET. In order to be in line with other competing polymers for food packaging, the target properties of these polymers are low oxygen and water vapor permeability, thermally stable at processing temperatures, and compostable. Once a composition or polymer is chosen, the next steps would be to scale-up production and estimate the cost and environmental impact to see where the polymer would fit in the market.

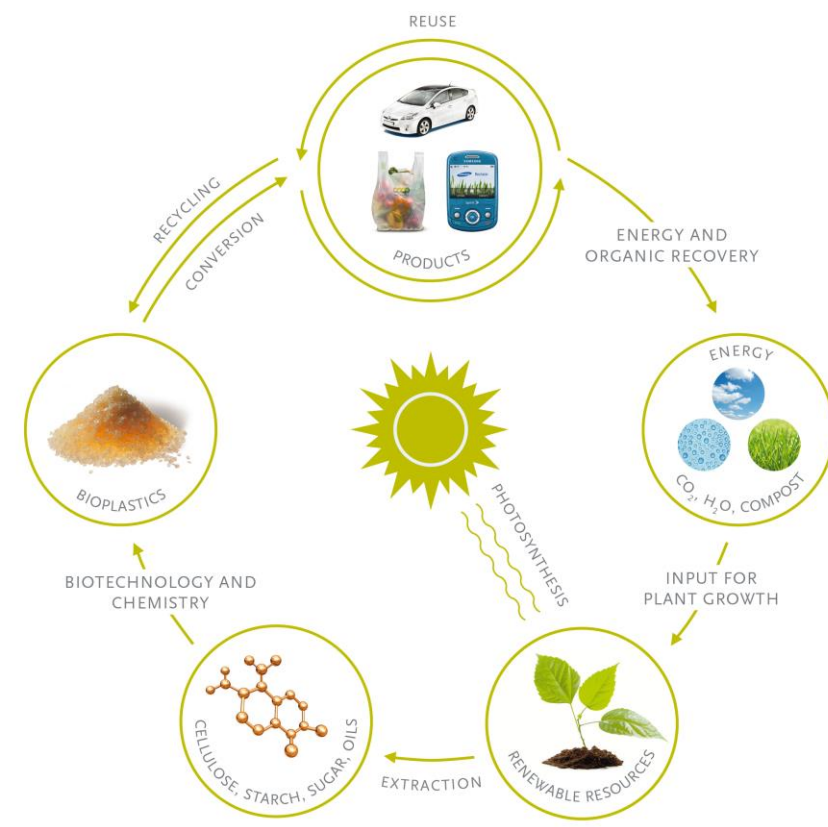


Figure 1: General life cycle analysis of plastic material and use from cellulose biomass¹

Thermal Properties

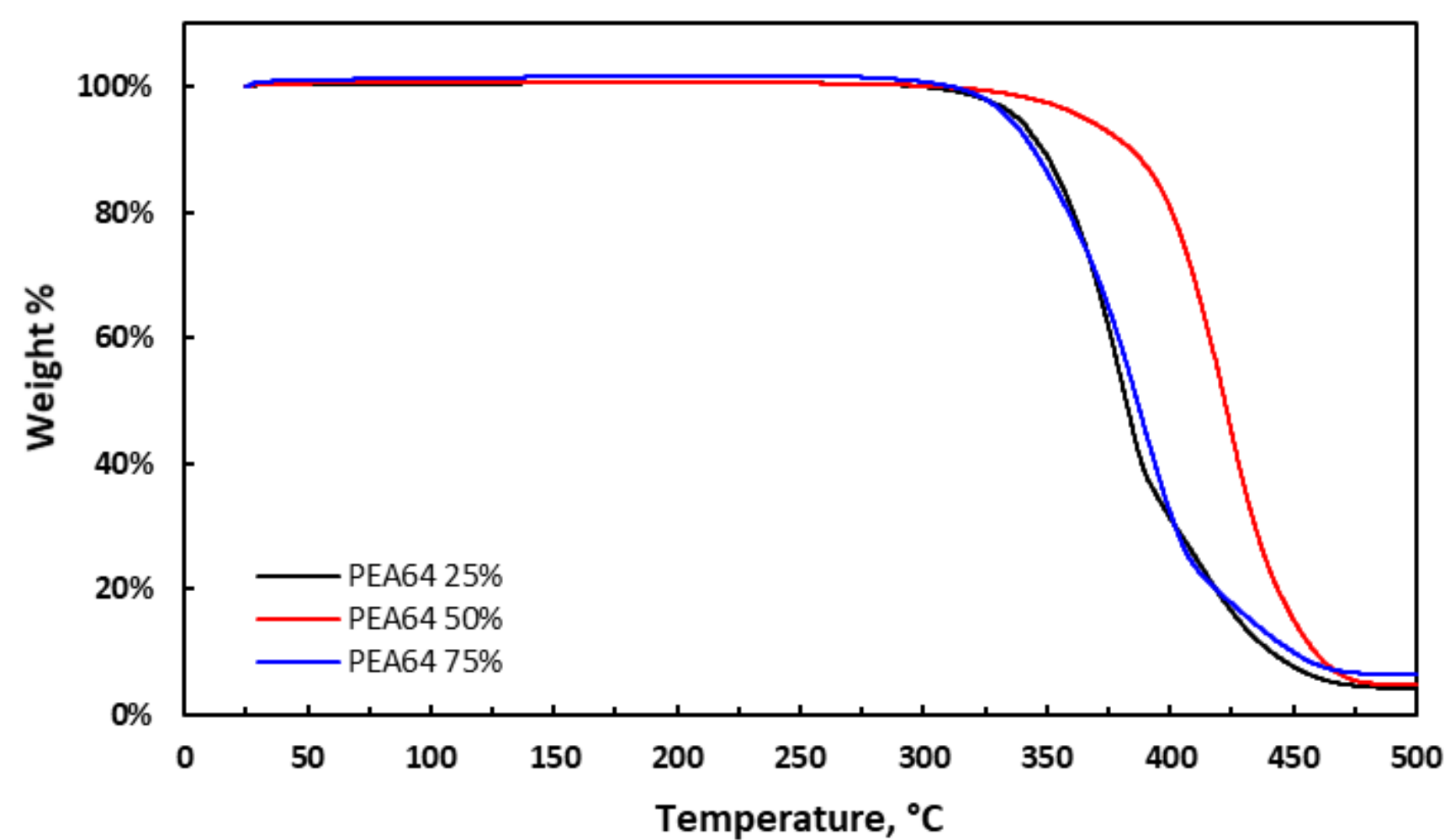


Figure 2: TGA curve of PEA64 samples with various amide content. Tests were conducted under nitrogen at a temperature range of 25 to 500 °C at 10 °C/min

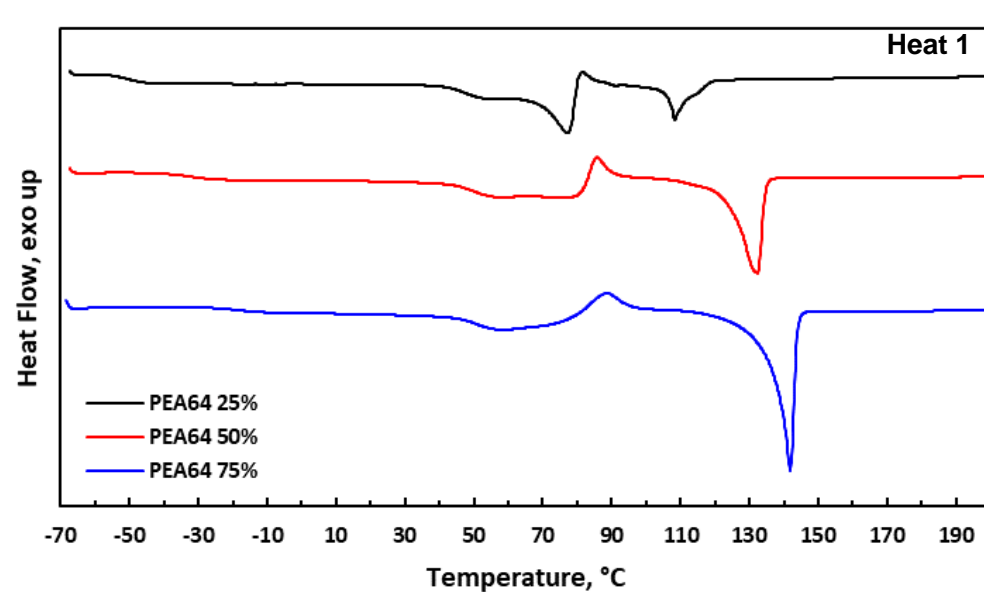


Figure 3: First DSC heat cycle for PEA64 of various amounts of amide content

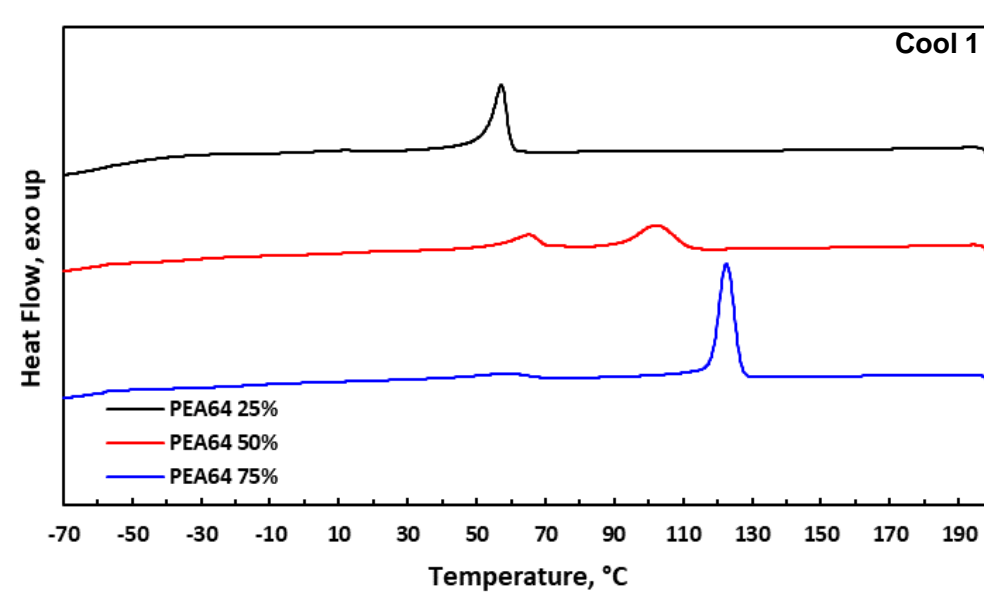


Figure 4: First DSC cooling cycle for PEA64 of various amounts of amide content

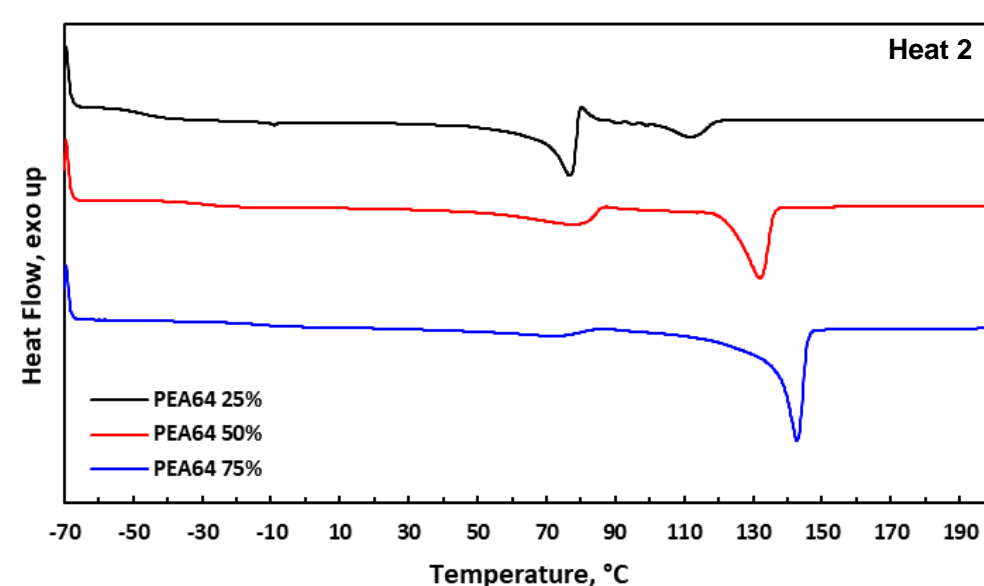


Figure 5: Second DSC heat cycle for PEA64 of various amounts of amide content

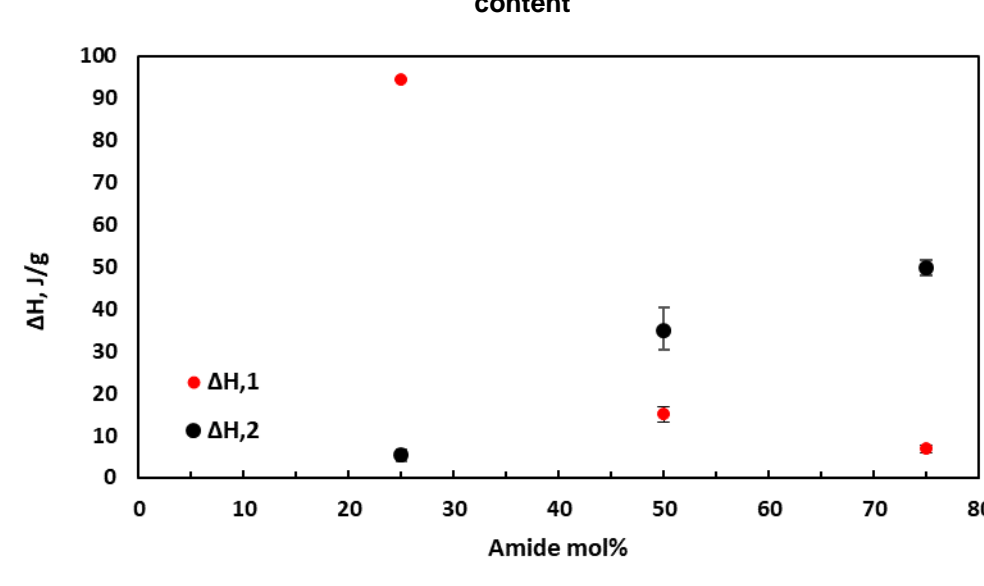


Figure 6: Enthalpy of melt for both melting peaks. ΔH,1 meaning the first melt peak observed, and ΔH,2 meaning the second melt peak

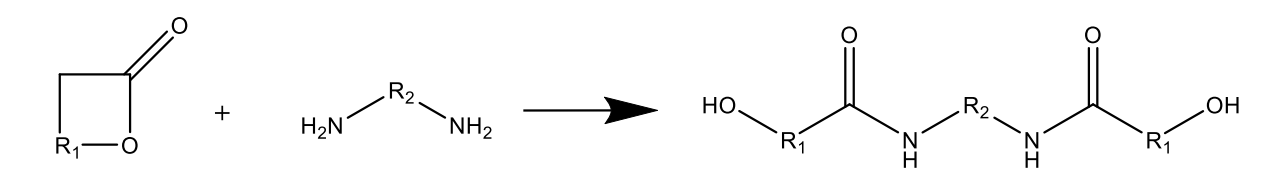
Comparing the melting temperatures and the degradation temperature of the various PEA64 samples, the polymers can be melt processed without degrading the polymer. There exhibits two separate melting and crystallization events that vary in energy depending on the amount of the hard segment. Shifts to higher temperature can be seen for the T_g and second melting event as the amount of hard segment increases. From this is it believed, the first melt is a result of the soft segment crystallization and the second melt is a result of hard segment crystallization.

References

- www.european-bioplastics.org
- Lange, J.; Wyser, Y., Recent innovations in barrier technologies for plastic packaging—a review. *Packaging Technology and Science* **2003**, *16* (4), 149-158.

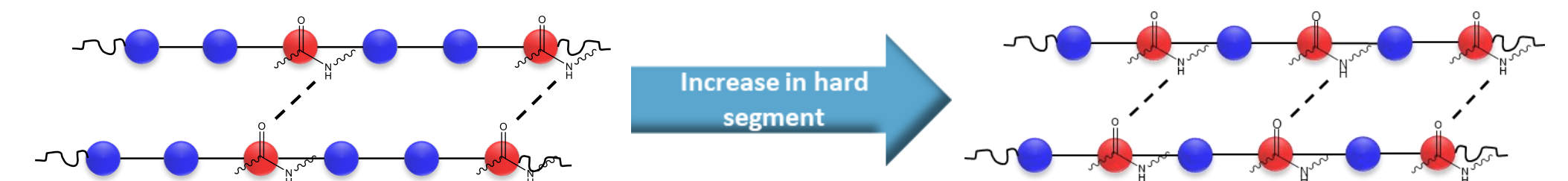
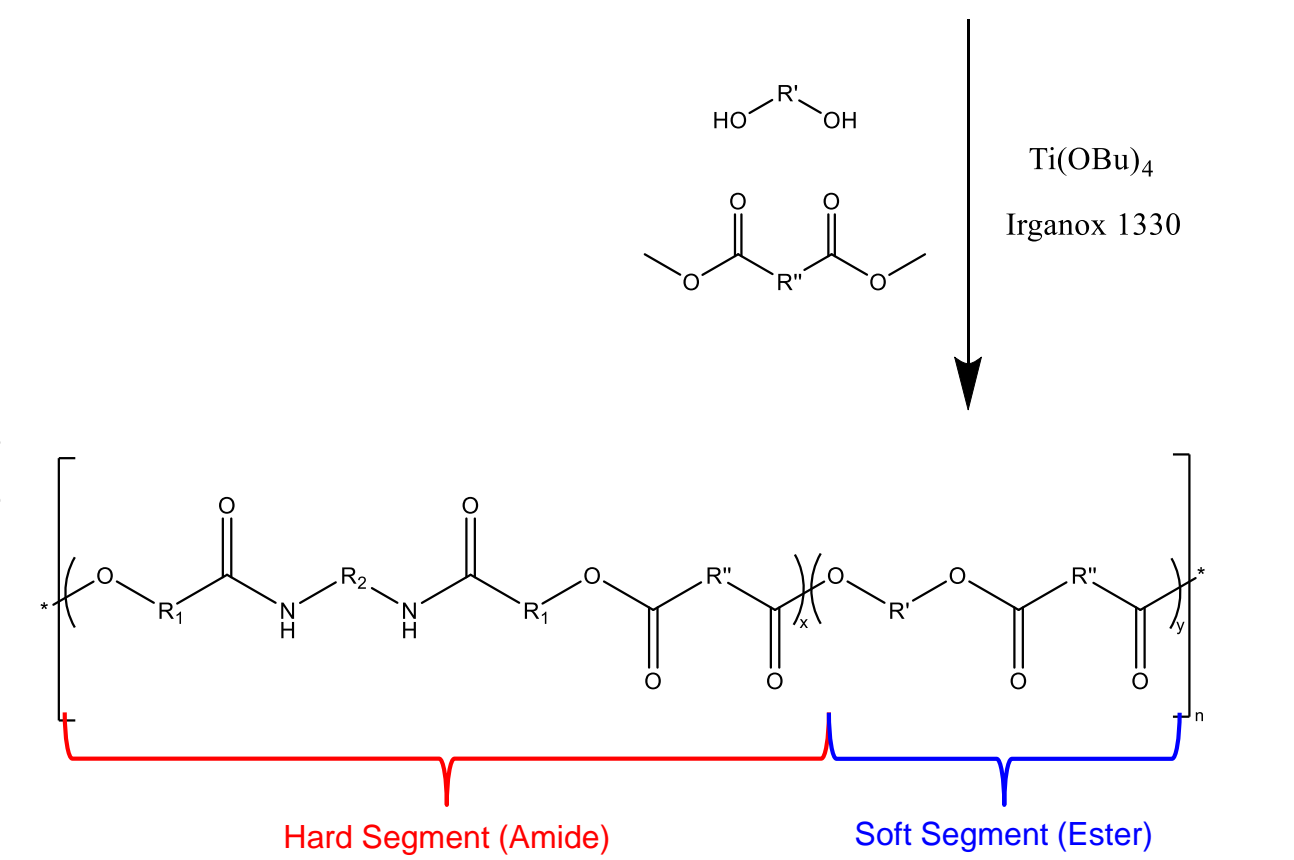
Synthesis of the polymer

Polycondensation reaction to develop a co-block polymer



Monomers sourced from cellulose biomass in the form of cyclic esters and diamines

Polymer consisting of hard and soft segments. Hydrogen bonding from the hard segments induce crystallinity in the polymer.



Mechanical and Permeability Properties

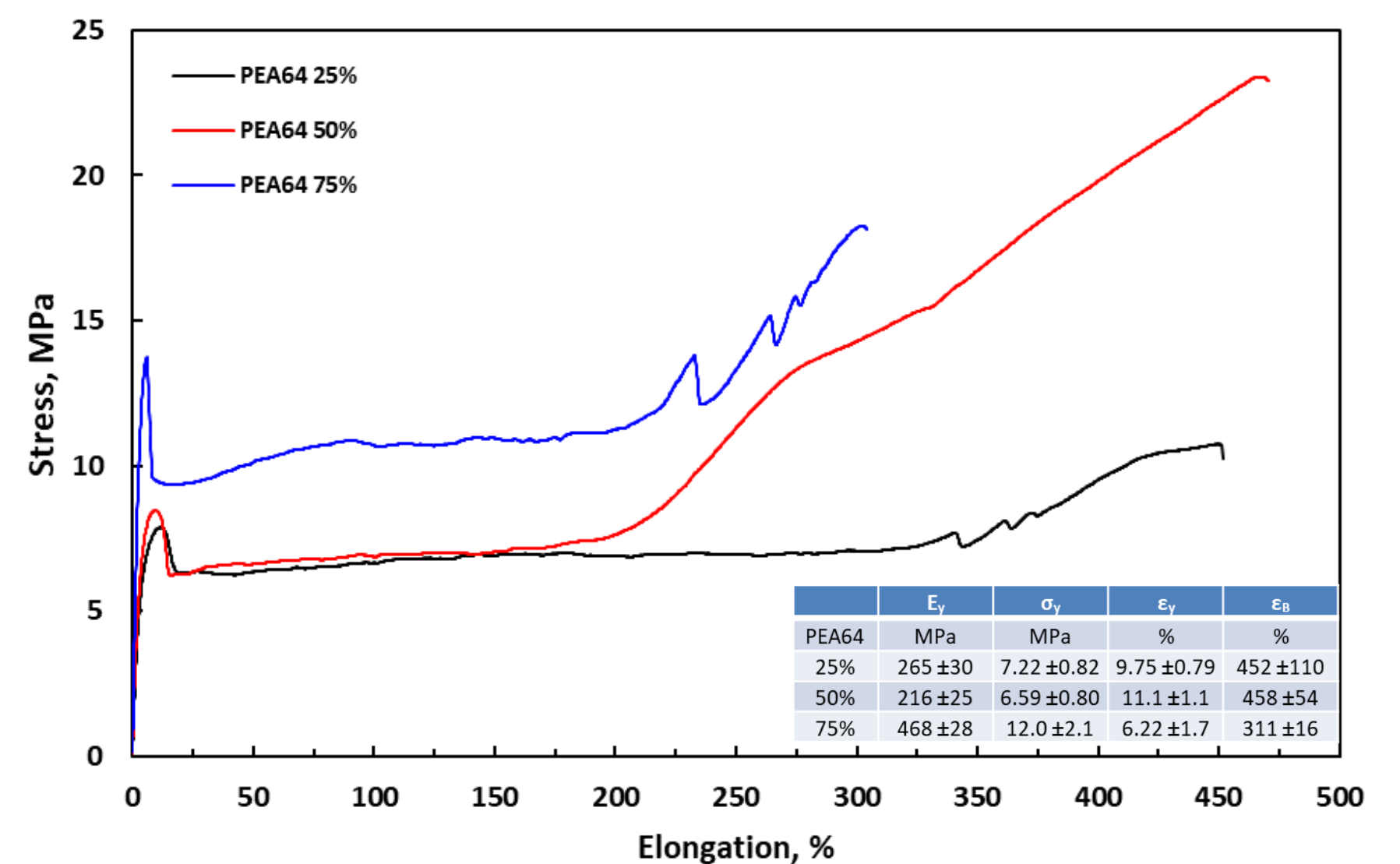


Figure 7: Tensile testing of PEA64 with various amide content. Tests were conducted at room temperature with a strain rate of 500mm/min

For both the 50% and 75% amide samples, the polymer exhibits strain induced crystallization. Increasing the amount of the hard segment results in the increase in strength properties. For oxygen permeability, the additional crystallization can lower the barrier properties of the polymer. Looking at an increase in the amide content results in a decrease in oxygen permeability. This correlates with the DSC data showing that at higher amide contents, the crystallinity of the polymer is higher. This polymer being comparable to polyolefins.

PEA64	$O_2 TR$ [$cm^3 \cdot mm / (m^2 \cdot day \cdot atm)$] at 23 °C, 0% RH
25%	166.4 ± 1.49
50%	57.43 ± 2.16
75%	29.77 ± 2.47
PET ²	1-5
PP ²	50-100
PE ²	100-150
PA ²	0.1-1
EVOH ²	0.001

Table 1: Oxygen permeability of PEA64 and reference materials

Conclusions

This project has introduced a bio-based poly(ester-amide) that is capable of having properties to the same degree as olefins for oxygen permeability. When looking at the strength of the polymer, it exhibits stiff, ductile properties with strain induced crystallization occurred with higher amounts of the hard segment. The melting behavior of the poly(ester-amide) can be altered by changing the amount of amide blocks. Further work should be done on biaxial and uniaxial stretched films. The induced crystallization seen in the tensile testing shows promise in increasing the crystallinity of the polymer which can correlate to a decrease in oxygen permeability.

Acknowledgments

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