Multifunctional additives for chemomechanical recycling of polylactide and other polyesters, derived by ATRP

Laura Dziugieł*, Matylda Szewczyk-Łagodzińska, Alicja Andrusiuk, Dawid Oleksiuk, Weronika Milanowska, Gabriel Kalbarczyk, Marta Dobrzyńska, Sebastian Kowalczyk, Andrzej Plichta

Warsaw University of Technology
Faculty of Chemistry, Noakowskiego 3 street, 00-664 Warsaw, Poland
***e-mail:** (laura.dziugiel.stud@pw.edu.pl)

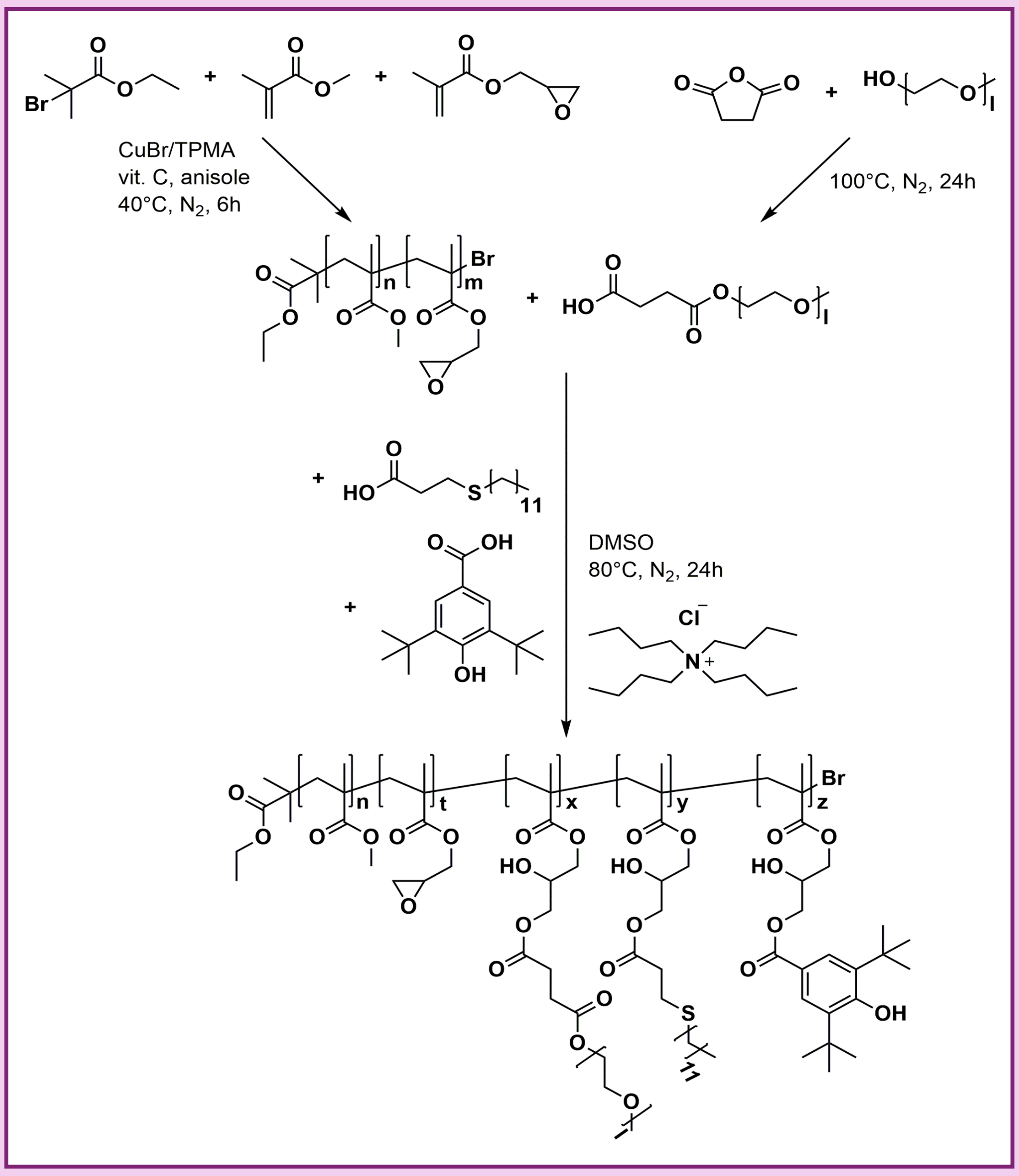
Research University Excellence Initiative

Faculty of Chemistry
Warsaw University of Technology

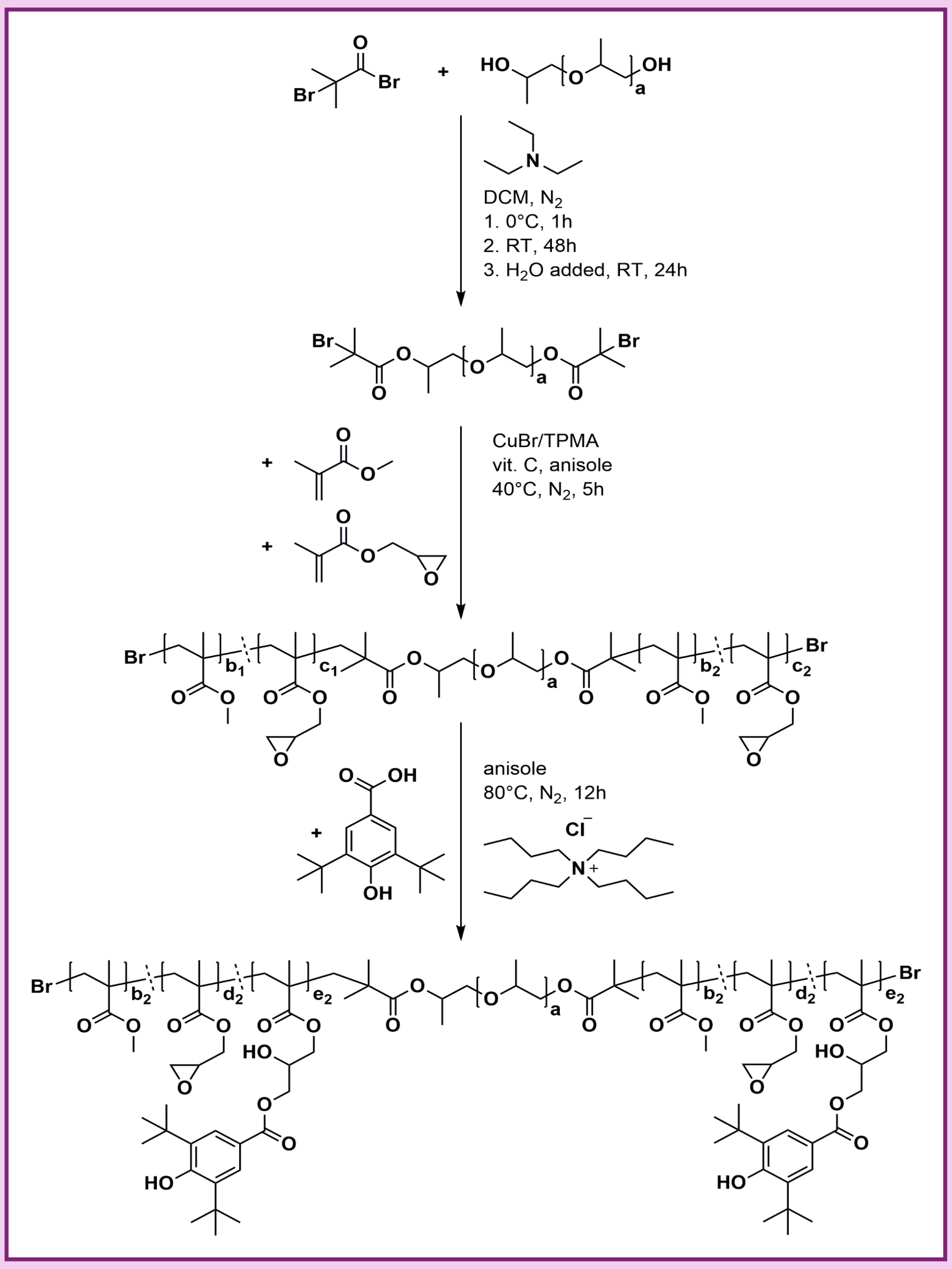
Introduction: Polylactic acid (PLA) is one of the most popular polymers in the industry due to its bio-based nature and biodegradability. However, PLA has mechanical properties similar to those of polystyrene, making it a brittle material, which limits its applications. In waste management, the long decomposition time of PLA and the need to ensure appropriate process conditions make mechanical recycling a better solution than biodegradation. Unfortunately, during repeated processing, degradation of polymer chains occur, leading to deterioration of both mechanical and processing properties.

Aim: In this work, macromolecular multifunctional additives designed for polyester recycling were presented. Those compounds simultaneously perform several functions: chain extender, primary and secondary antioxidants and as enhancer of the mechanical properties of PLA. Their performance was compared with similar additives synthesized via an alternative route. They were both analysed based on their effectiveness during PLA recycling and the mechanical testing of the obtained recyclates.

Synthesis route I



Synthesis route II[1,2]



[1]Szewczyk-Łagodzińska, M.; Oleksiuk, D.; Kowalczyk, S.; Czajka, A.; Dużyńska, A.; Łapińska, A.; Ryszkowska, J.; Dziewit, P.; Janiszewski, J.; Plichta, A. Multifunctional Block Copolymers, Acting as Recycling Aids, by Atom Transfer Radical Polymerization. ChemSusChem 2024, 17, e202301232.

[2]Plichta, A.; Jaskulski, T.; Lisowska, P.; Macios, K.; Kundys, A. Elastic Polyesters Improved by ATRP as Reactive Epoxy-Modifiers of PLA. *Polymer* **2015**, *72*, 307–316.

Results

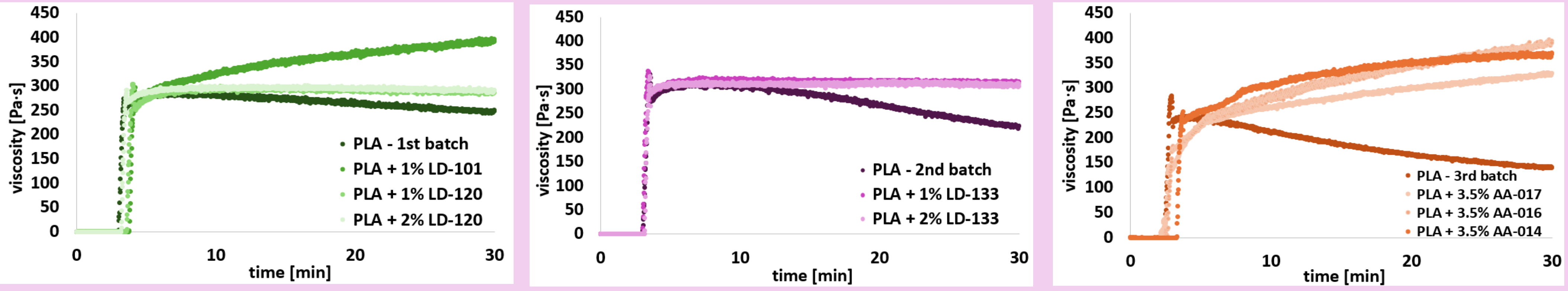
Name	N_{epoxy}	% opened by mPEG	% opened by primary antioxidant	% opened by secondary antioxidant	% epoxy groups left
LD-101	30	0%	0%	0%	100%
LD-120	24	20%	0%	0%	80%
LD-127	83	0%	0%	0%	100%
LD-133	12	20%	20%	20%	15%*

*25% of the epoxy groups were opened by the methanol remaining in the product after precipitation.
% of mPEG, primary and secondary, as well as epoxy groups were calculated based on ^{1}H NMR spectra.

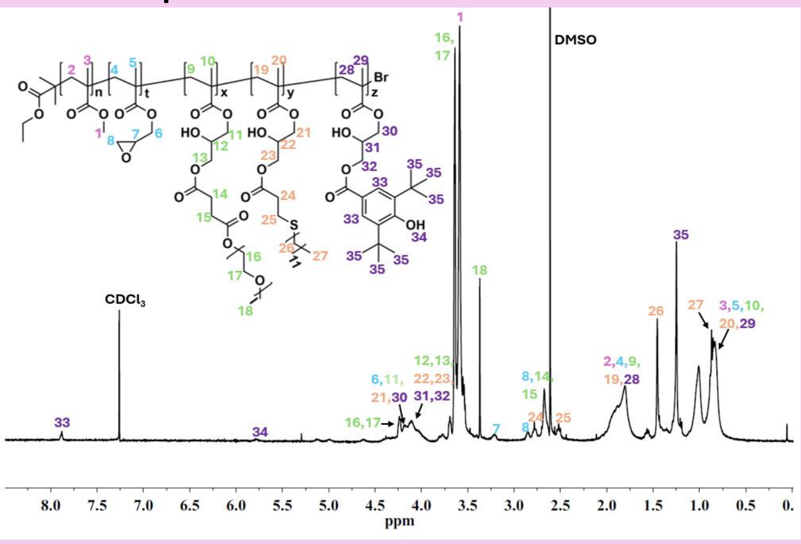
Name	N_{epoxy}*	Chain extender	Primary antioxidant
AA-014	23	Yes	No
AA-016	25	Yes	Yes*
AA-017	26	Yes	Yes*

*The presence of antioxidant was based on the obtained UV-Vis spectra and GPC results.
*N_{epoxy} was calculated based on ^{1}H NMR spectra.

Viscosity measurements:



1H NMR spectrum of LD-133:



Tensile strength test results: