

Upcycling of de-repolymerized polylactic acid and surface-modified cellulose composite

Ju-Hong Lee, Won-Bin Lim, Jin-Gyu Min, Jae-Ryong Lee, Yi Cheon Kim, Ji-Hong Bae and PilHo Huh*

Department of Polymer Science and Engineering, Pusan National University, Busan 46241, Korea

* pilho.huh@pusan.ac.kr

ABSTRACT

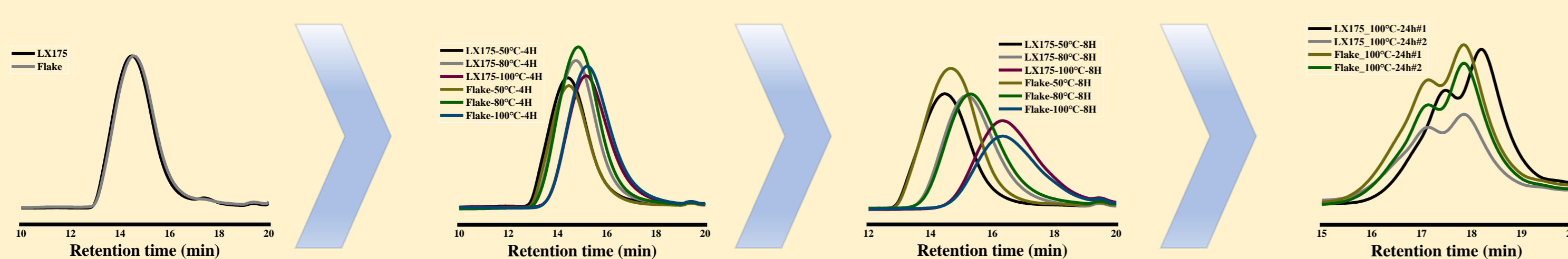
Poly(lactic acid) (PLA) synthesized using high-purity L-lactide manufactured through chemical recycling was compounded with cellulose nanofibers (CNF). CNF was hydrophobized as a silane coupling agent to produce a PLA-CNF composite. End of life PLA manufactured through hydrolysis was decomposed from molecular weight 60,000 ~ 65,000 to 3,000 ~ 5,000. PLA having low molecular weight depolymerized better than high molecular weight PLA. L-lactide having a high purity about 98~99% could be produced by back-biting using Sn-based organometallic catalyst. In this work, we report a repolymerized PLA was compounded with CNF. Composite of modified CNF-chemically recycled PLA (CNF-re-PLA) exhibited better mechanical properties than commercial PLA. The tensile strength and Young's modulus of CNF-re-PLA prepared through extrusion tend to improve as the content of modified CNF increases. As a result, CNF having a high substitution rate through the silane coupling agent showed good compatibility with PLA.

OBJECTIVES

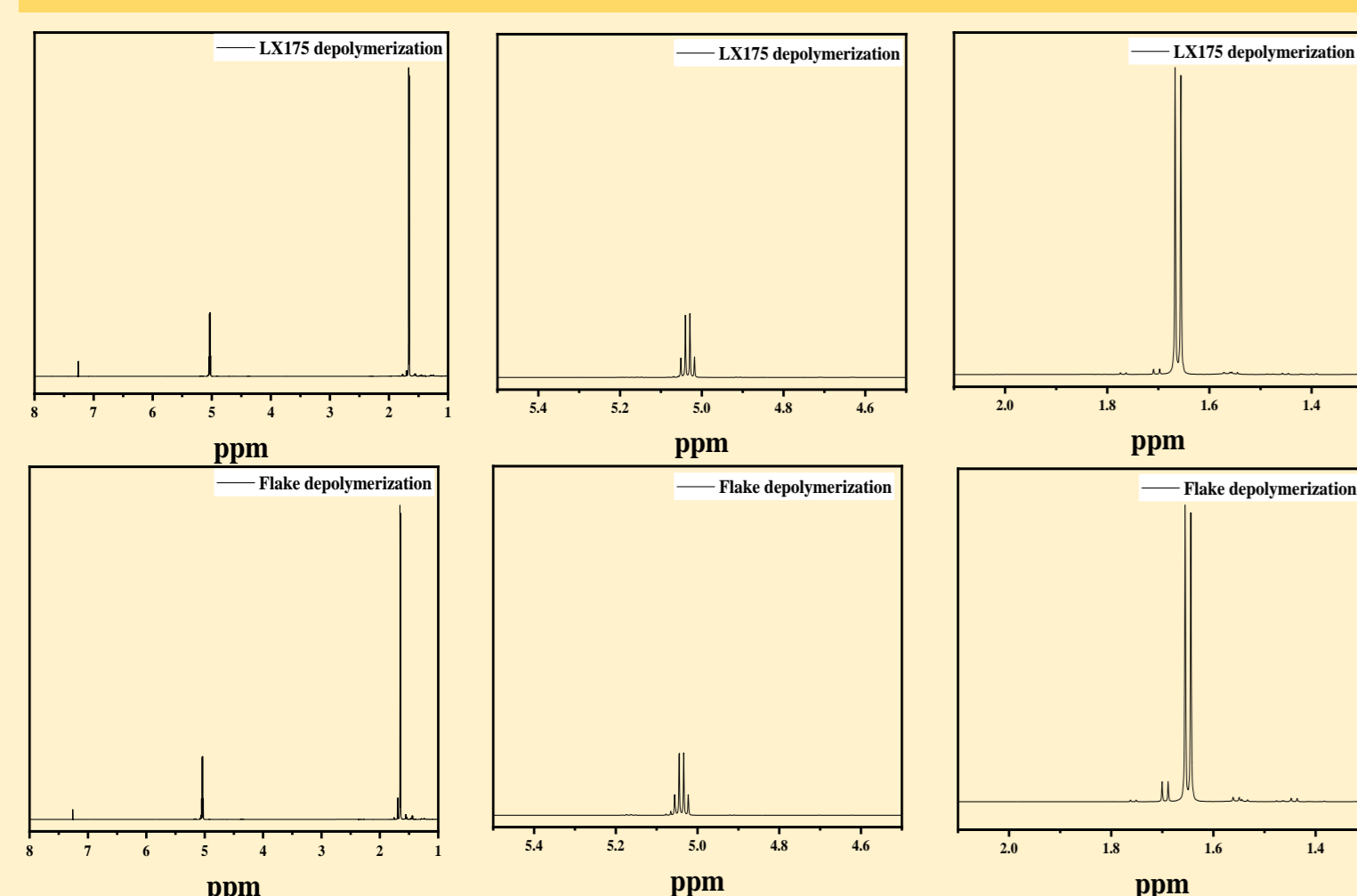
1. Carbon and energy savings from recycling end of life PLA
2. Improving the properties of high-purity PLA by chemical recycling
3. Optimization of high purity l-lactide synthesized under depolymerization reaction conditions (catalyst, temperature, etc.)
4. Improving physical properties that are lacking when using recycled PLA by using modified cellulose

RESULTS

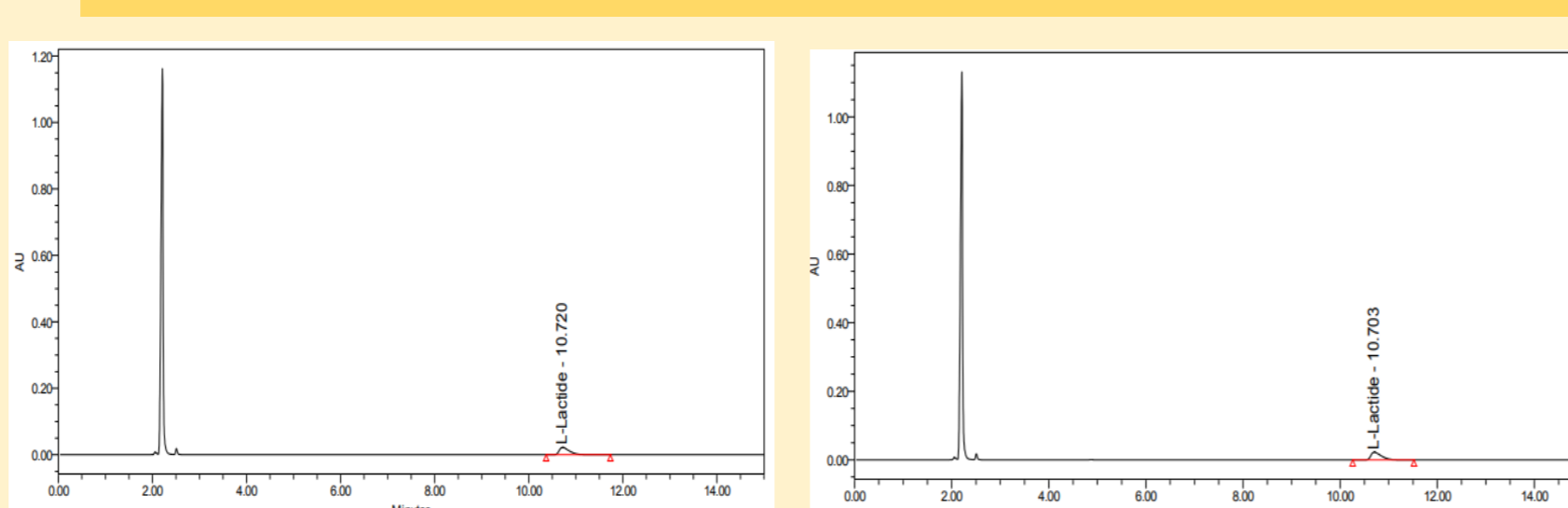
Hydrolysis PLA - GPC



Re-Lactide - NMR



Re-Lactide - HPLC

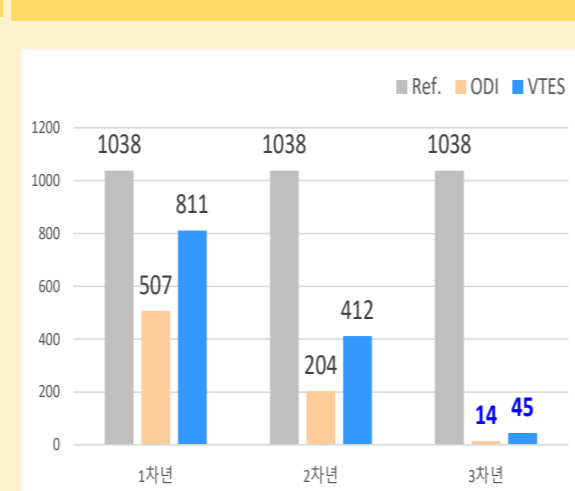


- As a result of structural analysis of lactide produced after depolymerization, it was confirmed that it was the same as L-lactide.
- According to the optimization of the synthesis ratio, the OH value decreased.
- After the purification process, HPLC was measured to confirm the purity of lactide, and it showed the highest purity at a constant ratio of water and ethanol.

Solvent dispersion & Water CA



OH-value



SEM



- Water contact angle: modification → 34° → 80° ~ 84°
- According to the optimization of the synthesis ratio, the OH value decreased.
- To confirm the composite properties of PLA and modified CNF, the surface of the specimen was observed with SEM, and the images are shown in (a) neat PLA, (b) PLA/ODI-CNF 1wt%, and (c) PLA/VTES-CNF 1wt%

CONCLUSIONS

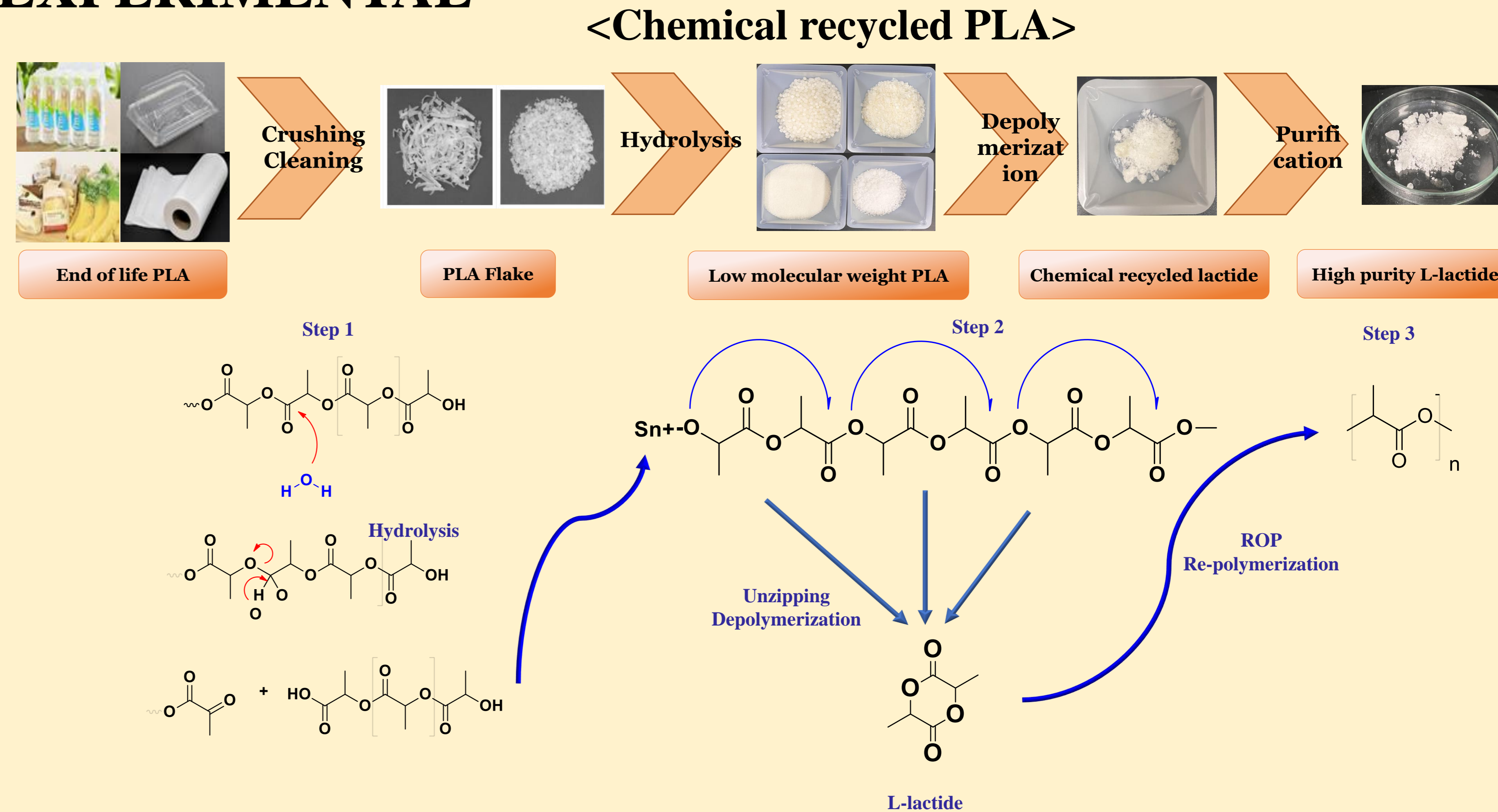
- ✓ End of life PLA through physical regeneration was hydrolyzed according to process conditions to produce PLA with a molecular weight of 3,000.
- ✓ Depolymerization was performed according to the catalyst type using a low molecular PLA, and a high-purity l-lactide was obtained after a purification process.
- ✓ Upcycling PLA with improved mechanical properties was prepared by combining recycled PLA and modified cellulose.

ACKNOWLEDGEMENT

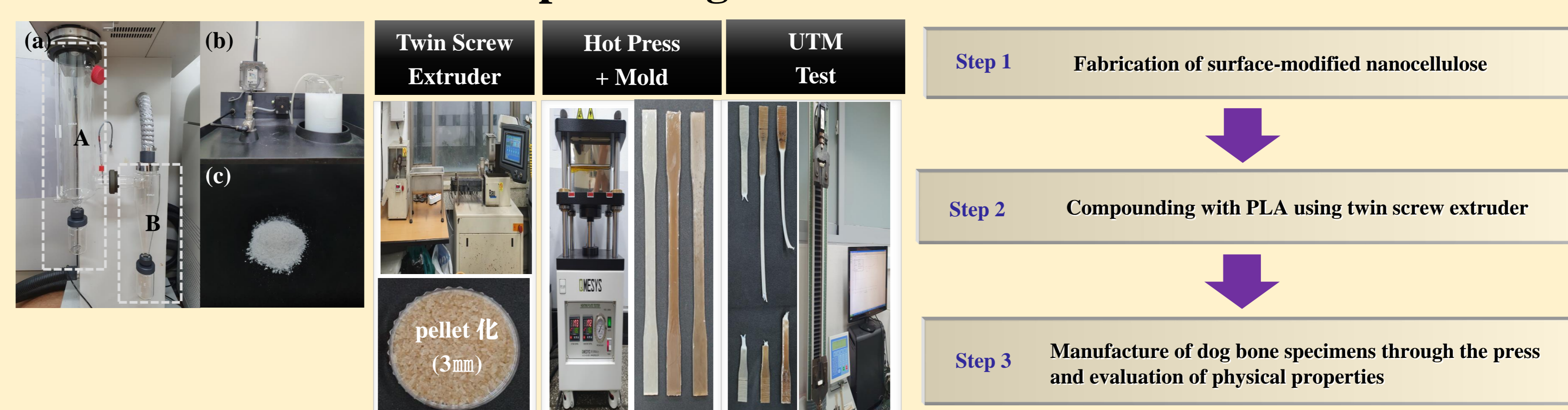
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Advanced Steric Polymer Lab., Department of Polymer Science and Engineering, Pusan National University

EXPERIMENTAL



<Compounding PLA with Modified cellulose>

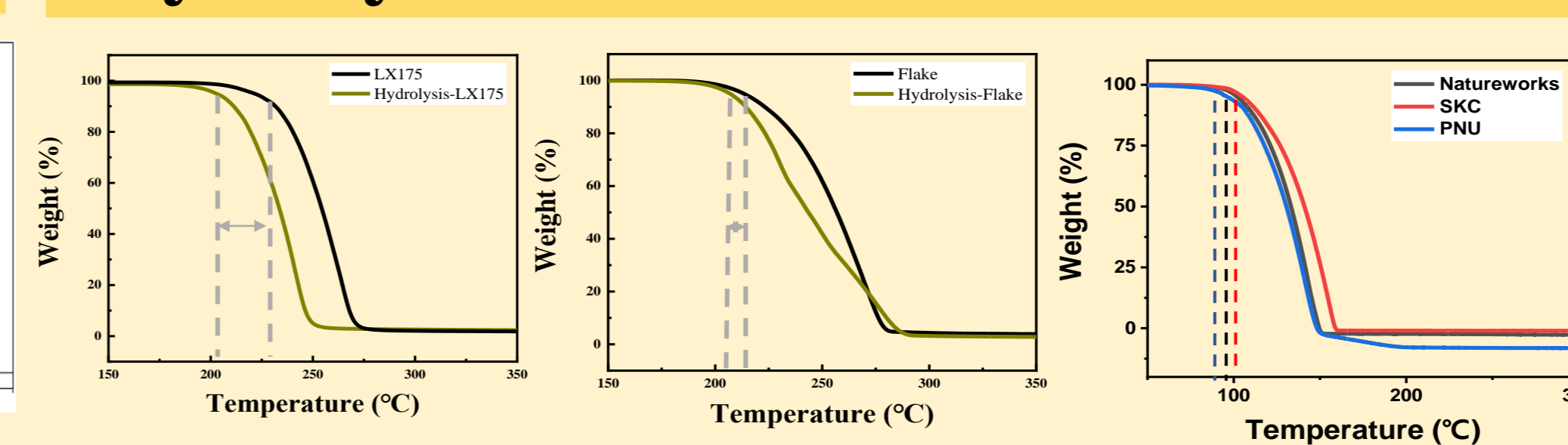


<Hydrolysis PLA molecular weight>

	Time (t)	temperature (°C)	Mn	Mw	PDI
LX175	4	100	36411	59211	1.63
	8	100	12264	21395	1.74
	24	100	3346	7050	1.83
Flake	4	100	35282	57853	1.64
	8	100	10421	20351	1.95
	24	100	3497	6809	1.94

- The change in molecular weight according to the hydrolysis time was confirmed.
- As a result of hydrolysis, PLA with a molecular weight of 60,000 was approximately changed to a molecular weight of 3000

Hydrolysis PLA and Re-Lactide - TGA



<L-lactide purities >

Sn catalyst	Ethanol	Ethanol : Water
#1-1	97.98	92.19
#1-2	98.49	92.22
#1-3	98.49	92.73
#2-1	93.53	95.15
#2-2	93.90	95.57
#2-3	94.19	95.71