



# Green Colloidal Electrospinning of Degradable Nanofibers

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## Significance

**Biobased nanofiber yarn may offer a viable green alternative to synthetic yarn.**

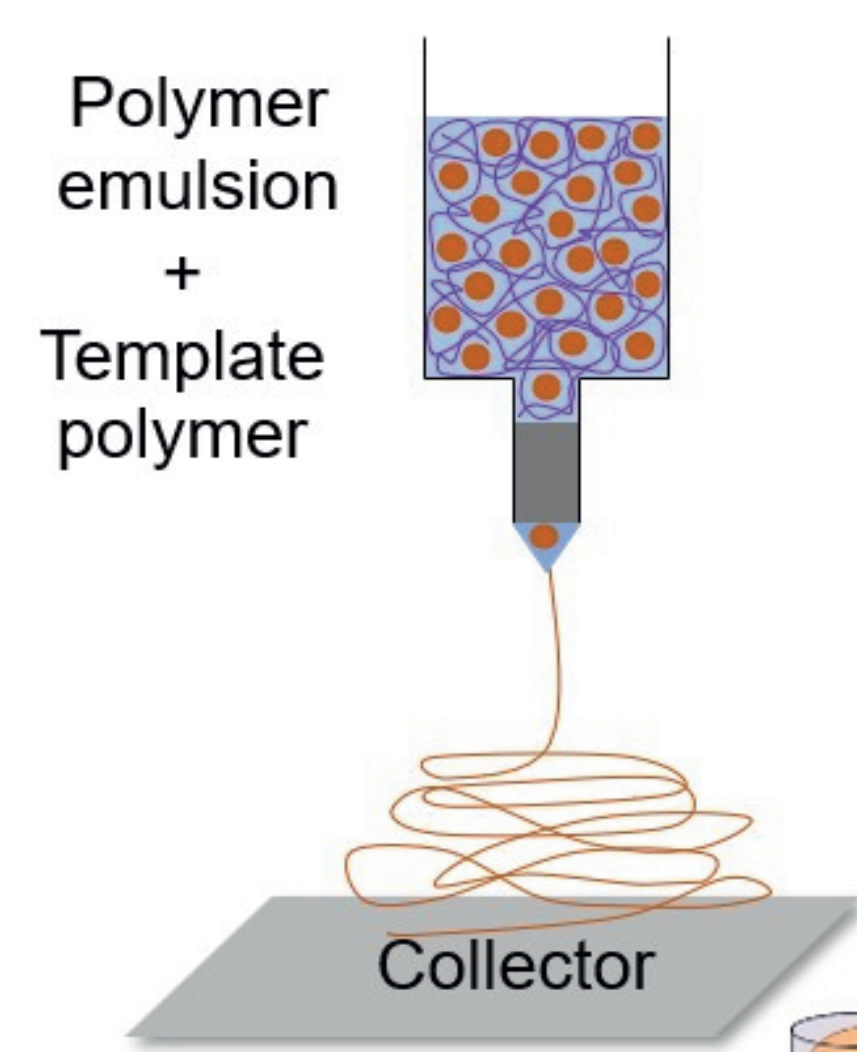


Fig 1: Diagram of green electrospinning process. [7]

The average American generates 82 lbs of textile waste annually. [1]

Synthetic fibers account for 35% of all microplastics in the ocean. [2]

Electrospinning typically uses organic solvents and low polymer concentrations. [6]

Green electrospinning uses a water-soluble polymer template with significantly higher polymer concentrations. [6]

## Objective:

**Attach degradable crosslinkers to a biobased polymer and use green electrospinning to convert the nanoparticles to nanofibers.**

Cross-linker degradation

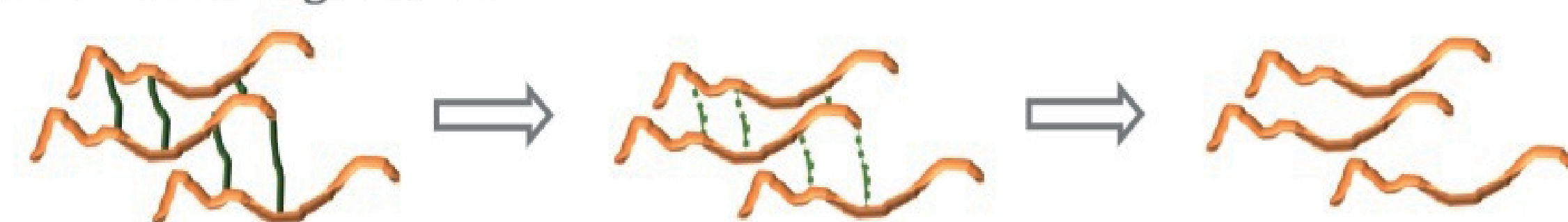


Fig 2: Molecular architecture of a degradable polymer. [4] Polymers can be degraded through crosslinker breakdown.

## Approach

**Synthesis of degradable polymers takes roughly 18 hours from making the crosslinker to electrospinning the fibers.**

Steps:

1. Synthesize  $\epsilon$ -caprolactone and lactide crosslinker using ring-opening polymerization.
2. Make latex seeds from 2OA or OMA [8] and IBOMA in batch emulsions.
3. Grow seeds in semi-batch emulsions with 2OA or OMA, IBOMA, and THFMA. [9]
4. Use no crosslinker, AMA crosslinker, or one of the biodegradable crosslinkers for each growth.
5. Electrospin mixtures of 10 wt% PVA solution and latex in the Spinbox at 17 Hz and analyze using Scanning Electron Microscope (SEM) imaging.
6. Analyze polymer degradation using base hydrolysis and Soxhlet extraction.

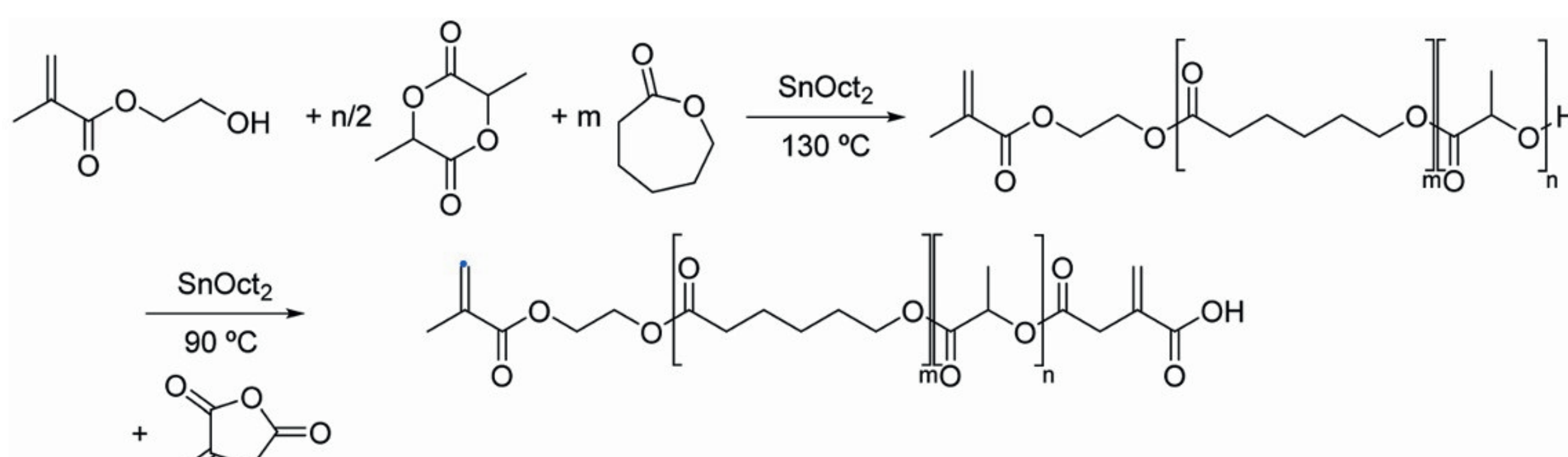


Fig 3: Mechanism for ring-opening polymerization of asymmetric crosslinkers. [5] This shows the chemistry used to synthesize the degradable crosslinkers.

## Results

**Crosslinker characterization data shows successful synthesis of degradable crosslinker.**

		ASY-LA2CL2	ASY-LA8CL8
Theoretical	MW (g/mol)	614.63	1731.86
GPC	MW (g/mol)	1037	2057
	Percent Error	68.7%	18.8%
H NMR	MW (g/mol)	515.03	1782.80
	Percent Error	16.2%	2.94%

Fig 4: Comparison of GPC and H NMR Molecular Weights to the Theoretical Molecular Weights of ASY-LA2CL2 and ASY-LA8CL8.

GPC MW has large error due to standard used, HNR was deemed more accurate.

**Conversion rate and latex characterization data shows room for improvement with degradable crosslinker integration.**

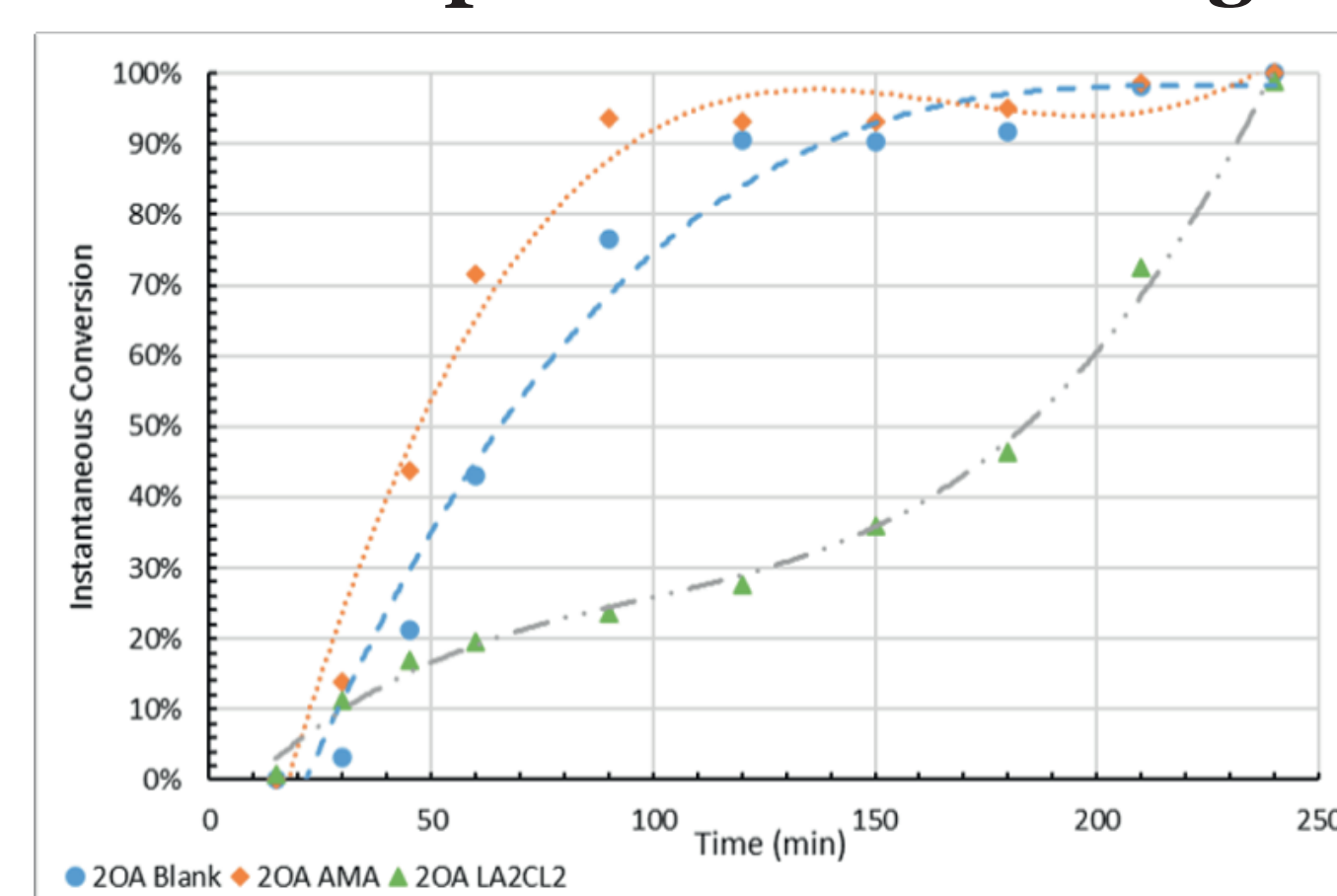


Fig 5: Rate of conversion over time for 2OA latexes. All latexes reach 100% conversion.

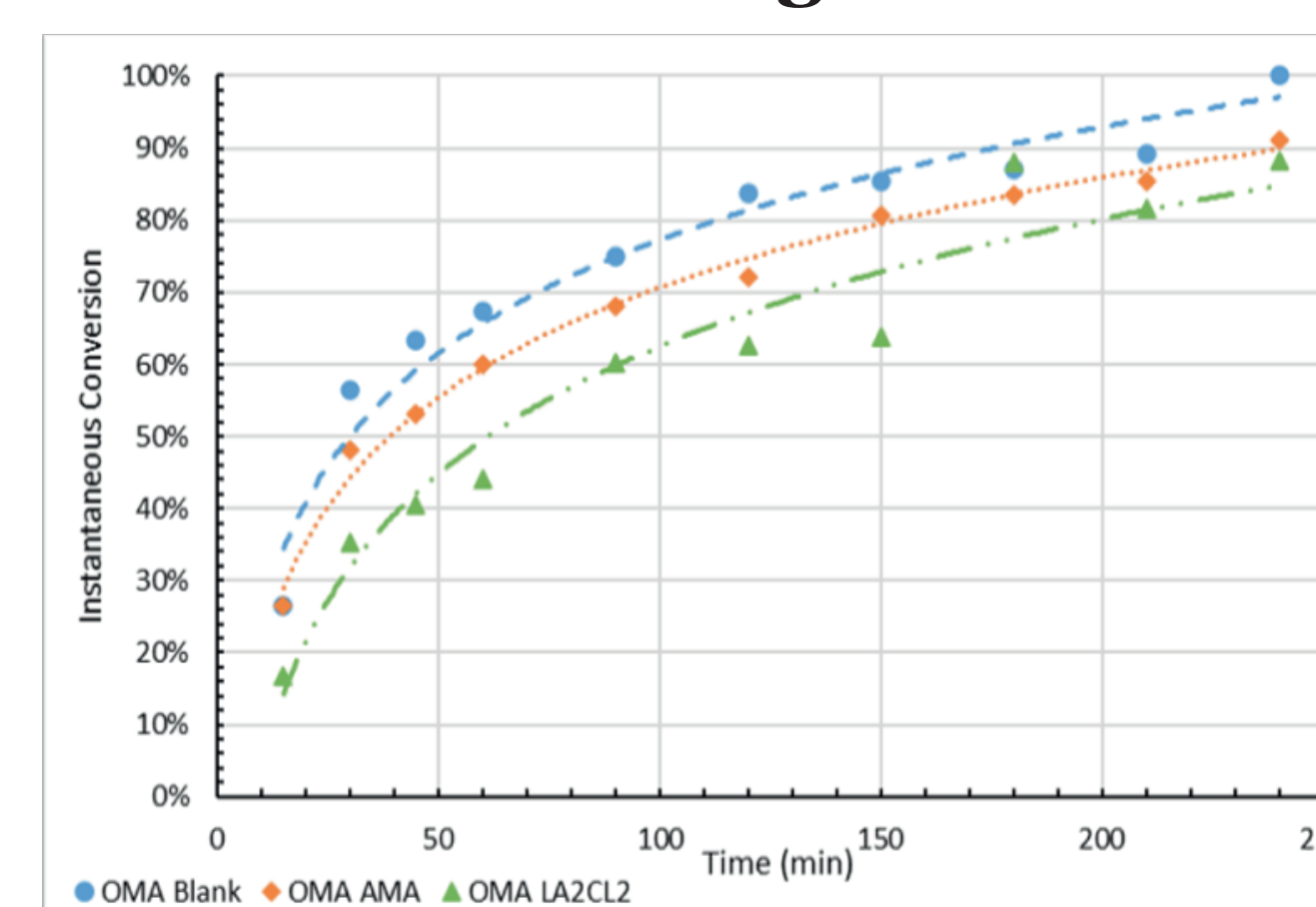


Fig 6: Rate of conversion over time for OMA latexes. Conversion decreases with crosslinker.

		Solid Content	Avg Gel Content	Avg MW (g/mol)	Avg Particle Size (nm)
$T_g = 15.5^\circ\text{C}$	2OA Blank	39.6%	77.8%	49769	234.6 ± 3.9
	2OA AMA	40.2%	93.1%	22940	233.2 ± 1.8
	2OA LA2CL2	38.7%	82.2%	42242	244.1 ± 2.4
$T_g = 8.3^\circ\text{C}$	OMA Blank	39.0%	0%	108620	183.8 ± 13.6
	OMA AMA	39.4%	83.7%	71127	176.7 ± 2.6
	OMA LA2CL2	38.7%	15.2%	179727	172.8 ± 12.7

Fig 7: Polymer characterization data. Gel content increases from Blank to LA2CL2 to AMA.

**SEM images show successful synthesis of uniform and continuous nanofibers.**

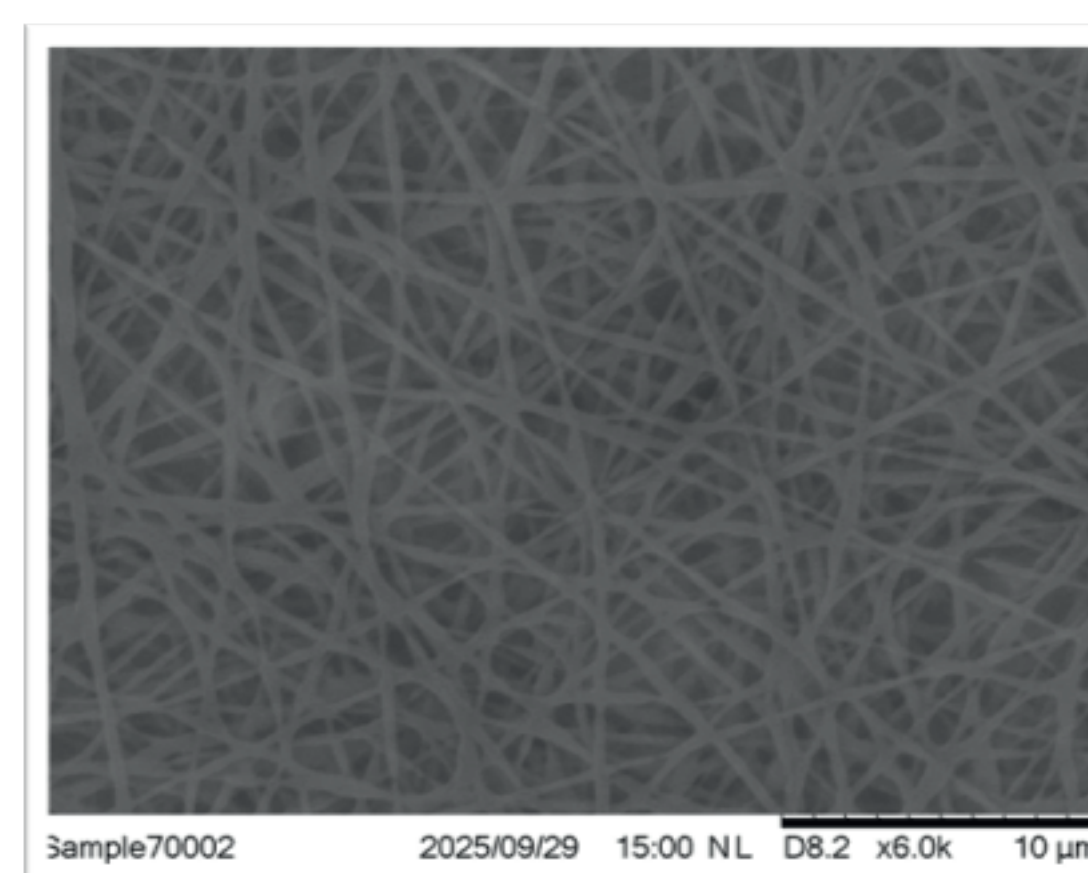


Fig 8: SEM image of 2OA Blank.

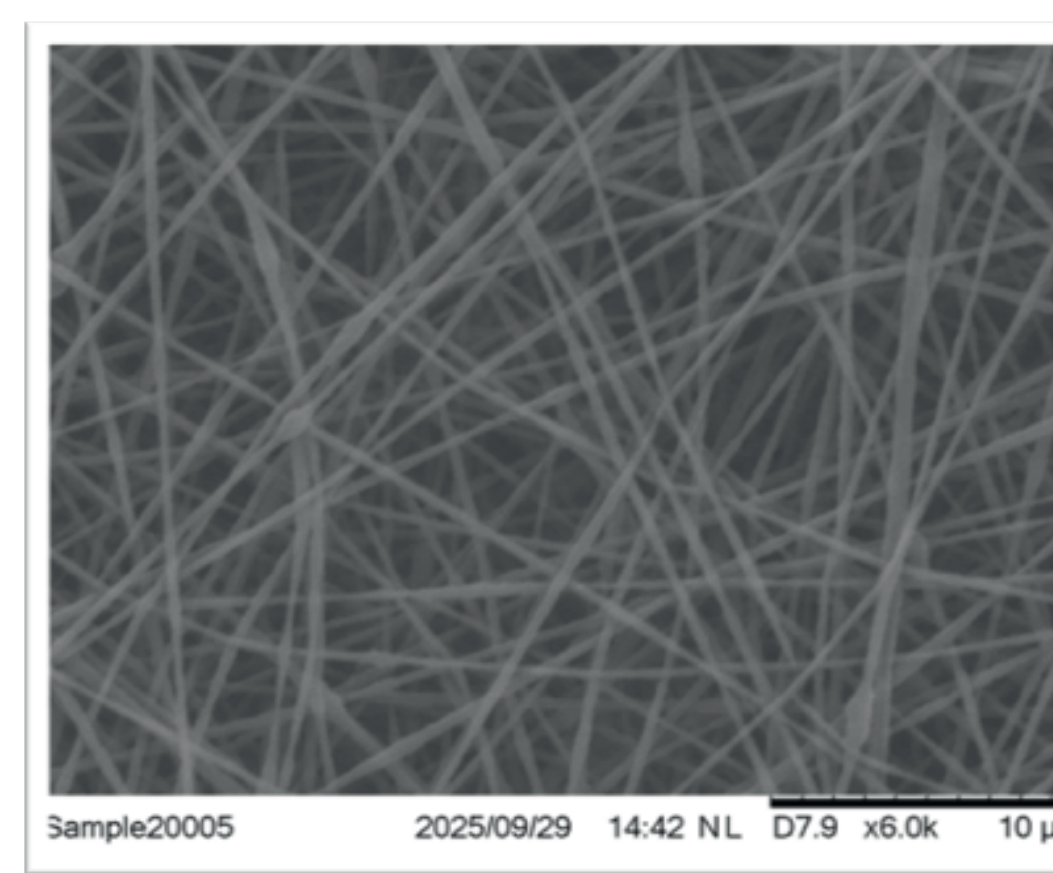


Fig 9: SEM image of OMA Blank.

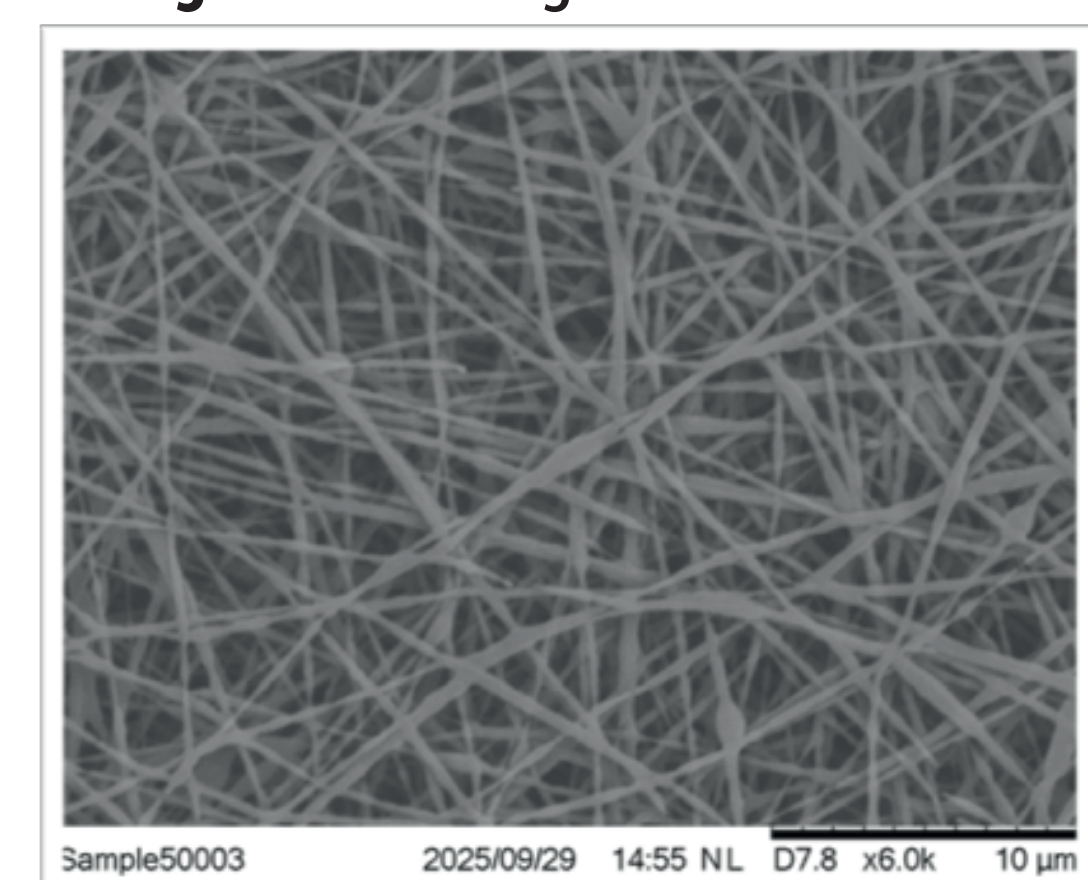


Fig 10: SEM image of 2OA AMA.

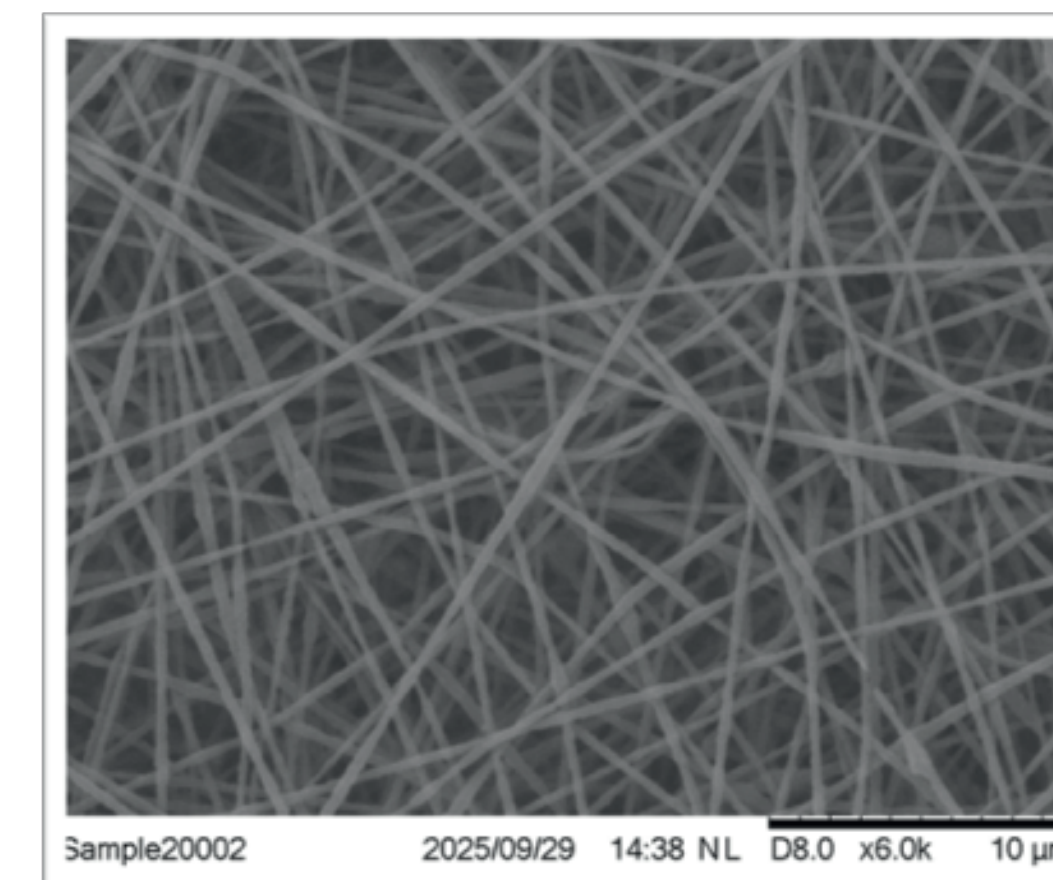


Fig 11: SEM image of OMA AMA.

## Results

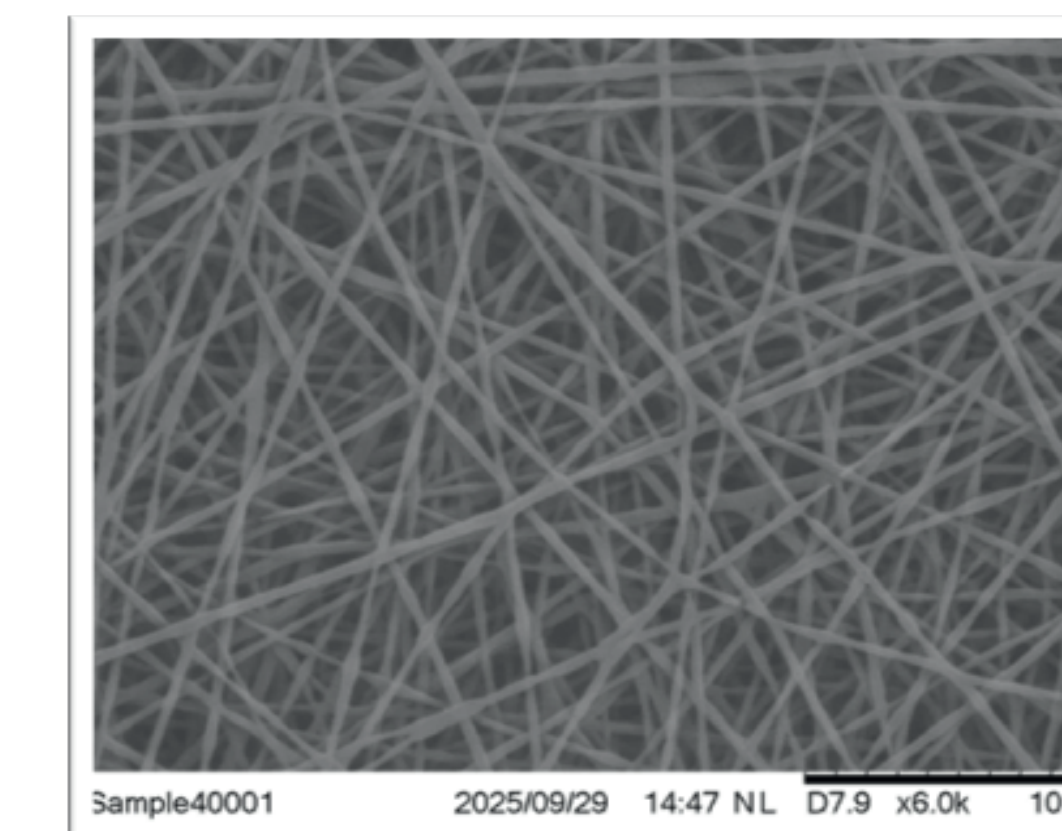


Fig 12: SEM image of 2OA LA2CL2.

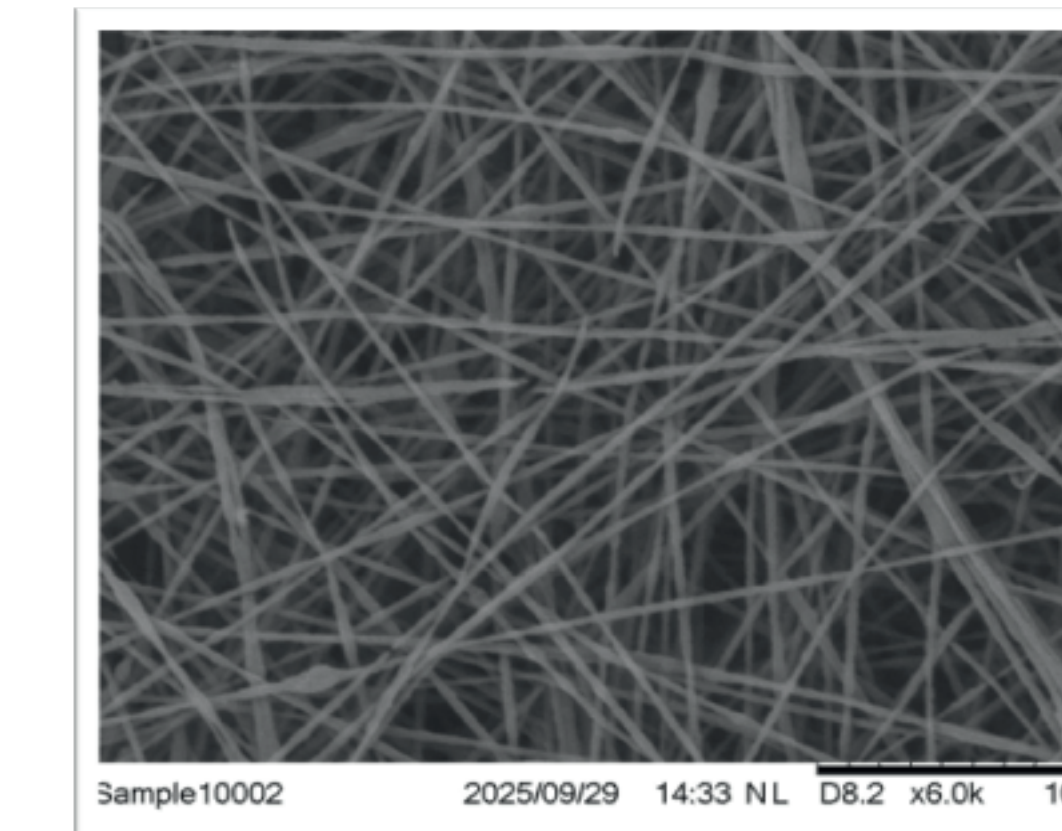


Fig 13: SEM image of OMA LA2CL2.

OMA LA2CL2 gives the most consistent nanofibers with minimal breaks, potentially due to lower crosslinking percentage.

**Base hydrolysis data shows significant latex degradation after 1 day.**

	Avg Gel Content Pre Degradation	Avg Gel Content Post Degradation	Percent Degraded	Total Time Degraded (hr)
OMA Blank	0%	0%	N/A	28.5
OMA AMA	83.7%	81.9%	2.18%	26.2
OMA LA2CL2	15.2%	0%	100%	23.2

Fig 14: Comparison of crosslinking density before and after degradation. OMA LA2CL2 showed complete degradation while OMA AMA remained constant.

OMA LA2CL2 had total crosslinker degradation in just under 24 hours. OMA AMA showed slight degradation, but can be considered negligible.

## Conclusions

**Biobased crosslinker does not promote as much crosslinking as industry alternative, but makes more consistent nanofibers.**

We were able to incorporate ASY-LA2CL2 into the biobased polymer, but it does not disperse in the monomer feed solution.

ASY-LA2CL2 crosslinked polymers were less crosslinked than AMA crosslinked polymers, but more crosslinked than polymers without crosslinker.

We achieved best continuous and uniform nanofibers from OMA LA2CL2.

Base hydrolysis tests showed substantial degradation of OMA LA2CL2 after 1 day.

## Future Directions

Synthesize OMA LA2CL2 with THFMA and ASY-LA2CL2 in a separate feed stream from other monomers to see if dispersion is achievable and aids in crosslinking.

Analyze wastewater degradation tests.

Make latexes with ASY-LA8CL8 crosslinker.

Determine how the latexes degrade over time through more base hydrolysis.

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