CAAP Quarterly Report

October 3, 2023

Project Name: Selection and Development of Safer Polymer and Composite Pipeline Liners through Microstructural and Macroscopic Study of Materials and Designs

Contract Number: 693JK32250001CAAP

Prime University: Brown University

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Reporting Period: July 1, 2023 – September 29, 2023 (Q2)

Project Activities for Reporting Period:

The Poling-Skutvik lab has officially hired the graduate research assistant responsible for this project, Mohammadjavad Hajirezaei. He is currently being trained on sample preparation techniques, including melt processing polymers to form samples for mechanical characterization and chemical aging. Additionally, they are machining a mold for these polymers to ensure reproducible measurements in tensile testing, shear rheology, and dynamic mechanical analysis.

During this quarter, Hyun Young Nam, a first-year Ph.D. student, has formally started on this project in the Srivastava lab. He is continuing the literature study on the constitutive damage model for liner polymer materials with an early focus on polyethylene. During the first year, Young will be partially helped by another graduate student, Kevin LoGiudice, with experimental design, set-up and mechanical test plans. The effect of the chemical environment on the pipe leading to damage in the polymer materials and reduction in the load capacity of pipeline and liners is aimed for the modeling work. Papers discussing and presenting chemo-mechanical damage, micromechanics-based elastic viscoplastic damage, void and crazing damage, and the effect of crystallinity models are listed in references [1] through [9]. Mechanical long-term (low-stress) creep test experimental set-ups are being considered and designed. This test setup is aimed at experimentally studying polymers' failure/damage under mechanical load after various chemical and pressure exposures. Various geometry of creep test is also being considered, and a suitable test specimen geometry will be soon selected based on the ongoing literature review. The specimen geometries under consideration are dog-bone sample (ASTM D638), Pennsylvania edge notch test sample (PENT; ASTM 1473) [3,4], double edge notch sample (DENT) [1,2], and full notch creep test sample (FNCT). One of these specimen geometries (current preference is ASTM dog-bone as it is most commonly used for mechanical characterization) will be the focus for the mechanical slow rate and creep experiments. Besides continuum mechanics-based damage models for high-density polyethylene (HDPE), damage models for polyamides (PA), polyvinylidene difluoride (PVNF), and glass fiber-epoxy (GFE) will also be researched.

In Dr. Mathiowitz's lab, the first-year Ph.D. student Zakhar Lyakhovych has been onboarded on this project. He has compiled a list of lab-grade materials that will be utilized for our experimental studies. Table 1 refers to some of the materials of interest. The graduate student has been learning the polymer microstructural characterization experimental method and has become proficient with many characterization techniques. We are presenting preliminary FTIR data (Figures 1 and 2), DSC results (Figures 5 and 6), and XRD analyses as preliminary investigation results on polymer samples already present in our lab (Figures 3 and 4). In the preliminary experiments, commercial MDPE, HDPE piping, and PVC, as well as lab-grade MDPE, were examined. Additionally, Figure 7 showcases a series of hot-stage X-ray images, illustrating our approach to characterizing various polymers after subjecting them to aging conditions at different pressures and temperatures.

Polymer	Lab Grade	Commercial Grade	
PVDF	Light Link™ SLA Resin Made With Kynar® PVDF (UNPOLYMERIZED)	1/4" X 20' Schedule 80 Natural PVDF Pipe	
	3DXSTAT ESD PVDF		
Epoxy		Thin Epoxy Resin	
		HH Epoxy Base Resin Part A	Epoxy specifically for CIPP
Polyethylene	Available at Mathiowitz Lab LDPE, MDPE, UHMWPE	INTREPID™ 2499 NT Bimodal Polyethylene Resin	Trial HDPE samples available at Srivastava Lab
	Polyethylene - High Density	HDPE, pellet (2 lb or 900 g)	
Polyamide 12	Nylon 12- 181161	NYLON (PA12) POWDER, SINTRATEC	
		VESTAMID® NRG 2101 YE	

Table 1: Lab grade as well as commercially relevant samples of the focus polymers (PE, PA, Epoxy and PVDF) being considered for the early experimentation.

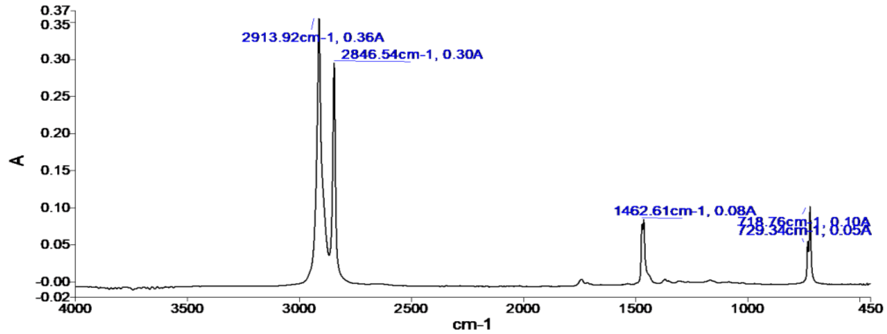

Figure 1: Experimental FTIR of commercial unprocessed polyethylene

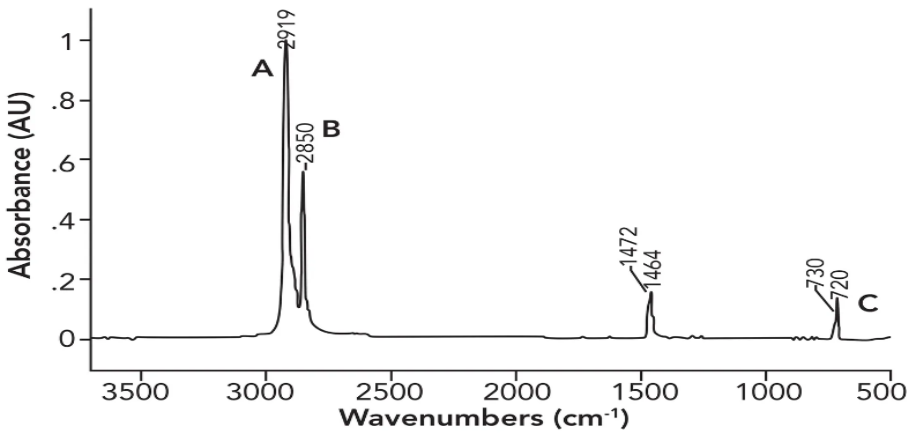

Figure 2: General FTIR of HDPE from literature (Smith, 2021 [10])

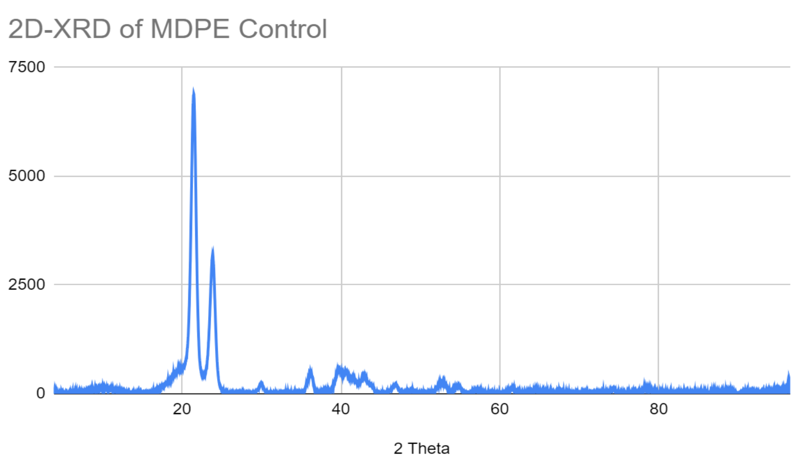

Figure 3: Experimental 2D-XRD of unprocessed MDPE samples

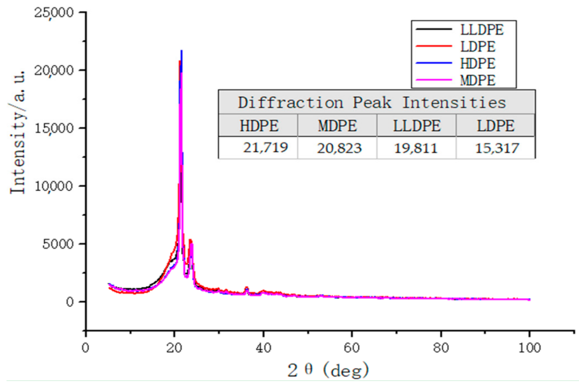

Figure 4: XRD of linear low density, low density, medium density and high density polyethylene from literature (Li et al., 2019 [11])

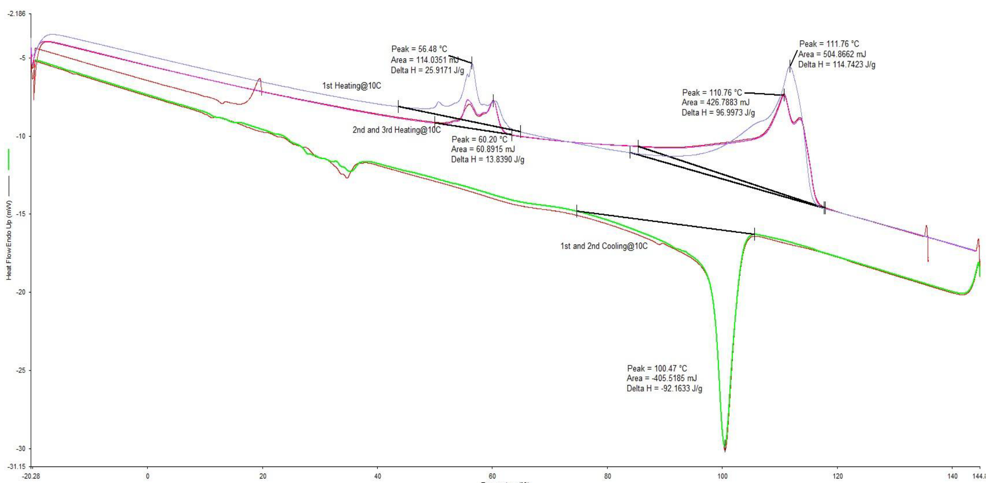

Figure 5: Experimental DSC scan of lab grade MDPE with preliminary analysis of thermal events

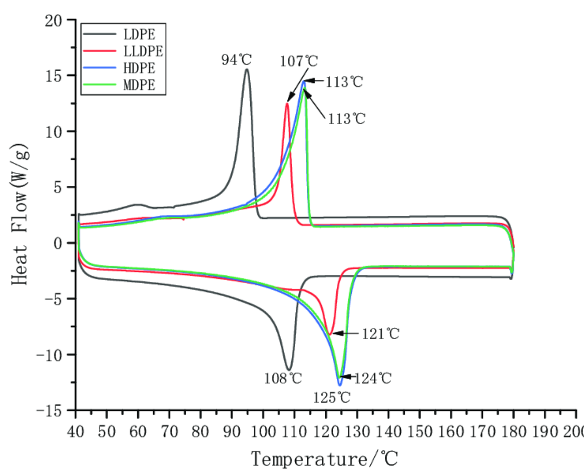

Figure 6: DSC scan of linear low density, low density, medium density and high density polyethylene from literature (Li et al., 2019)

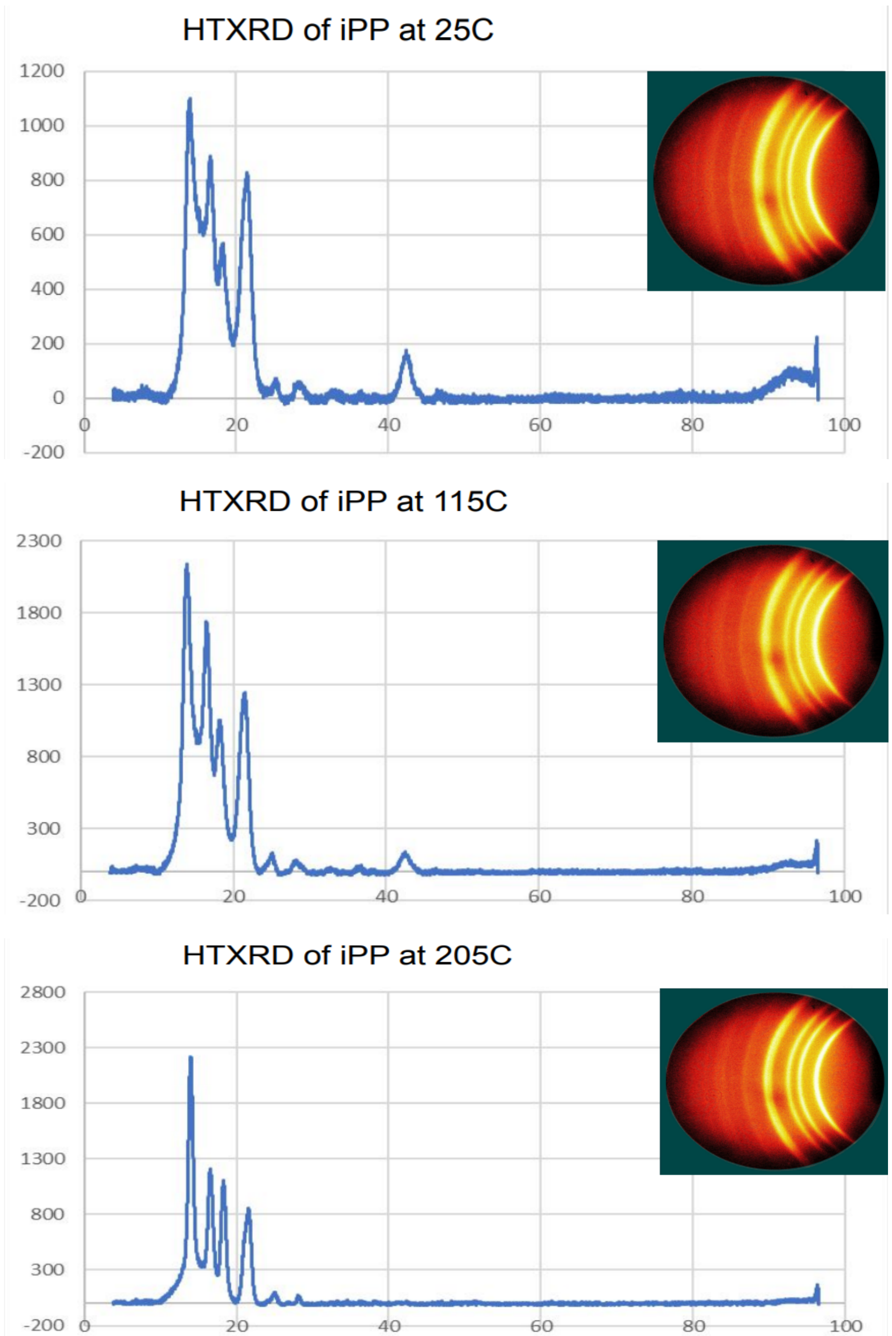

Figure 7: 2D-XRD scans of isotactic polypropylene under different temperature conditions (25C, 115C and 205C)

Project Financial Activities Incurred during the Reporting Period:

The Poling-Skutvik lab has purchased a larger drying oven (~$2000) to store samples for the long duration necessary to complete aging experiments. Small expenditures are covering laboratory supplies, including gloves and processing supplies such as non-stick paper and solvents for cleaning. Some funds are being disbursed to cover the tuition and fringe benefits for some of our graduate student researchers. Some of the first students have their graduate assistantship fully covered and provided by the University under the first academic year fellowship program.

Project Activities with Cost Share Partners:

Partial support for graduate students is provided as per the cost-share agreement.

Project Activities with External Partners:

The PI discussed getting some polymer samples from Dow Chemicals with a Dow polymer subject matter expert. The discussion was promising, and it is possible that we may get some polymer samples from them in the future to try. For the lab tests, polymer samples will be purchased/obtained from suitable vendors based on their availability to procure.

Potential Project Risks:

The Poling-Skutvik lab is currently awaiting delivery of pressure vessels to begin the advanced aging process. This delivery may have a longer than expected lead time which will slow the implementation of aging tests to evaluate polymer stability over time. We are working to ensure rapid delivery to begin these measurements.

In the long run, since the research work and research findings for liner polymer materials will be new, there could be a risk of unanticipated new findings. This risk will be managed by adjusting the research methods as new data comes.

Future Project Work:

The immediate future work being conducted in the Poling-Skutvik lab includes forming rheological samples in 20 mm disks and ASTM dogbone shapes for rheological and mechanical analysis. Additionally, Mohammadjavad is being trained on the x-ray microscope to conduct surface analysis of these samples. Hyun Young Nam will be trained on Scanning Electron Microscope. Hyun and Kevin will design and fabricate creep test and measurement systems for unaged and aged polymers.

Potential Impacts to Pipeline Safety:

The fundamental understanding of liner polymer materials' response, a materials property database, and material and design guidelines obtained through this collaborative research will help increase liner materials and design combinations for safer pipelines.

References

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