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Engineering Plastics Case Study

Released by:

Mark Jordi, Ph.D.
President

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MATERIAL SOLUTIONS. UNCOMPROMISING INTEGRITY.

200 Gilbert Street
Mansfield, MA 02048
P: (508) 966-1301
jordilabs.com

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The following test was performed:

1. Standardized Gel Permeation Chromatography (GPC)

Objective

The goal of this study was to demonstrate the importance of GPC in the analysis of commercially available plastics that are used in modern engineering materials. Herein, 5 types of plastics, namely nylon 6, nylon 12, polycarbonate, polyacetal, and polysulfone were analyzed by standardized Gel Permeation Chromatography (GPC), an analytical service offered at Jordi Labs.

Summary of Results

Five (5) engineering plastics were analyzed by GPC. The results are summarized in **Table 1-Table 5**.

Background

Engineering plastics have garnered increased industrial attention in the past decades due to the considerable benefits that they offer in such areas as aerospace, automotive manufacturing, electronic packaging, and more.[1] Due to their relatively easy and inexpensive fabrication requirements, reduced weight, and equaling or increased material strength and chemical stability, engineering plastics have slowly replaced wood, ceramic, and metals in the fabrication of engineering materials, and continue to find new applications.

Examples of engineering plastics include polycarbonates used in the making of automotive bumpers, headlamp lenses, and phones cases due to their high impact resistance, nylon largely used in the synthesis of fiber and in the electronic industries, polysulfone used in the fabribation of fuel cells and it can be reinforced to with glass fibers to produce high tensile materials, and more.

[1] https://www.sciencedirect.com/topics/materials-science/engineering-plastic

The molecular weight distribution of these engineering plastics is a key parameter used to estimate their mechanical strength and the onset of their degradation. Gel permeation chromatography (GPC), an analytical technique for the determination of the molecular weight distribution of polymers (**Figure 1**), can be used to determine the rate at which a polymeric material might decompose as part of accelerated aging studies.

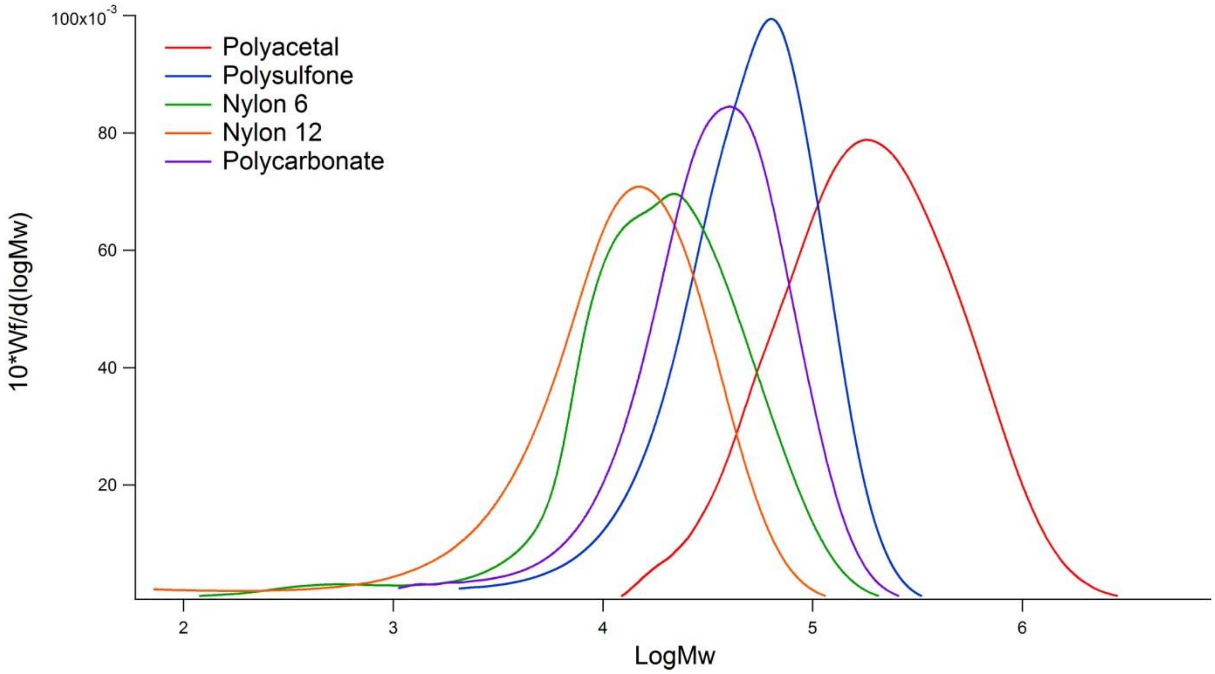

Figure 1. Overlay of the molecular weight distributions of the engineering plastics in this study

1. Nylon 6 & Nylon 12

Nylon is a group of plastics chemically described as linear aliphatic polyamides. Nylons are identified by their repeat units that are linked by amide bonds similar to the peptide bonds in proteins. Nylon consists of a broad range of material types, such as nylon 6, nylon 12, nylon 6,12, and more which offer a wide range of properties and applications.

Nylons are generally obtained via two synthetic routes. The first is a condensation reaction of a diamine and a dicarboxylic acid monomers to produce a nylon polymer or copolymer. When naming the resulting polymer, the first number of the nylon type consists of the number of carbons in the diamine monomer, while the second number refers to the number of carbons in the dicarboxylic acid monomer. For example, nylon 6,6, nylon 6,12, or nylon 1,6.

The second synthetic route to nylon consists of a ring-opening polymerization of a cyclic amide, otherwise referred to as a lactam ring. The identity of the resulting nylon is based on the number of atoms in the lactam monomer. For example, nylon 4, nylon 6, and nylon 12.

As a material, nylon is a thermoplastic material that has found significant applications in several domains. Nylon is used in a wide range of commercial materials including apparel, carpet manufacturing, car parts, electrical equipment, food packaging, and more.

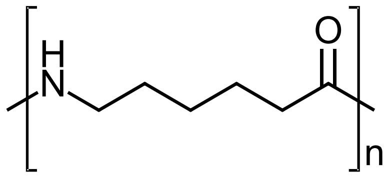

Figure 2. The chemical structure of Nylon 6

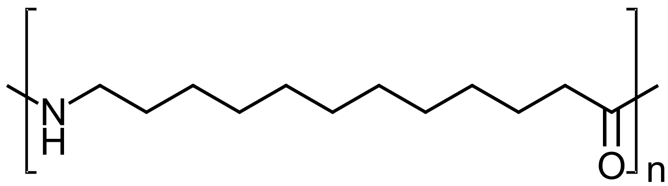

Figure 3. The chemical structure of Nylon 12

Sample Preparation

Nylon polymer samples were dissolved into HFIP with 0.01M NaTFA. The resulting solutions were agitated overnight at room temperature, yielding transparent solutions. The samples were then analyzed on a **Jordi Resolve Xstream Mixed Bed** column without further preparation.

Results

The calculated molecular weight averages (M_n, M_w, M_z) and dispersity values (PDI) are presented in **Table 1** and **Table 2**. The resulting weight fraction below 1 kDa is also presented in **Table 1** and **Table 2**. The refractive index chromatogram is presented in **Figure 4**.

Nylon 6
Table 1

Actual Mw Unknown

Polymer	M_n (Da)	M_w(Da)	M_z (Da)	PDI	Weight % < 1000 Da
Nylon 6 (Relative to PMMA)	6,295	25,606	48,942	4.07	2.33

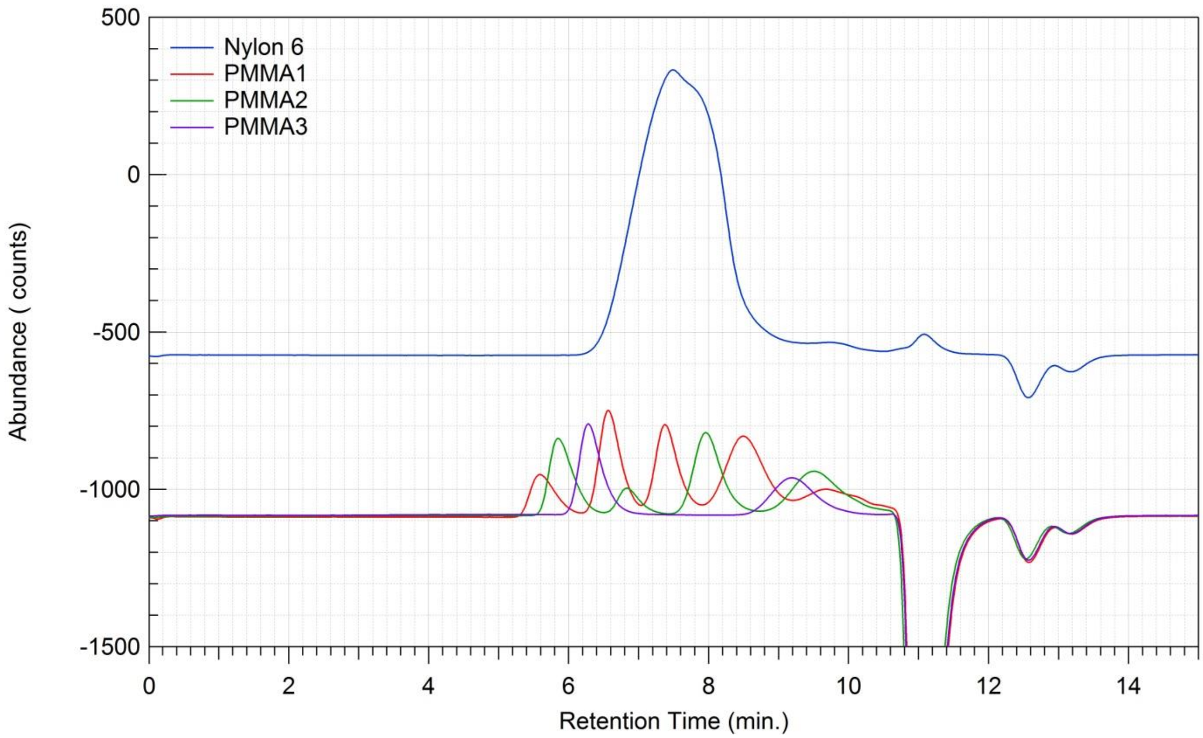

Figure 4. Refractive index (RI) chromatogram of Nylon 6

Nylon 12
Table 2

Actual Mw Unknown

Polymer	M_n (Da)	M_w(Da)	M_z (Da)	PDI	Weight % < 1000 Da
Nylon 12 (Relative to PMMA)	4,653	16,862	29,536	3.62	2.58

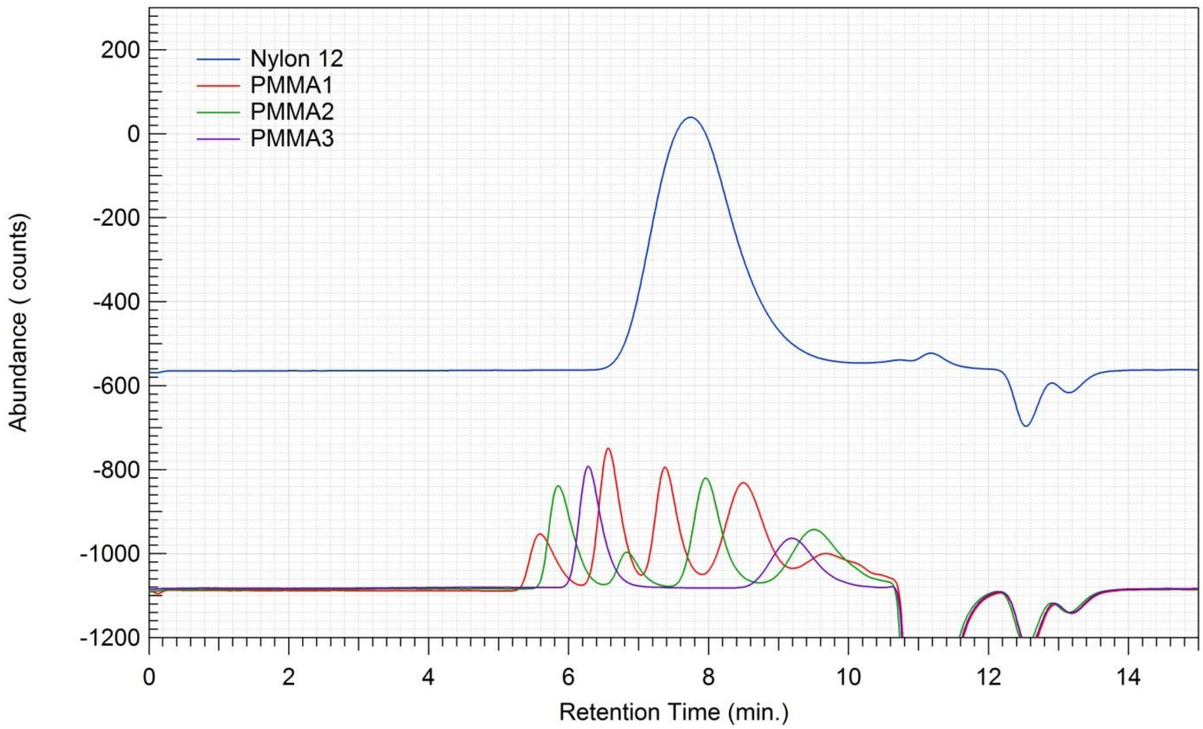

Figure 5. Refractive index (RI) chromatogram of Nylon 12

2. Polycarbonate

Polycarbonates are a group of thermoplastic polymers that contain carbonate groups in the backbone of the polymer chain. The most used polycarbonate is obtained by a condensation polymerization of bisphenol A and a carbonyl chloride such as phosgene or a diphenyl carbonate.

Structurally, polycarbonates are amorphous and transparent, allowing for the internal transmission of light in a similar way as glass materials. Additionally, polycarbonates are characterized by their rigidity, heat and flame resistance, and biocompatibility, which makes them perfect candidates for use in materials where impact resistance and/or transparency are a requirement. As a result, polycarbonates are found in a wide range of materials such as in the production of bulletproof glass, eyewear lenses, greenhouses, protective gear, automotive aircraft components, medical devices, phones, and more.[2]

Furthermore, the properties of polycarbonates can be readily adjusted and tuned by blending them with other polymers such as ABS and PET.

[2] https://www.creativemechanisms.com/blog/everything-you-need-to-know-about-polycarbonate-pc

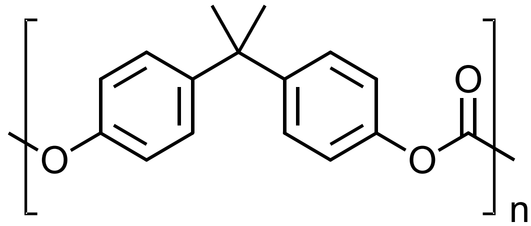

Figure 6. Chemical structure of Polycarbonate (derived from bisphenol A)

Sample Preparation

A polycarbonate sample was dissolved into THF. The resulting solution was agitated overnight at room temperature, yielding a transparent solution. The sample was then analyzed using a **Jordi Resolve DVB Mixed Bed** column without further preparation.

Results

The calculated molecular weight averages (M_n, M_w, M_z) and dispersity values (PDI) are presented in **Table 3**. The resulting weight fraction below 1 kDa is also presented in **Table 3**. The refractive index chromatogram is presented in **Figure 7**.

Polycarbonate
Table 3

Actual Mn 17,300

Polymer	M_n (Da)	M_w(Da)	M_z (Da)	PDI	Weight % < 1000 Da
Polycarbonate (Relative to PS)	18,752	40,469	65,912	2.16	N.D.

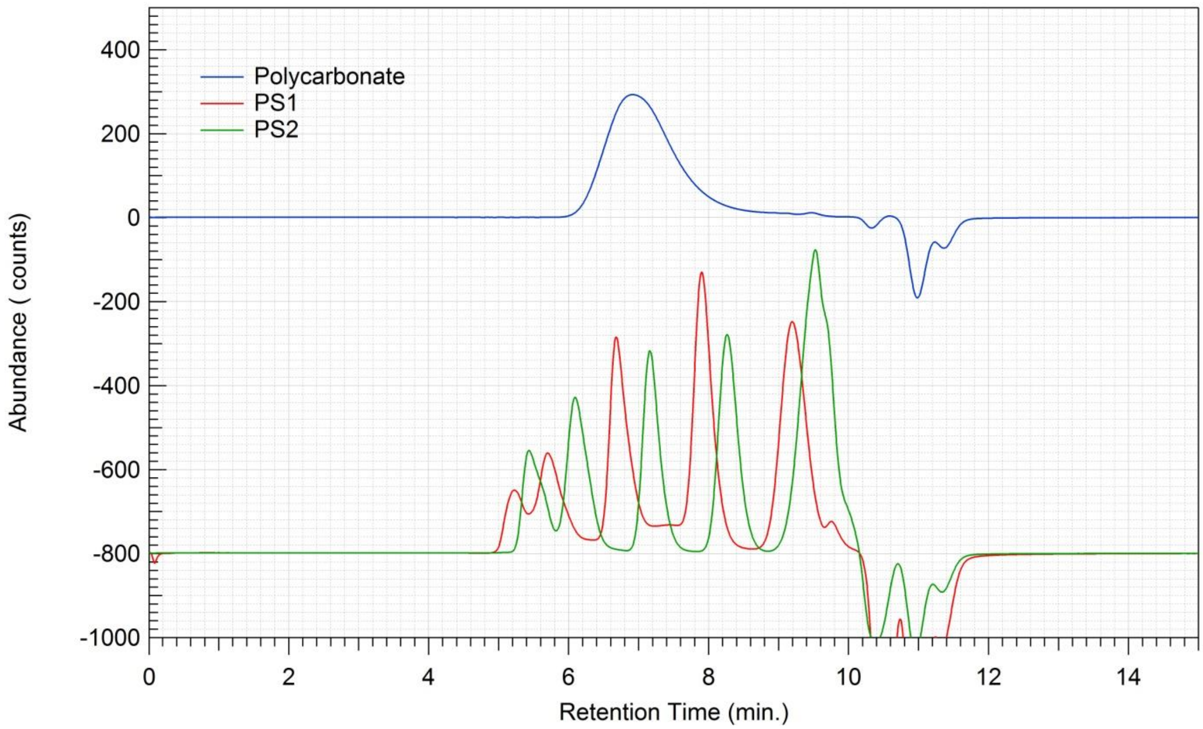

Figure 7. Refractive index (RI) chromatogram of Polycarbonate

3. Polyacetal

Polyoxymethylene (POM), also known as polyacetal or polyformaldehyde, consists of oxymethylene repeat units. Polyacetal homopolymers are obtained by polymerizing anhydrous formaldehyde in the presence of an anionic polymerization catalyst.[3]

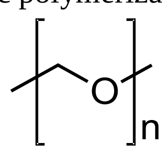

Figure 8. Chemical structure of Polyacetal

Physically, polyacetal is a crystalline thermoplastic polymer characterized by its tensile strength, stiffness, toughness, high heat resistance, low friction and low water absorption. As a result, polyacetal is used as a replacement for metal parts in electronic components, mechanical and automotive parts. Polyacetal is also used in the production of rods, pipes, profiles and sheets that are often further processed to make high precision finished products.[4]

[3] https://academicworks.cuny.edu/cgi/viewcontent.cgi?article=1642&context=gc_etds
[4] https://polymerdatabase.com/polymer%20classes/Polyacetal%20type.html

Sample Preparation

Polyacetal sample was dissolved into HFIP with 0.01M NaTFA. The resulting solution was agitated overnight at room temperature, yielding transparent solution. The sample was then analyzed on a **Jordi Resolve Xstream Mixed Bed** column without further preparation.

Results

The calculated molecular weight averages (M_n, M_w, M_z) and dispersity values (PDI) are presented in **Table 4**. The resulting weight fraction below 1 kDa is also presented in **Table 4**. The refractive index chromatogram is presented in **Figure 9**.

Polyacetal
Table 4

Actual Mw Unknown

Polymer	M_n (Da)	M_w(Da)	M_z (Da)	PDI	Weight % < 1000 Da
Polyacetal (Relative to PMMA)	107,297	275,581	671,529	2.57	N.D.

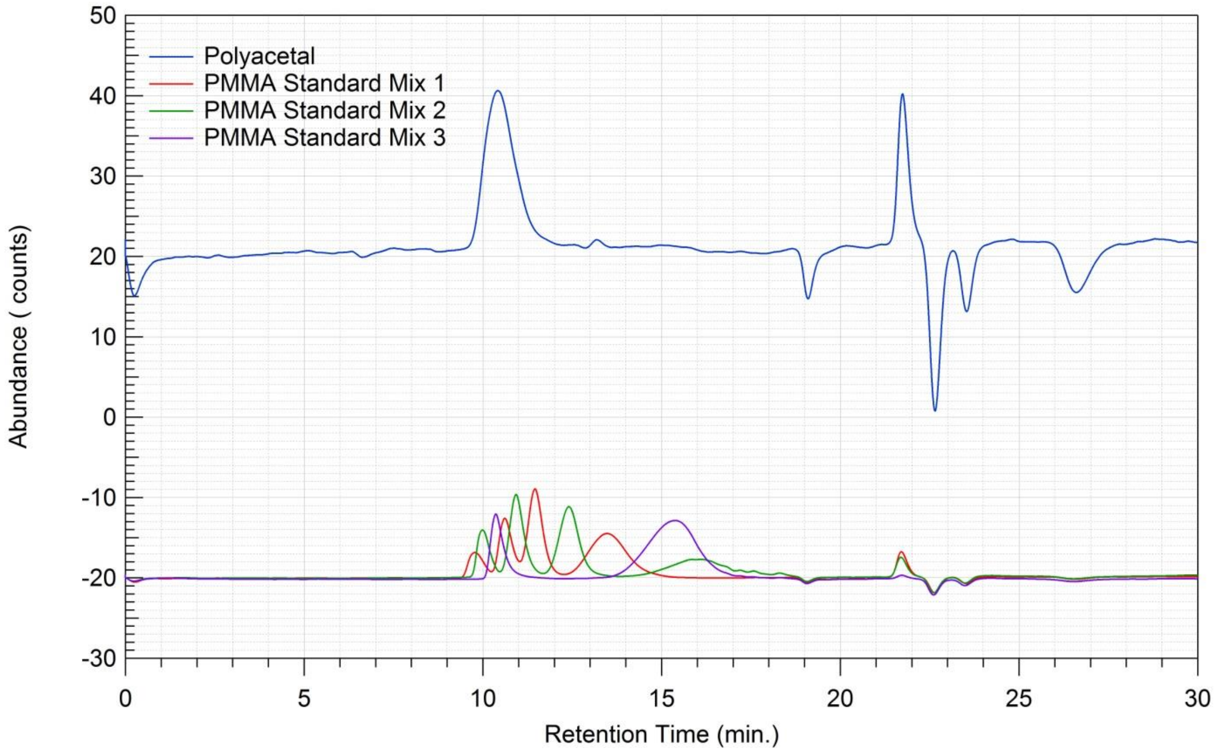

Figure 9. Refractive index (RI) chromatogram of Polyacetal

4. Polysulfone

Polysulfones, also referred to as polyaryl sulfones, are a group of thermoplastic polymers that contain an aryl-SO2-aryl subunit in the backbone of the polymer chain. Polysulfones are obtained by a condensation polymerization of the sodium salt of an aromatic diphenol and bis(4-chlorophenyl)sulfone.[5]

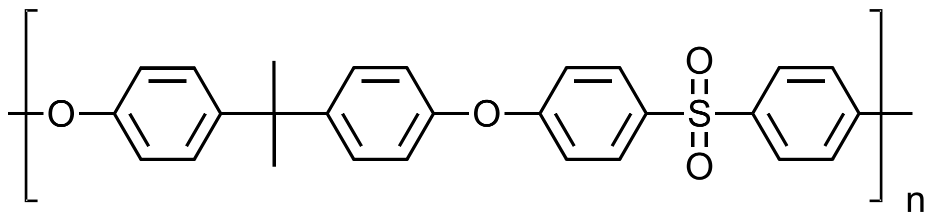

Figure 10. Chemical structure of Polysulfone

Similar to polycarbonates, polysulfones are characterized by their rigidity, stiffness, high strength, and transparency, and their ability to retain these properties within a wide temperature range of -100 °C and 150 °C. Polysulfones are also known to possess a high chemical resistance to oxidizing agents, mineral acids, alkali, and electrolytes within a pH range of 2 to 13.[5]

Due to the aforementioned properties, polysulfones are heavily used in the production of filter cartridges and membranes for medical applications. Polysulfones are also used in fuel cells, and the reinforcement of glass fibers.[6]

Sample Preparation

A polysulfone sample was dissolved into DMAC with 0.1M LiBr. The resulting solution was agitated overnight at room temperature, yielding a transparent solution. The sample was then analyzed on a **Jordi Resolve DVB Mixed Bed** without further preparation.

Results

The calculated molecular weight averages (M_n, M_w, M_z) and dispersity values (PDI) are presented in **Table 5**. The resulting weight fraction below 1 kDa is also presented in **Table 5**. The refractive index chromatogram is presented in **Figure 11**.

[5] Parker, D. , Bussink, J. , van de Grampel, H. T., Wheatley, G. W., Dorf, E. , Ostlinning, E. and Reinking, K. (2000). Polymers, High-Temperature. In Ullmann's Encyclopedia of Industrial Chemistry, (Ed.). doi:10.1002/14356007.a21_449

[6] https://www.sciencedirect.com/science/article/pii/S0376738808007813?via%3Dihub

Table 5

Actual Mw 60,000

Polymer	M_n (Da)	M_w(Da)	M_z (Da)	PDI	Weight % < 1000 Da
Polysulfone (Relative to PMMA)	28,860	60,301	93,402	2.09	N.D.

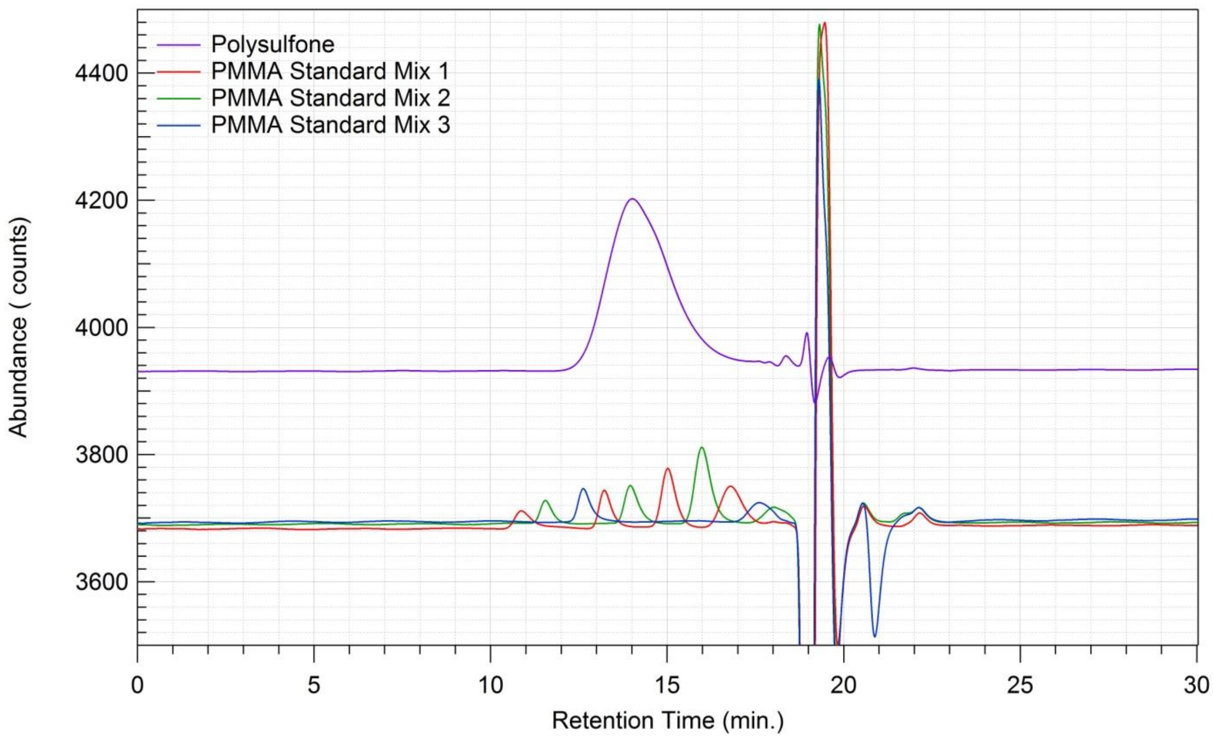

Figure 11. Refractive index (RI) chromatogram of Polysulfone

Closing Comments

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Jordi Labs specializes in polymer analysis and has more than 35 years' experience performing regulatory, quality control and failure testing. We are one of the few labs in the United States specialized in this type of testing. We will work closely with you to help explain your test results and complete your project goals. We appreciate your business and are looking forward to speaking with you concerning these results.

Sincerely,

Yuanlin Deng

Yuanlin Deng, Ph.D.
Senior Chemist
Jordi Labs LLC

Mark Jordi

Mark Jordi, Ph. D.
President
Jordi Labs LLC

Pierre C. Mbarushimana

Pierre C. Mbarushimana, Ph.D.
Senior Chemist
Jordi Labs LLC