SUSTAINABLE COMPOSITES BASED ON POLYAMIDES AND CELLULOSE FIBERS

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Ford's Sustainable Materials Strategy

➢ Vision

- ✓ Ford Motor Company will ensure that our products are engineered to enable sustainable materials leadership without compromise to Product Quality, Durability, Performance or Economics.

➢ Key Positions

- ✓ Recycled and renewable materials must be selected whenever technically and economically feasible.
- ✓ When we use recycled and renewable materials, there will be no compromise to Product Quality, Durability & Performance or Economics.
- ✓ We will enhance technologies, tools and enablers to help validate, select and track the use of these materials in our products.
- ✓ The use of recycled and renewable content is increased year by year, model by model where possible.

Lee 2013

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Ford-Plastic Research Group

PLASTIC RESEARCH

- Bioplastics
  - Hydrocarbons from Biomass
  - Alcohols PET, PU, TPU
  - Acids PLA, PA
  - CO/CO2 PPC
- Nano-Composites
  - Thermoplastic Nanocomposites
  - Polyurethane Foams
  - 3D P/Additive Manufacturing
- Recycled and Agricultural Composites
  - Post Consumer Plastics
  - PIR Carbon Fibers
  - PIR TPU
  - Agricultural Wastes
- Advanced Technologies and LCA
  - Microcellular Foaming
  - 3D P/Additive Manufacturing
  - Comparative LCA

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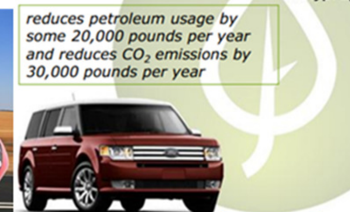
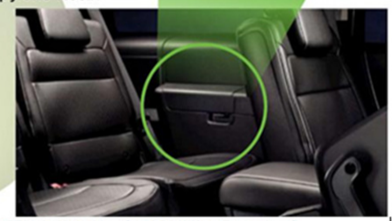
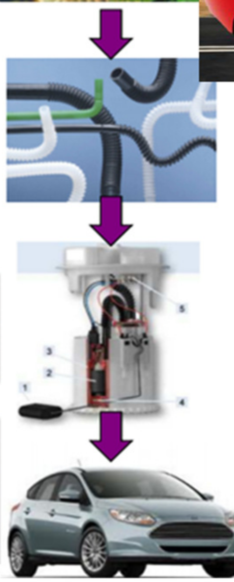
Sustainable Materials at Ford Today

“Henry Ford (the founder of Ford) was first to introduce bio-based materials (soy-bean products) to automobiles in 1940. Continuing the legacy, Ford has been actively involved in conducting active renewable materials research and development program.”

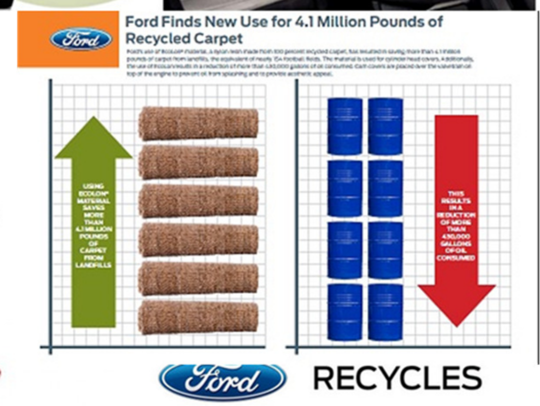


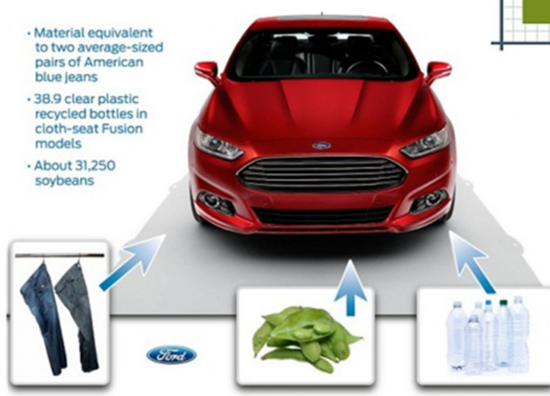


“The average Ford vehicle now uses between 20 to 40 pounds of renewable materials.”



“Ford use more than 50 million pounds of post-consumer recycled materials on the exterior of Ford vehicles made in NA, which translates to more than 17.8 pounds per vehicle on average across our NA fleet.”





“We're making changes to reduce our environmental footprint. In addition to reducing our greenhouse gas emissions, supporting conservation efforts and making more fuel-efficient vehicles, we're also improving the materials we use to build our vehicles”.

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Project Overview

Background

- ✓ Promising cellulose-polymer concept from cellulose and bio-based nylon.
- ✓ Fully or partially bio-based
- ✓ Good mechanical properties
- ✓ Perceived naturalness

Challenges

- ✓ Lack of viable industrial production methods to make end consumer products
- ✓ Degradation and odor

Objective

- ✓ Development of a processing technology that allows to make injection molded parts out of cellulose and nylon but keeping material bio identity.

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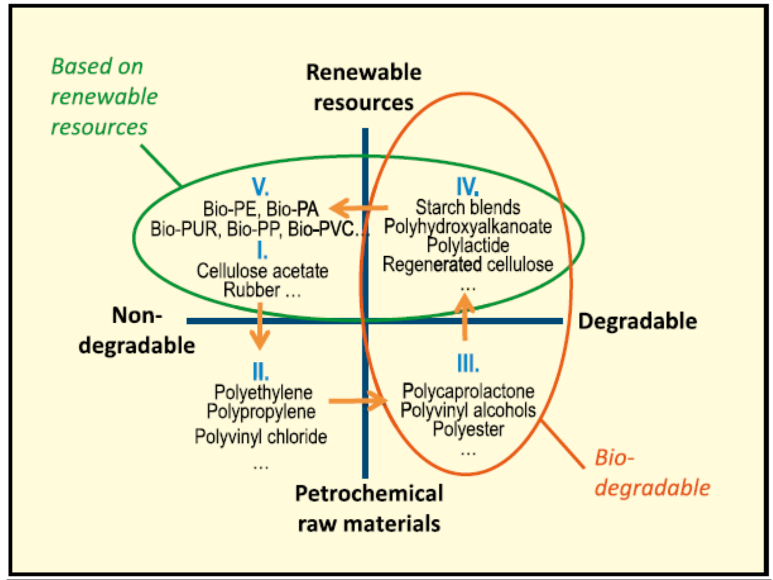
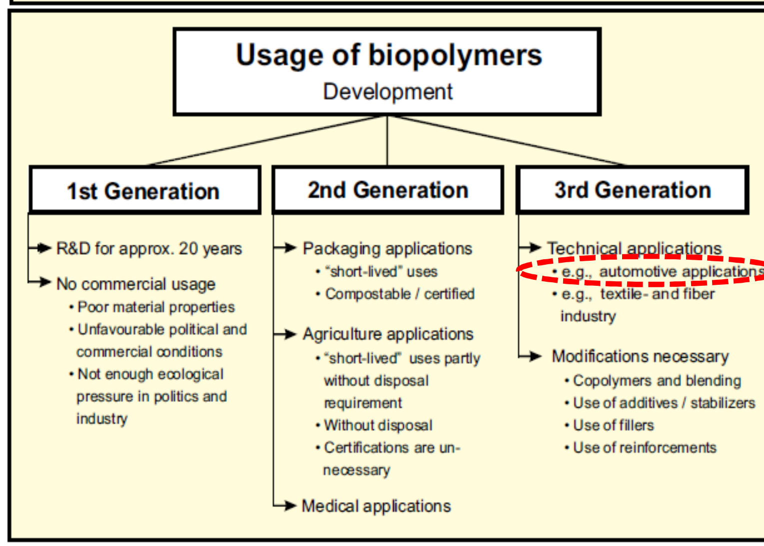
Background-Bio-Based Polymer

- Limited fossil resources, increased cost of fossil resources and public concern about climate change are significant drivers.
- The bio-based polymer business is 0.4% of the total polymer.
- Bio-based polymers not only replace existing polymers in a number of applications, but also provide new combinations of properties for new applications.





Endres, Hans-Josef and Siebert-Raths, Andrea 2011

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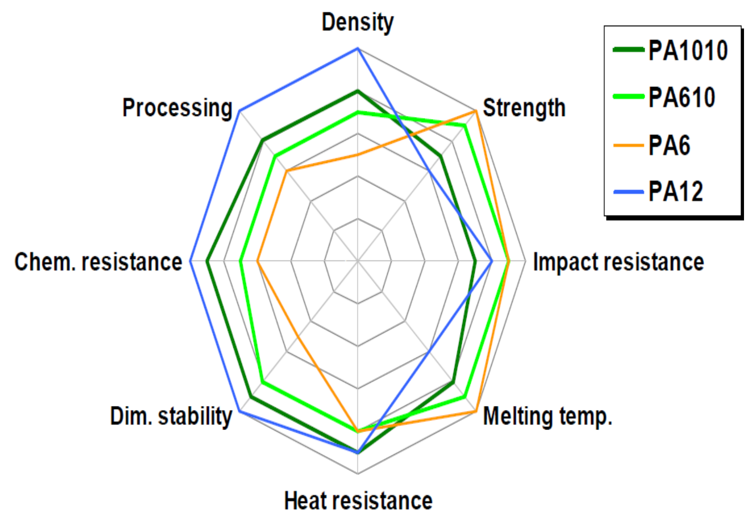
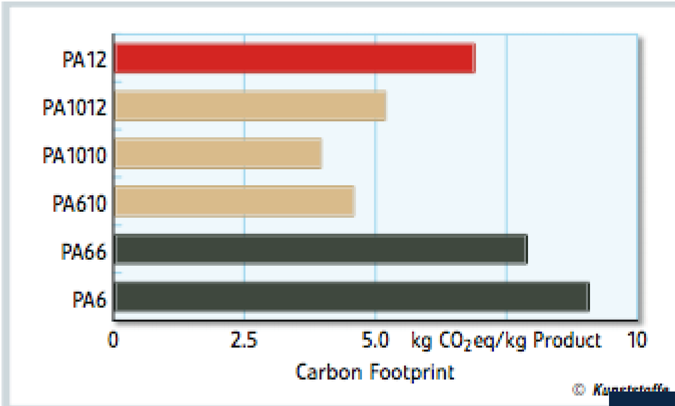
What is Bio-Based Nylon?

- **High bio content,**
- **Significant reduction of CO2 emissions,**
- **Polymers with strong properties,**
- **True alternatives to crude oil based Engineering Plastics,**
- **Fully recyclable polymers,**
- **Non-biodegradable and durable polymers.**





http://www.biyoplastik.net/

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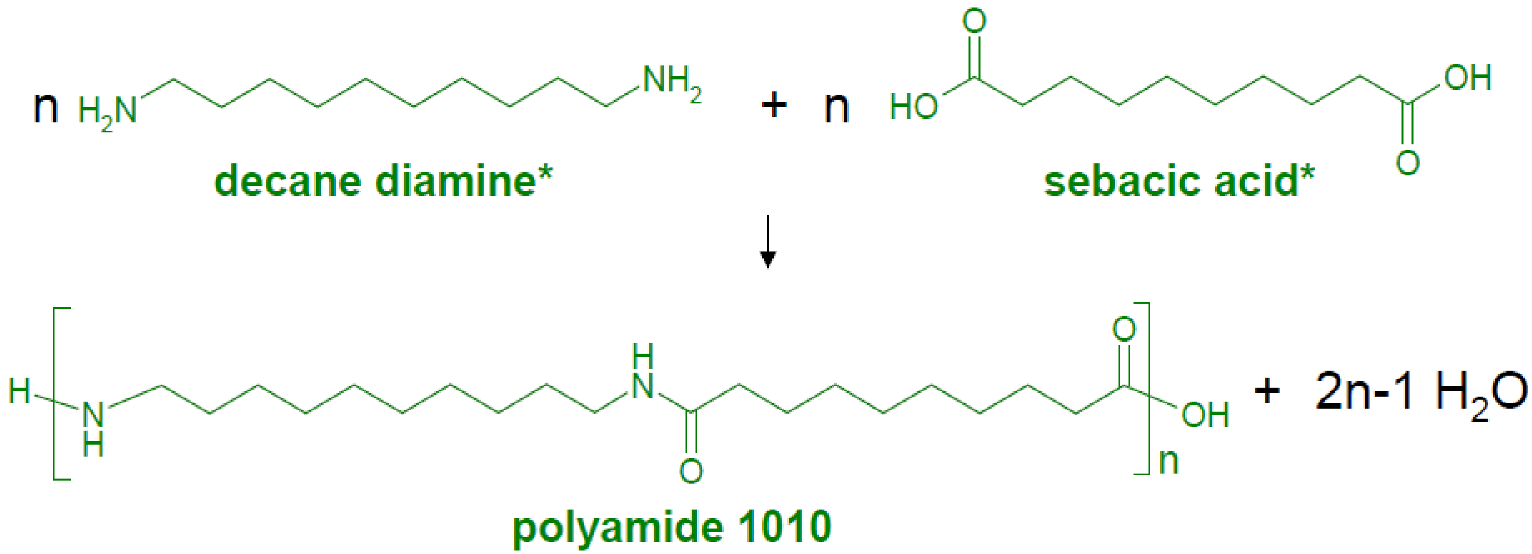
Why Nylon 1010?



- **Very high bio content up to 99% (Grilamid 1S PA1010),**
- **Properties similar to PA12,**
- **Very low moisture absorption,**
- **Strong UV and chemical resistance,**
- **For injection molding and extrusion,**
- **Low melting temperature compared to other bio-based nylons.**

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Formulations

Sample Number	Compounding	PA1010	PA610	PA6	Cellulose
1	TSE	100	-	-	-
2	TSE	-	100	-	-
3	TSE	-	-	100	-
4	TSE	50	50	-	-
5	TSE	50	-	50	-
6	TSE+MB	90	-	-	10
7	TSE+MB	80	-	-	20
8	TSE+MB	70	-	-	30
9	TSE+MB	-	90	-	10
10	TSE+MB	-	80	-	20
11	TSE+MB	-	70	-	30
12	TSE+MB	40	40	-	20
13	TSE+MB	40	-	40	20

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Production – TSE and IM

Cellulose
PA6/PA610/PA1010

Melt Blend
TSE

Dry Ground Mixture

Injection Molding

ASTM Test Samples

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Temperatures Profiles for Composites (°C)

PA1010

TSE	IM
195	235
195	240
200	245
200	250
205	250
205	
210	

PA610

TSE	IM
215	240
215	245
220	250
220	255
225	260
225	
230	

PA6

TSE	IM
215	235
215	240
220	245
220	250
225	250
225	
230	

TSE Screw Speed:200rpm

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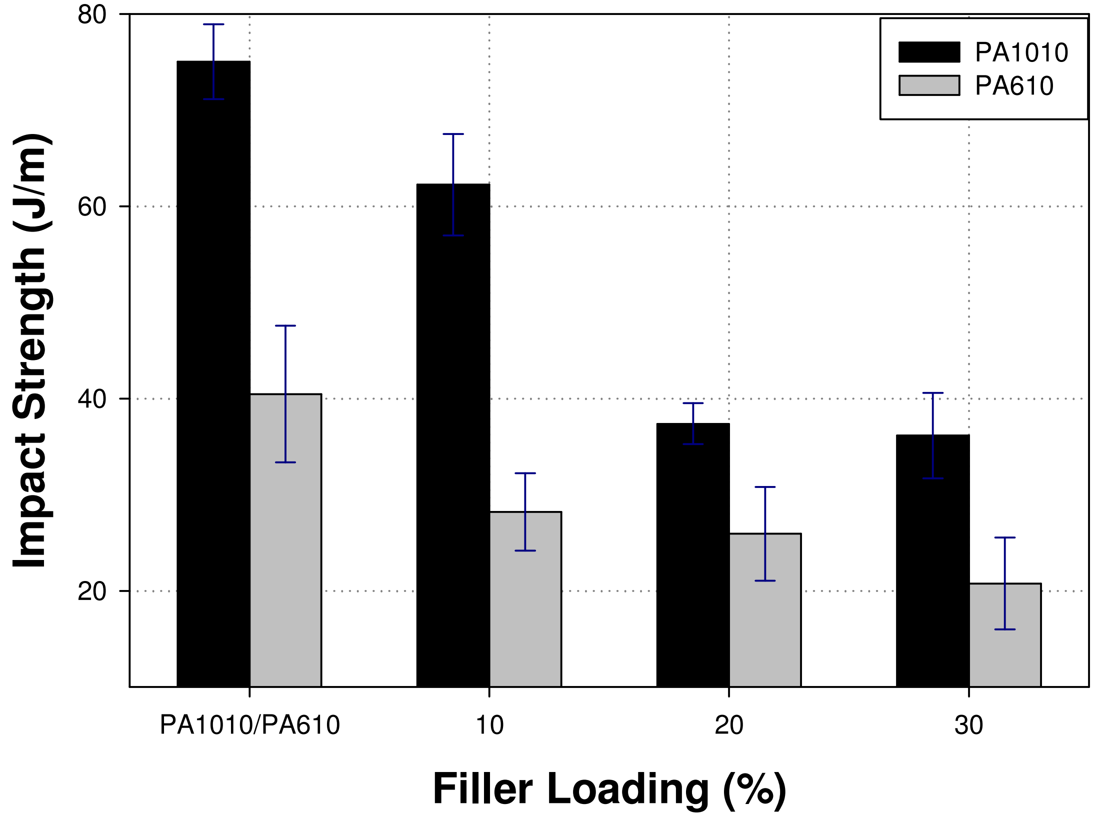
Impact Strength of Composites



➢*Increased cellulose loading has a negative effect on impact strength.*

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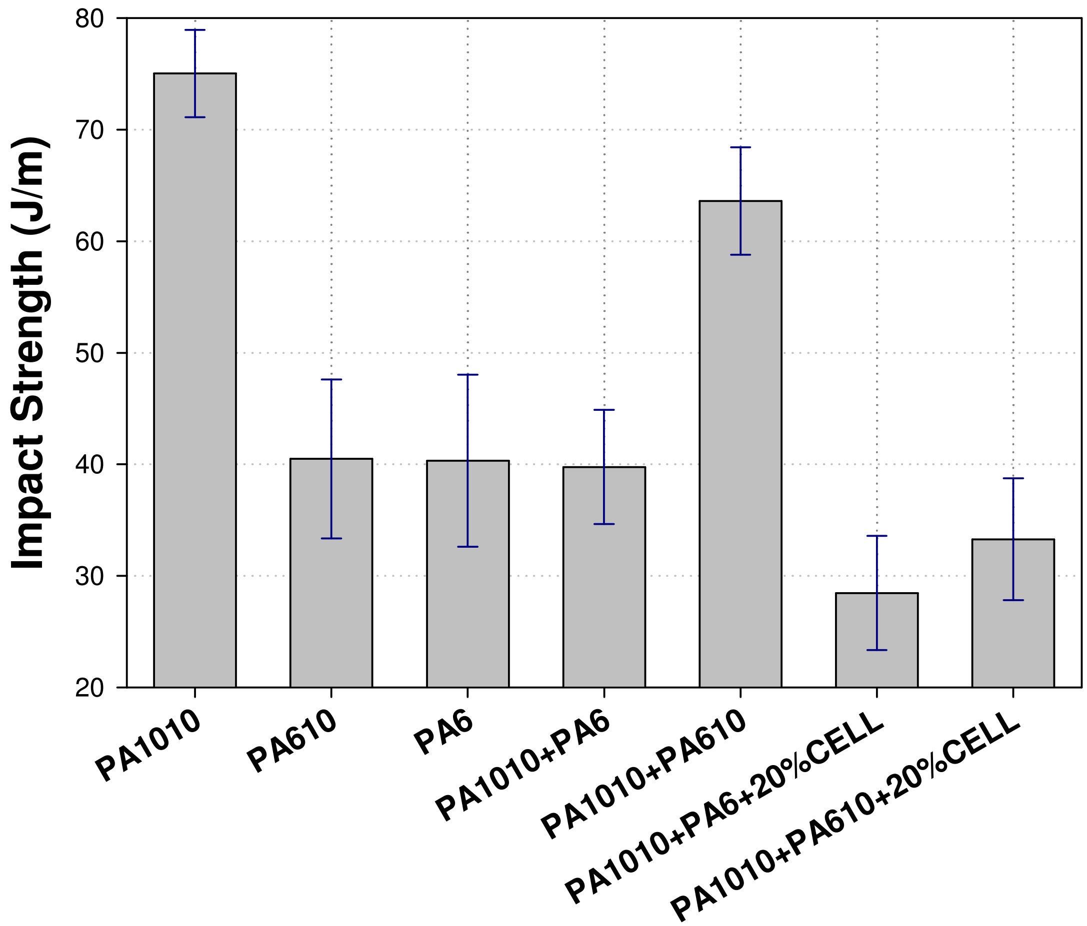
Impact Strength of Blends and Composites



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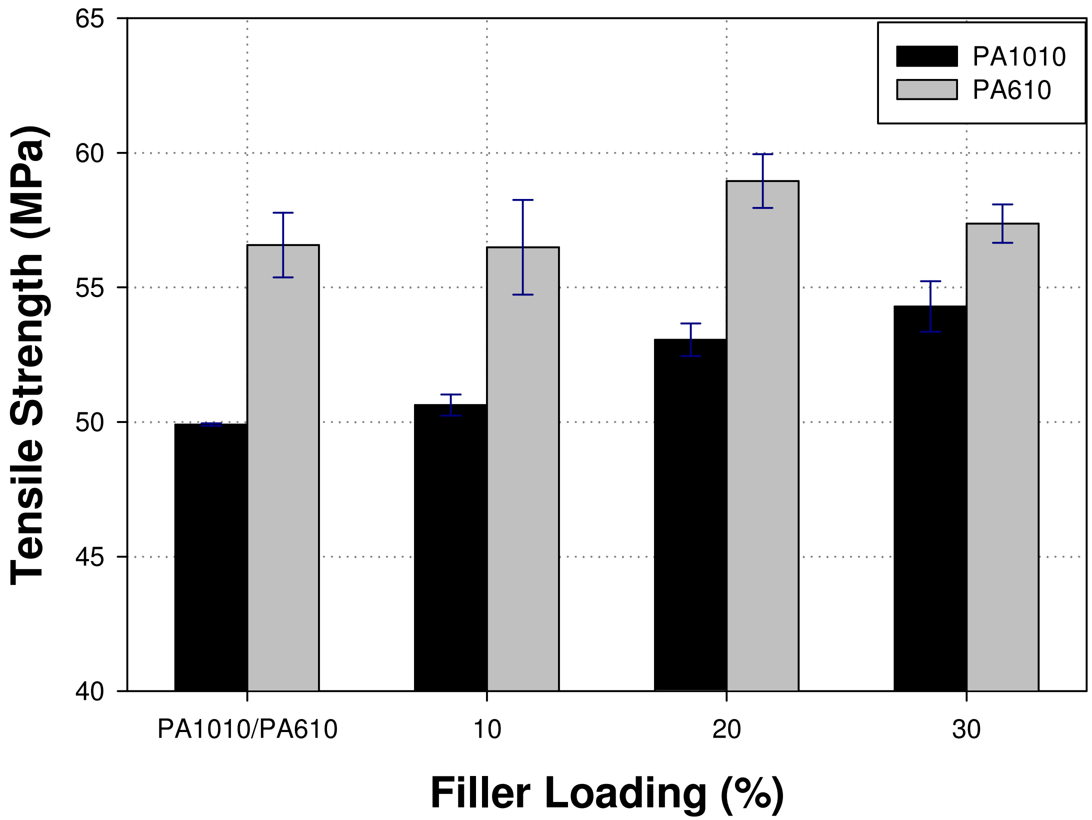
Tensile Strength of Composites



➢*Increased cellulose loading has a positive effect on tensile strength.*

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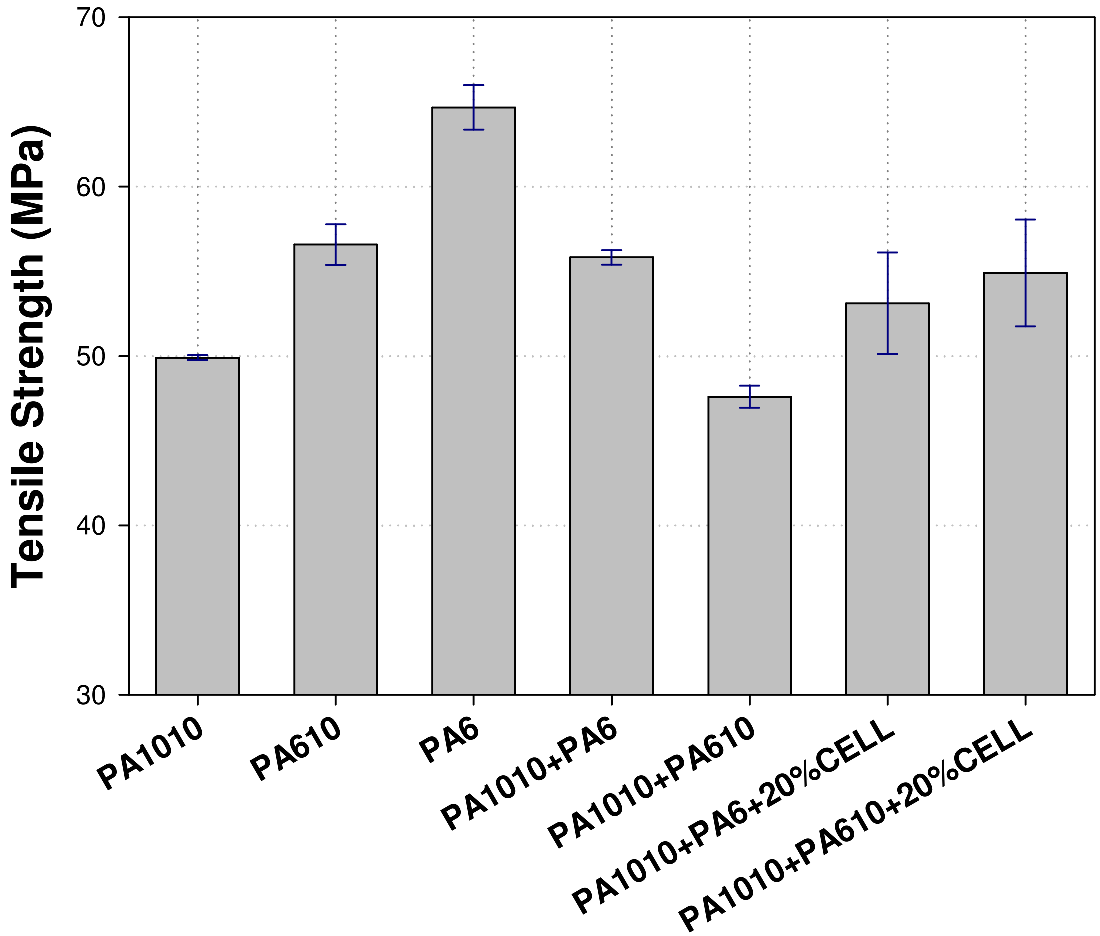
Tensile Strength of Blends and Composites



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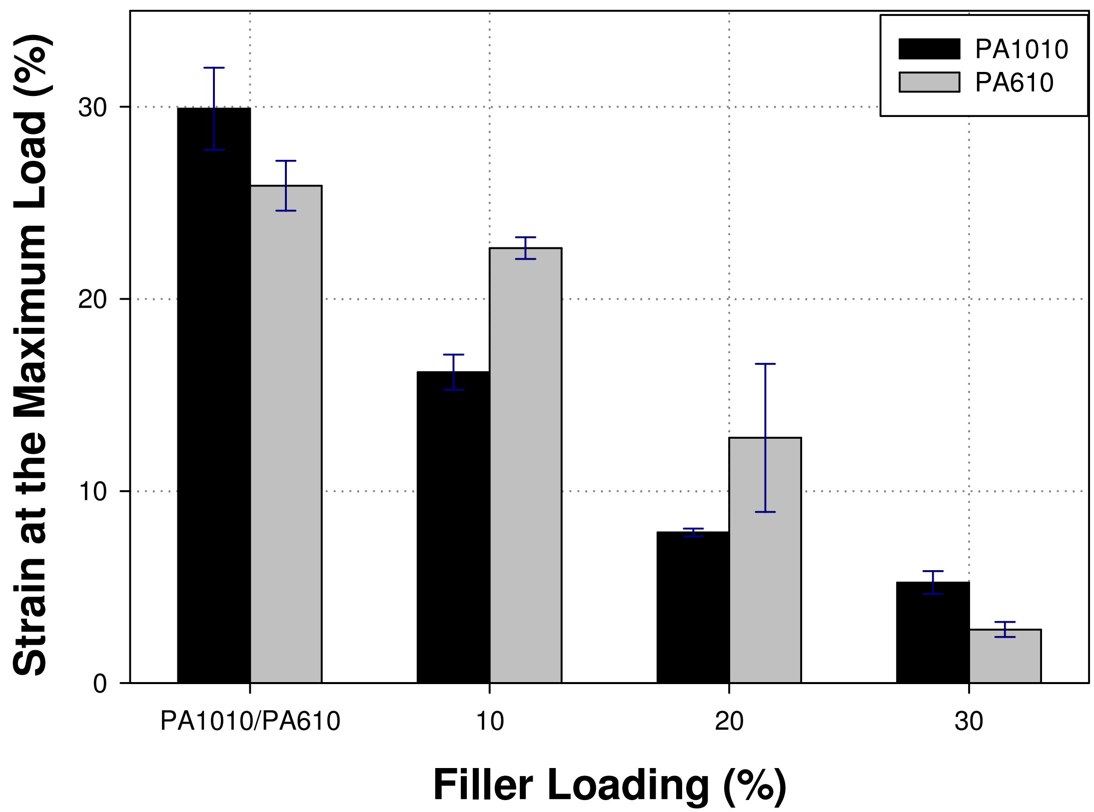
Strain at the Max. Load of Composites



➢ ***The elongation at break of composites was shorter than neat composites.***

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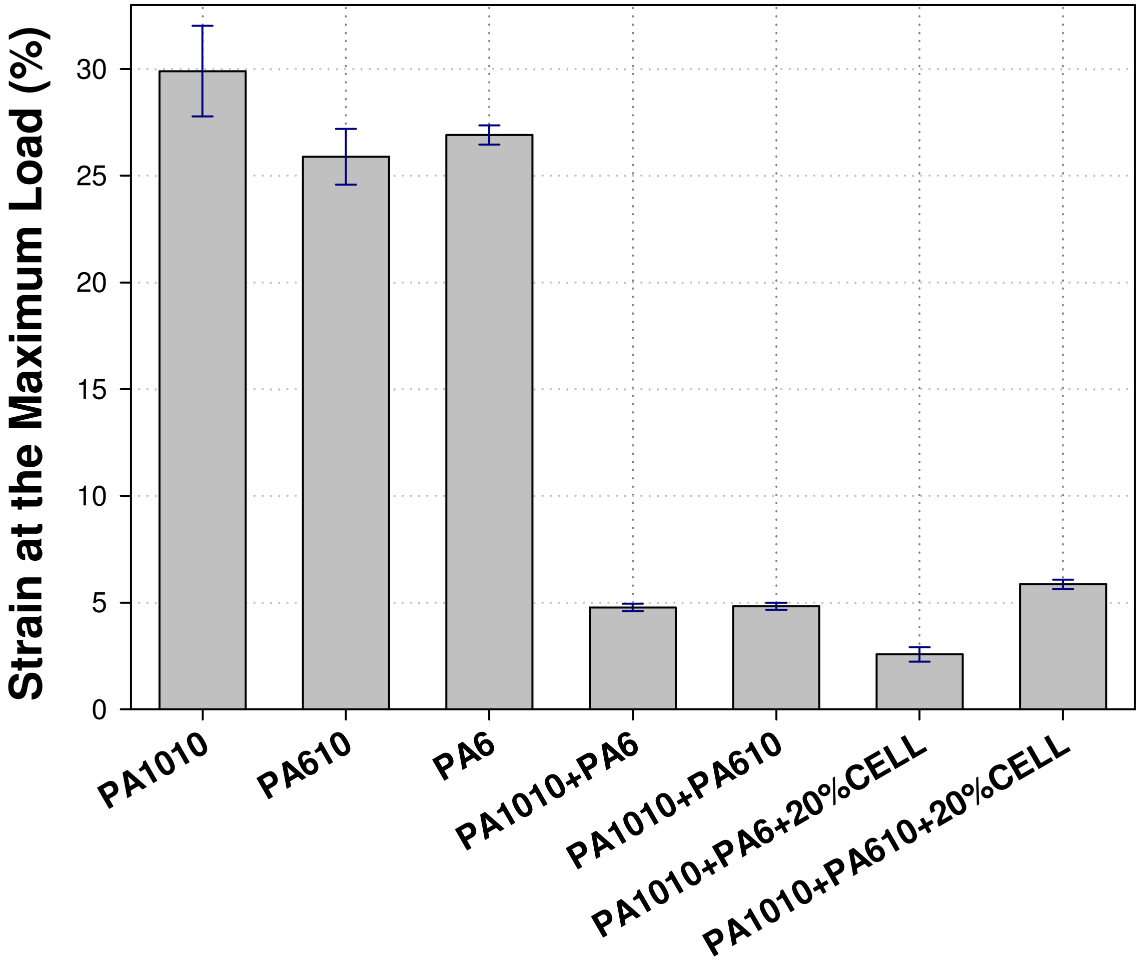
Strain at the Max. Load of Blends and Composites



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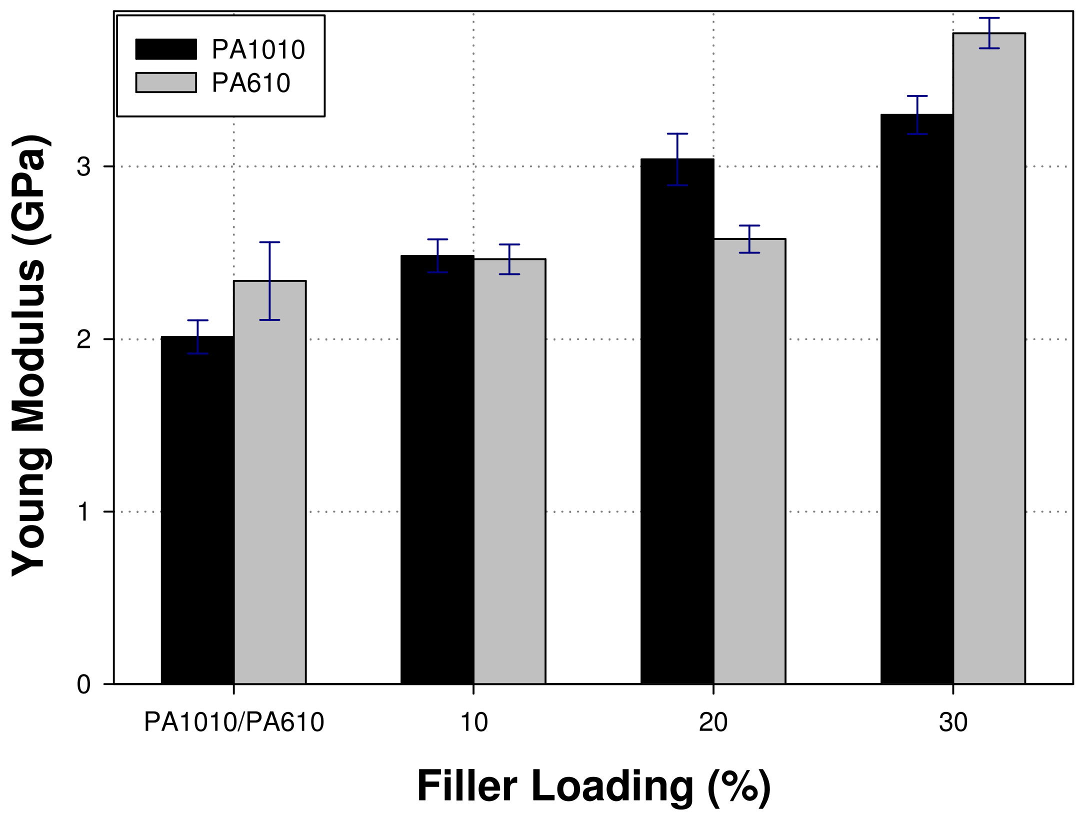
Young Modulus of Composites



➢ ***MOE increased with the addition of cellulose. The increase in MOE is only to the reinforcement effect of dispersed cellulose.***

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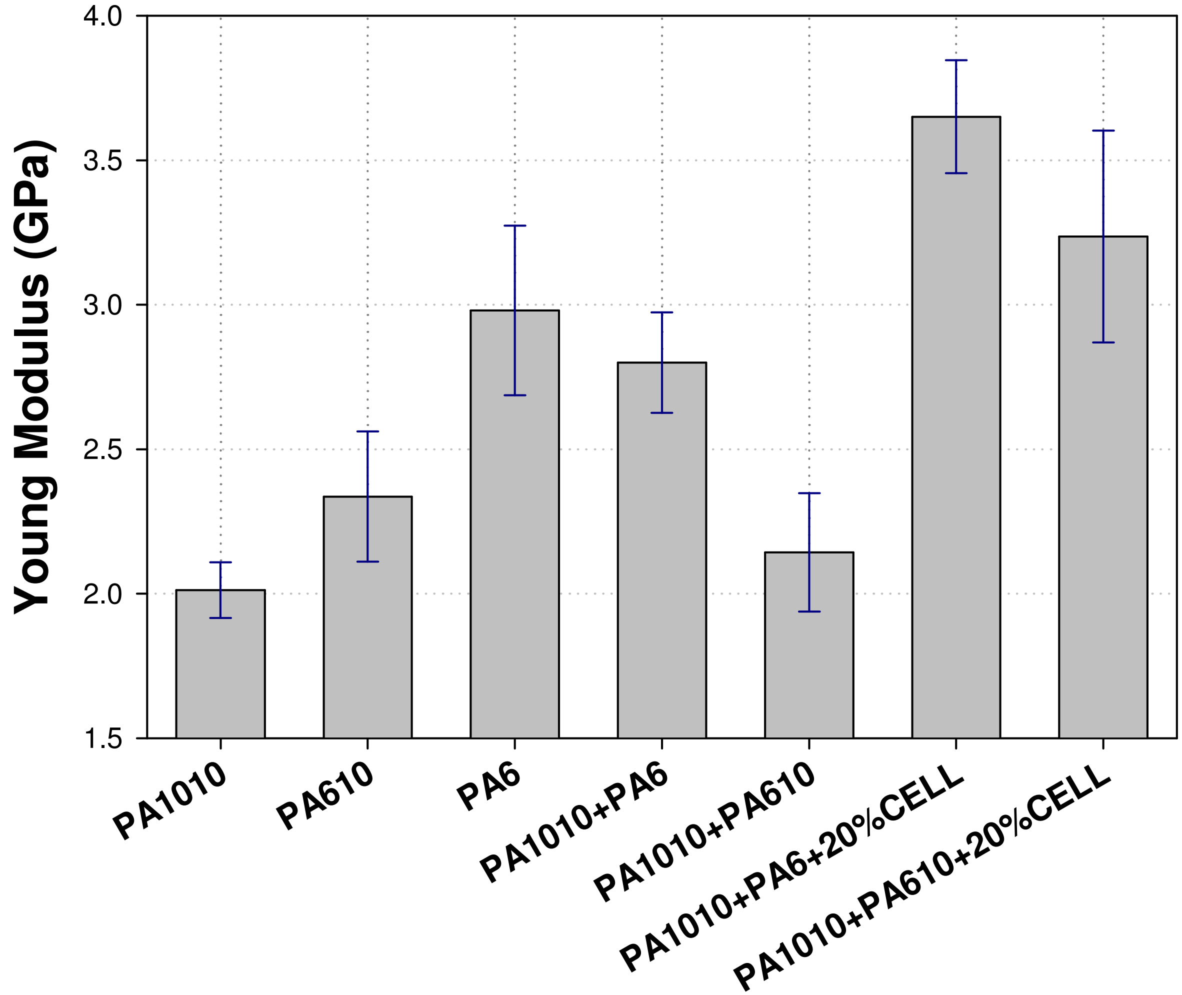
Young Modulus of Blends and ETPCs



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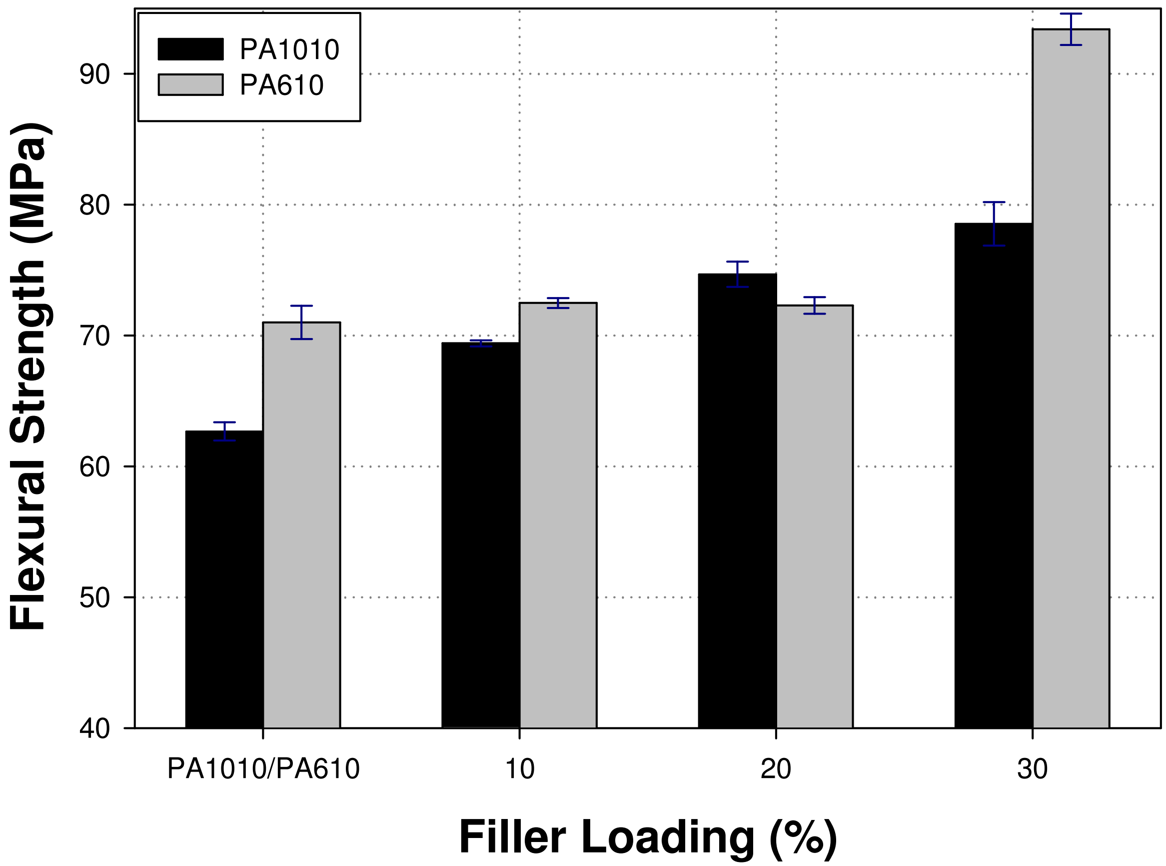
Flexural Strength of Composites



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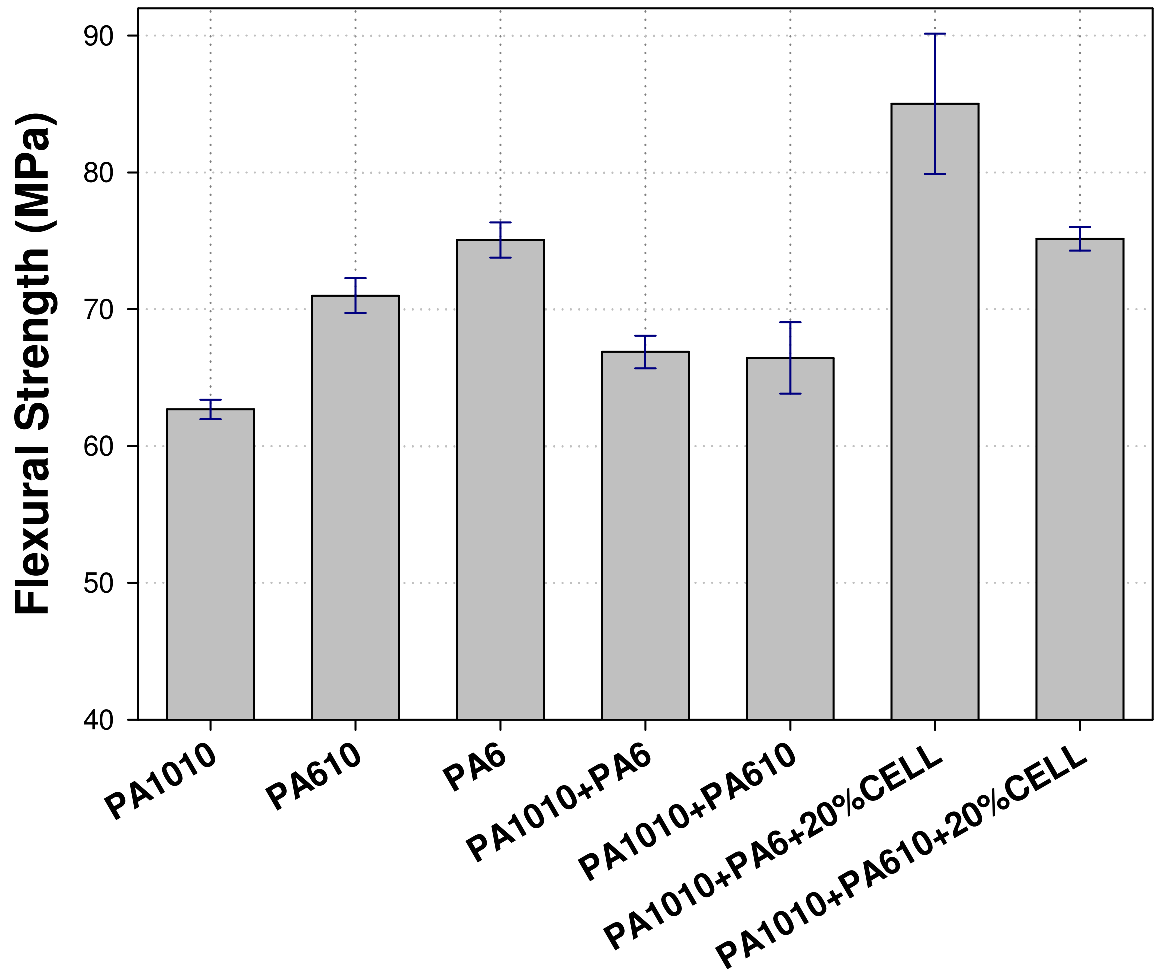
Flexural Strength of Blends and Composites



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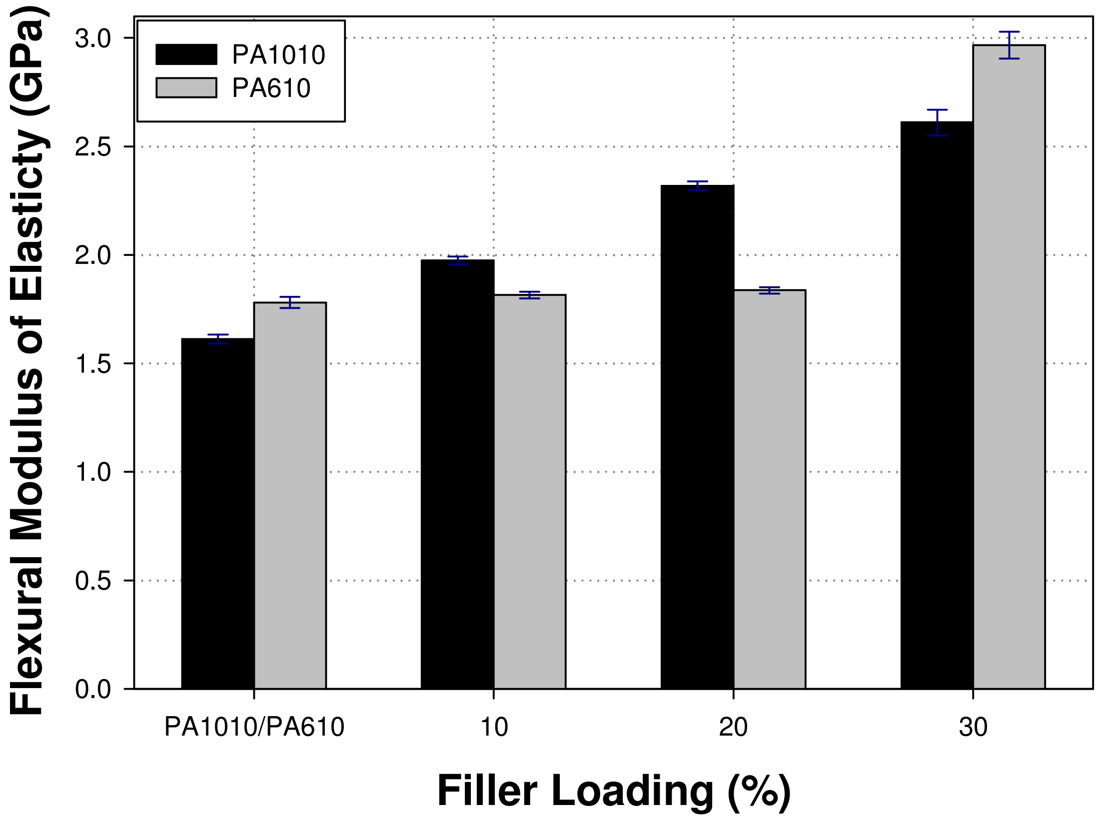
FMOE of ETPCs



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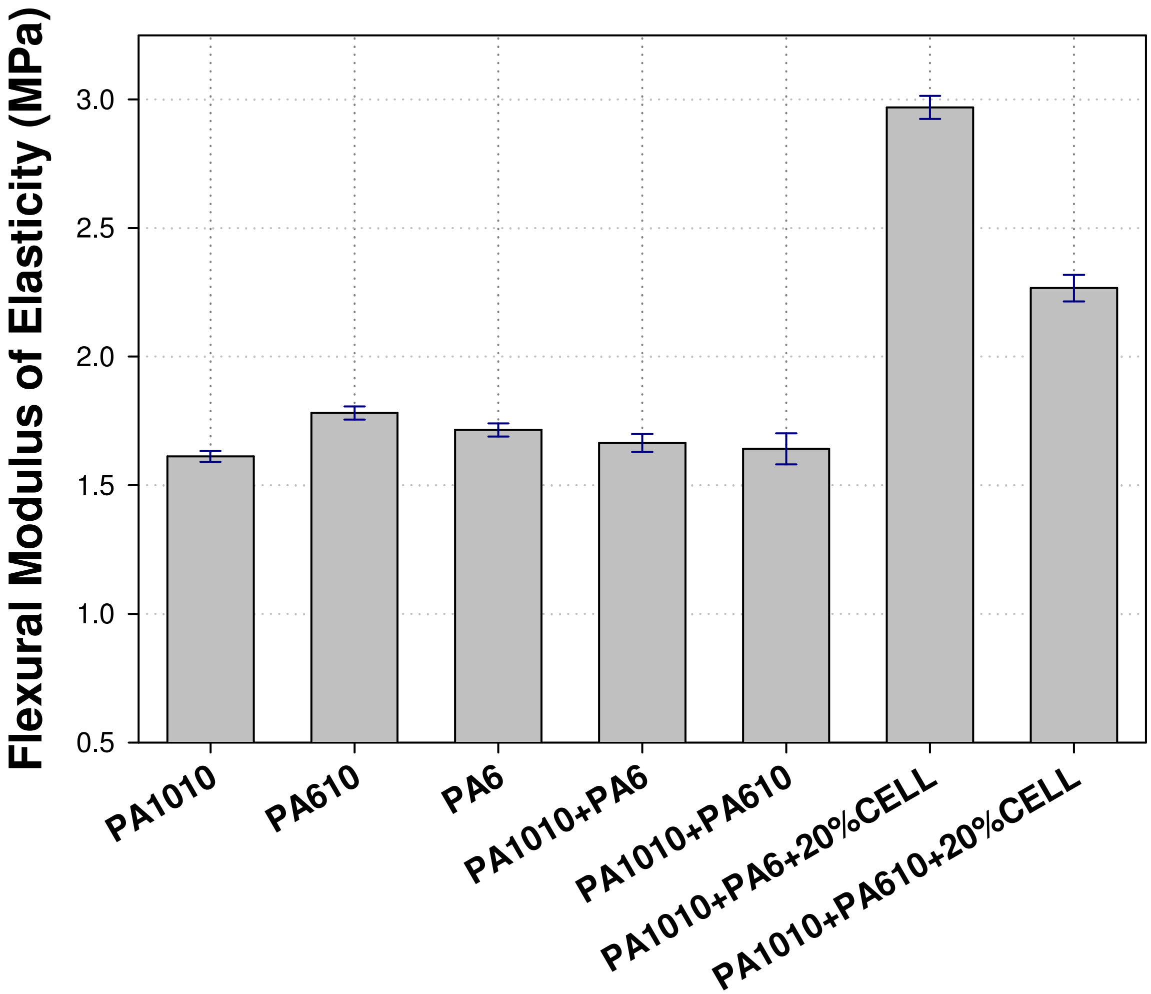
FMOE of Blends and Composites



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Expected Impact and Target Groups

Novel cellulose reinforced composite

- 100% bio-based composite (PA 1010& cellulose)
- Injection molding

Significantly increasing of using cellulose reinforced biopolymers

- Open up the market of consumer products
- High efficient processing technology (IM)
- High-quality products
- Light-weight, natural perception
- Good eco-balance

Potential Applications in Automotive Industry

- Air Cleaner Housing, Air duct, Air inlet manifold
- Air ventilation, Air Resonator, Air Injector

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Ongoing Studies

- SEM for dispersion properties.
- Viscoelastic properties of composites using DMTA.
- Rotational rheometer for rheology study.
- Heat ageing studies.

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Acknowledgements

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- Till Skoerde

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THANKS FOR YOUR ATTENTION !

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