



Impact of mechanical recycling on performance of plastics

Sustainable Materials Conference & Expo
Cologne, Germany

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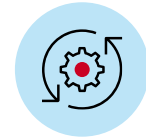
Our services



Certification



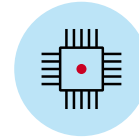
Verification



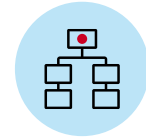
Testing



Auditing and inspection



Software



Data insights



Advisory



Learning and development



Field evaluation



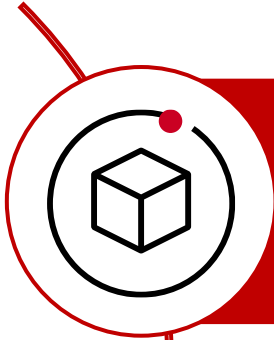
Enabling market access

Through our deep technical expertise, extensive market knowledge and 150+ locations around the world, including 90+ with laboratories, we help customers gain market access quickly.

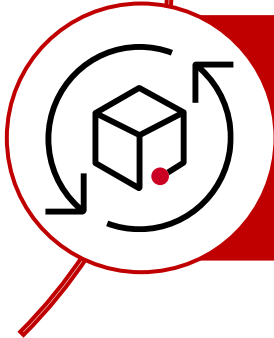


Location information is per August 2024.
Some sites contain more than one laboratory.

Market drivers of using sustainable materials



- Reduce environmental impact
- Reduce production cost/materials
- Enhance manufacturer's social responsibility, improve sustainability



- Customer requirements, public pressure
- Fulfill overseas product design
- Comply with environmental legislation
- Business competition



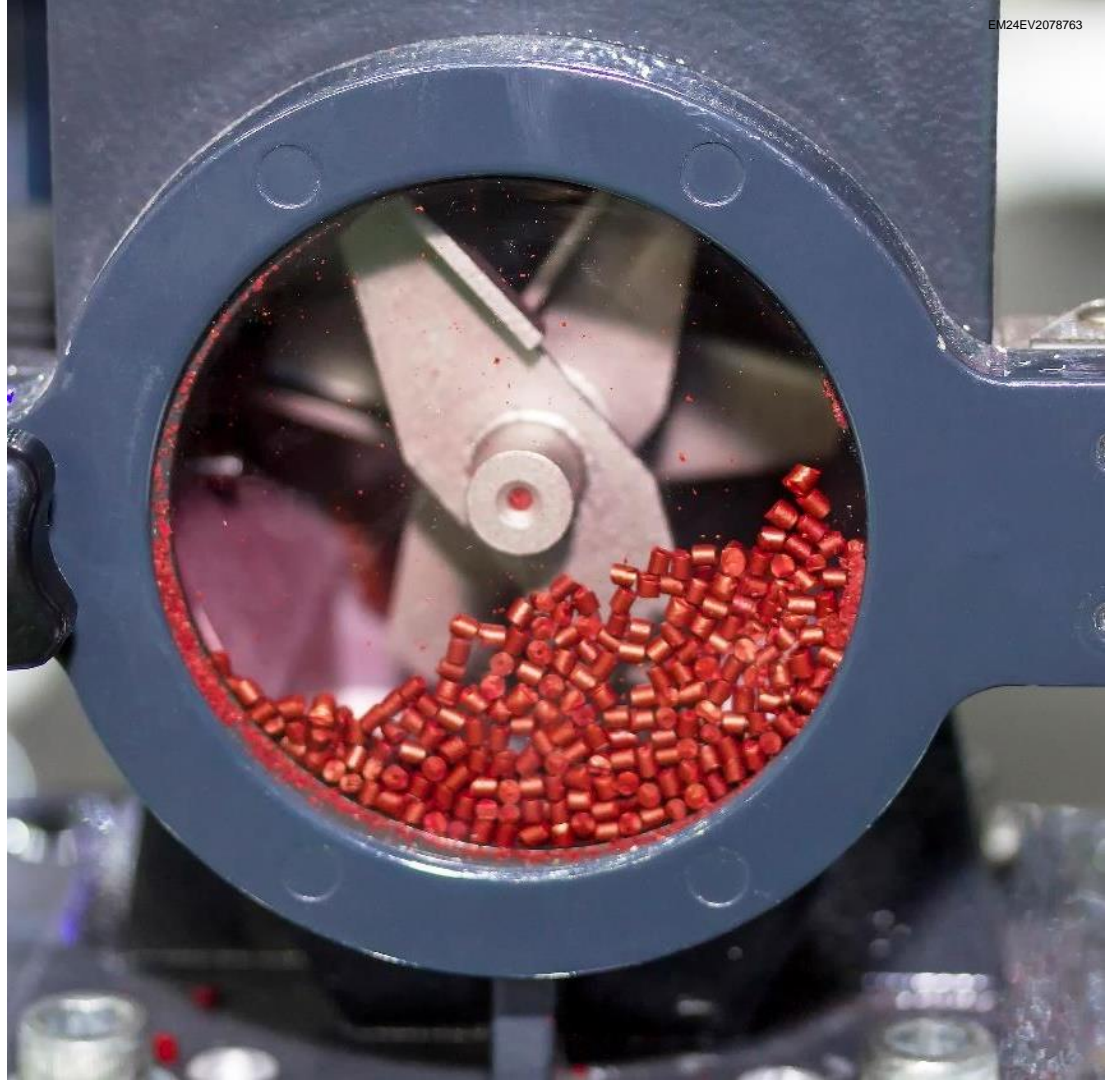
What are the challenges for electrical and electronic (E&E) products for using recycled plastics?

- Quality and consistency of recycled plastic materials
- Durability and performance requirements
- Technological limitations
- Source control and contamination
- Aesthetic and cosmetic issues
- Supply chain and availability

Research on safety performance of materials with PCR* content

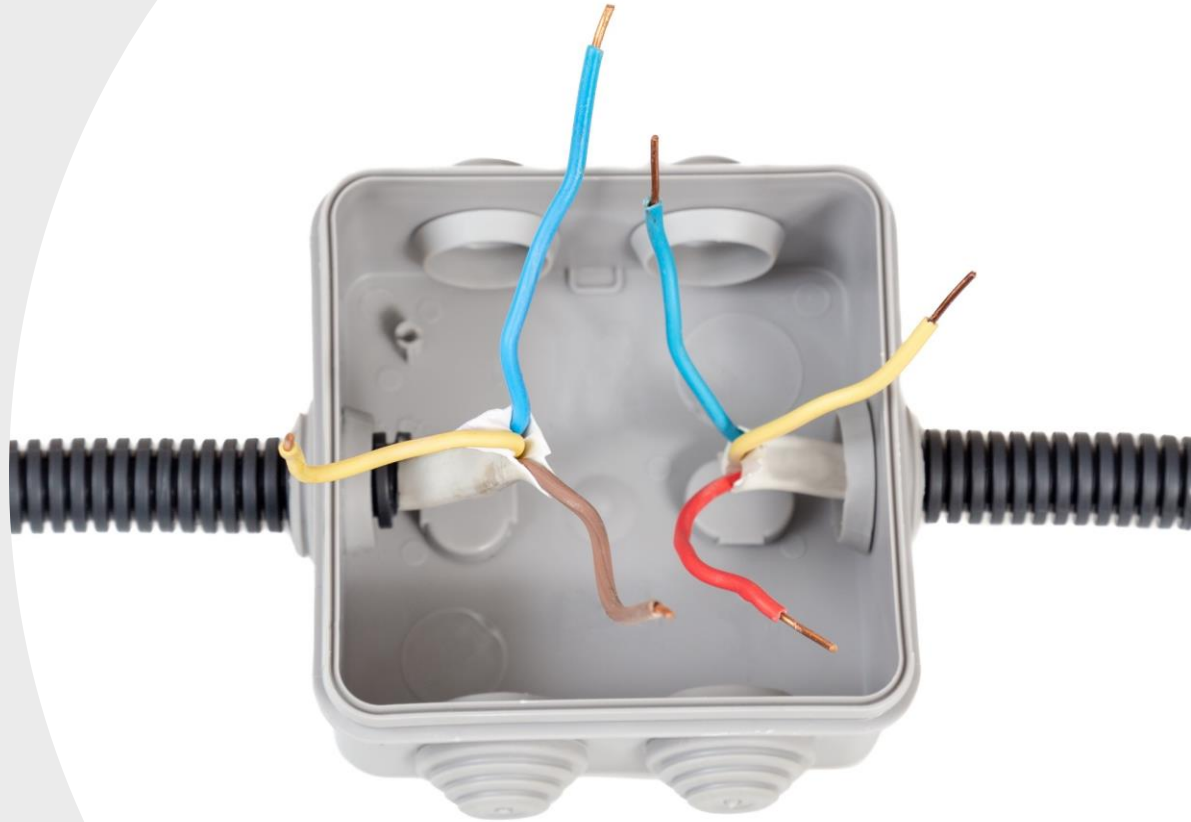
A study on mechanically recycled materials with consistent formulation

*Post-consumer recycled (PCR)



Application of plastics in E&E products

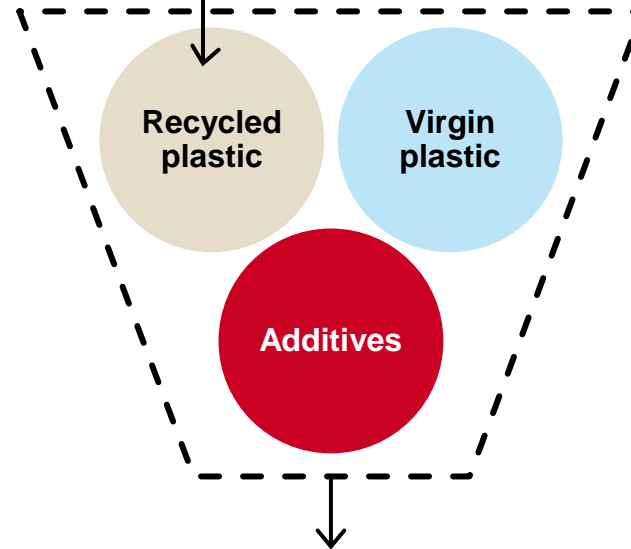
- Safety requirements
 - Dielectric/insulation property
 - Flammability
 - Resistance to ignition
 - Tracking resistance
 - Mechanical characteristics
 - Thermal stability
 - Durability
- Aesthetic



Mechanically recycled plastics

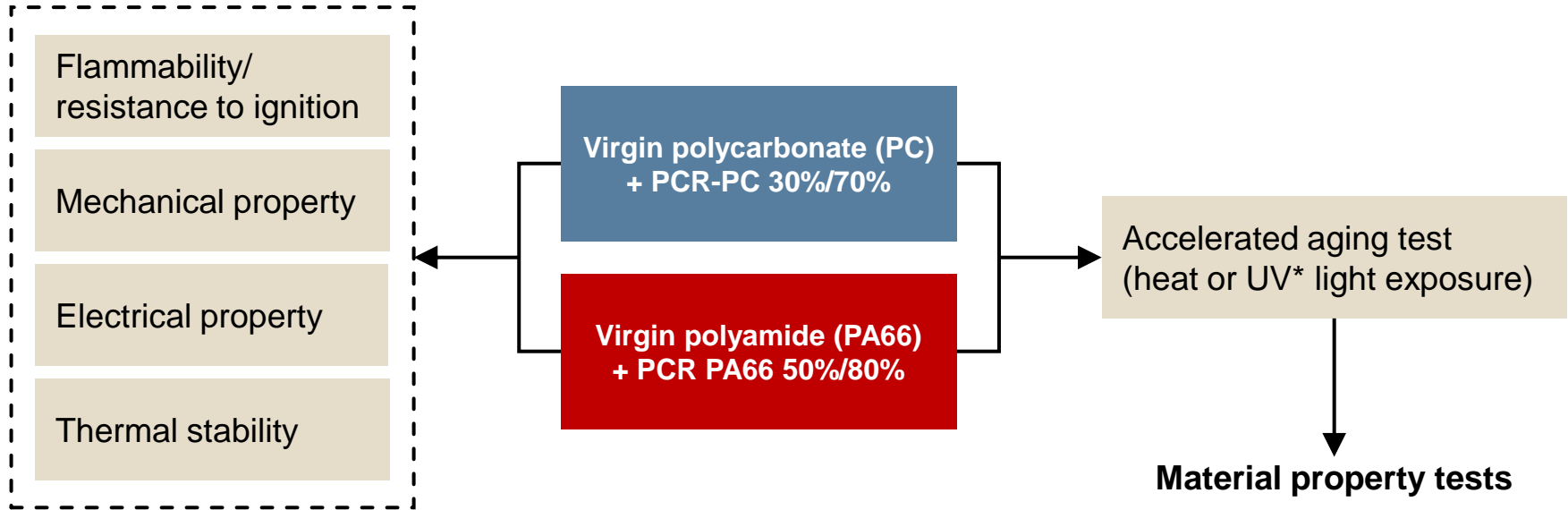
Common mechanical recycling process of plastics:

Sorting, shredding, washing and drying, granulating, compounding, pelletizing, reprocessing



Plastics with recycled content

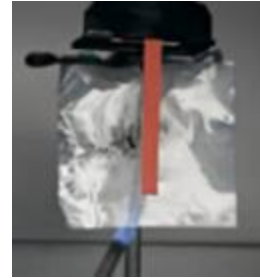
Research scope



*Ultraviolet (UV)

Flammability: UL 94* vertical burning test

Virgin PC	With 30% PCR-PC	With 70% PCR-PC
V0	V0	V0
Specimen did not drip	Specimen did not drip	Specimen did not drip

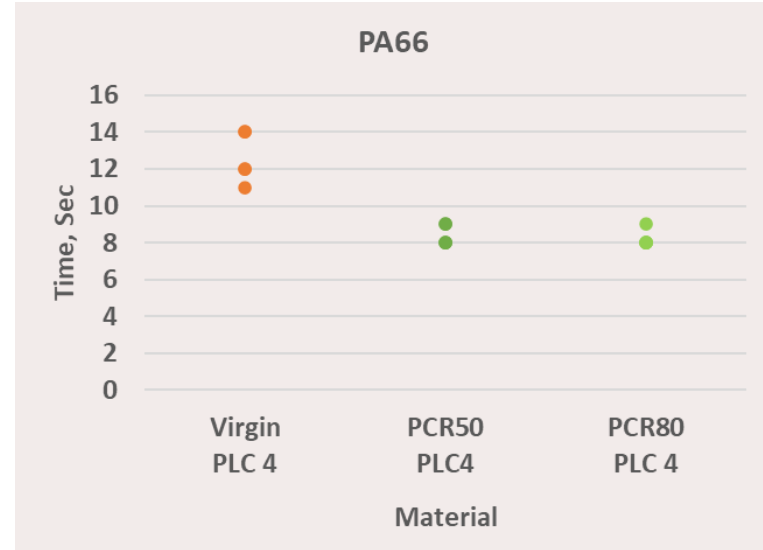


Virgin PA66	With 50% PCR-PA66	With 80% PCR-PA66
V0	V2	V2
Specimen dripped particles, which did not ignite cotton	Specimen dripped particles, which ignited cotton	Specimen dripped particles, which ignited cotton

*UL 94, the Standard for Tests for Flammability of Plastic Materials for Parts in Devices and Appliances

Flammability: Hot wire ignition test

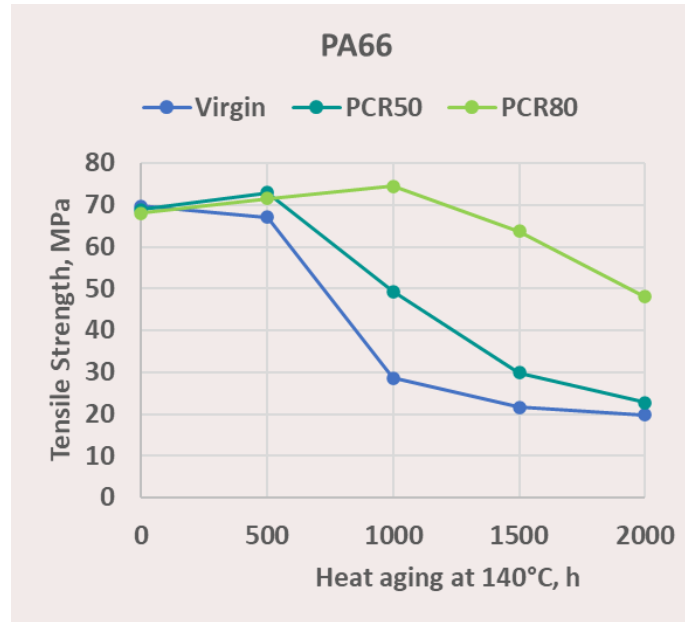
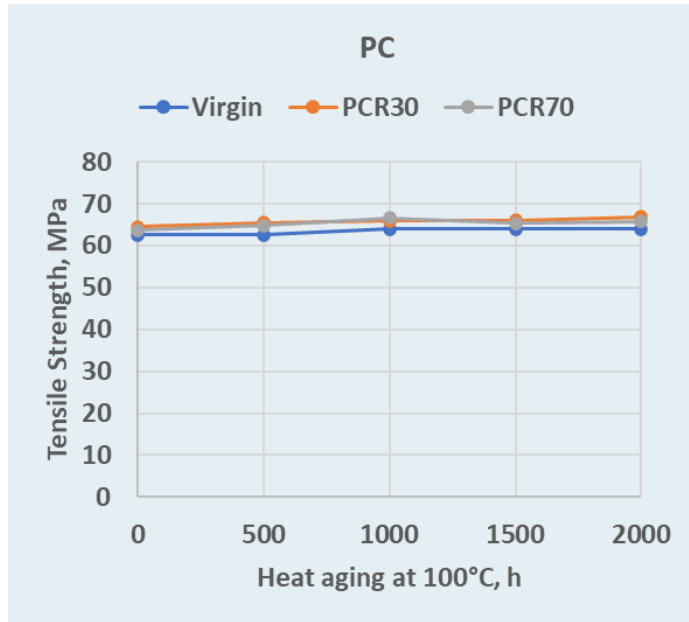
- ASTM D3874
- UL 746A, the Standard for Polymeric Materials – Short Term Property Evaluations, Sec. 32



Source: UL Solutions

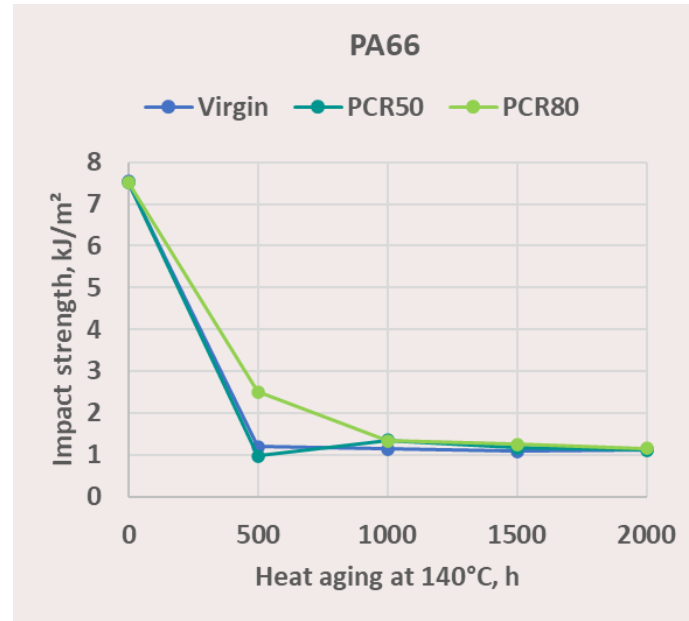
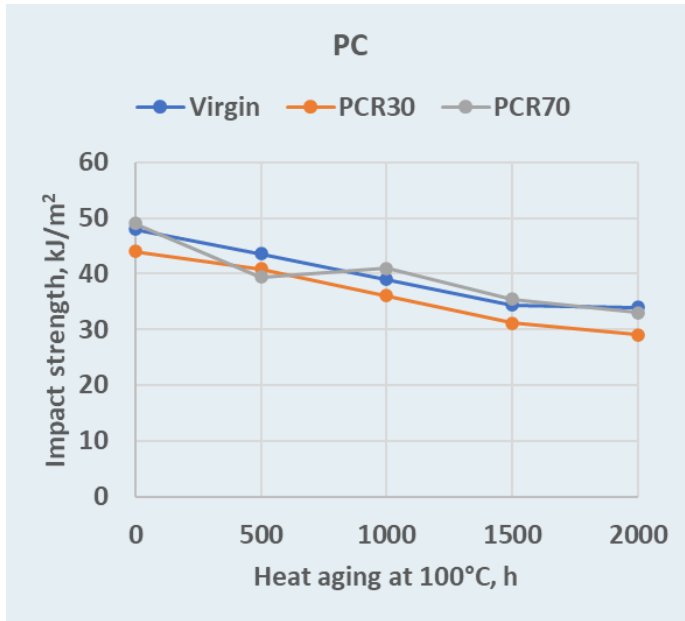
Effect of heat aging on tensile strength

- UL 746B, the Standard for Polymeric Materials – Long Term Property Evaluations, Sec. 20
- ASTM D638 tensile strength test



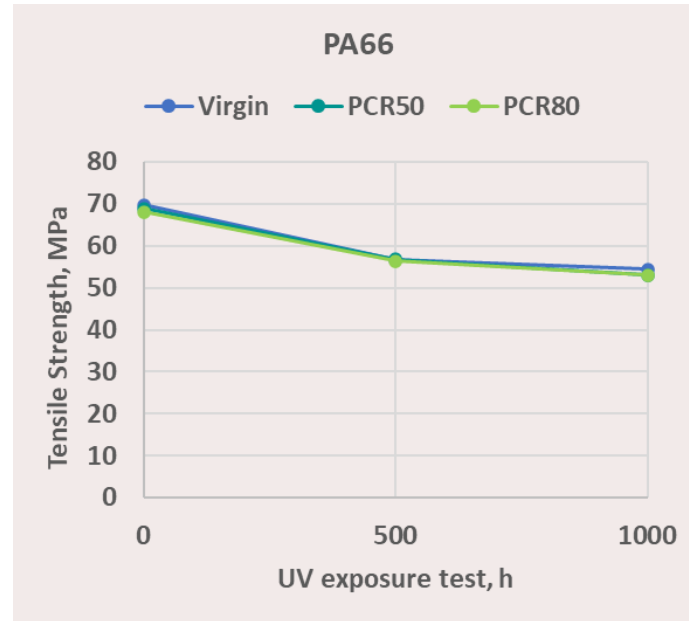
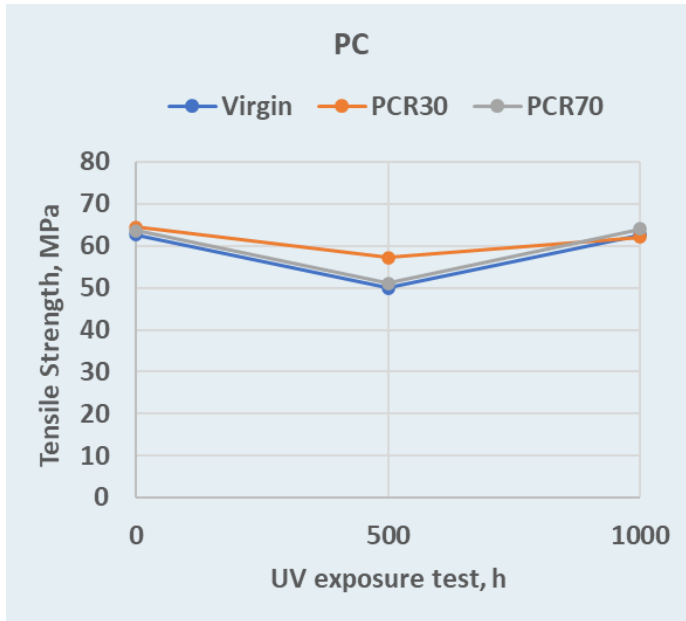
Effect of heat aging on impact strength

- UL 746B, the Standard for Polymeric Materials – Long Term Property Evaluations, Sec. 20
- ASTM D256 Izod impact test



Effect of UV exposure on tensile strength

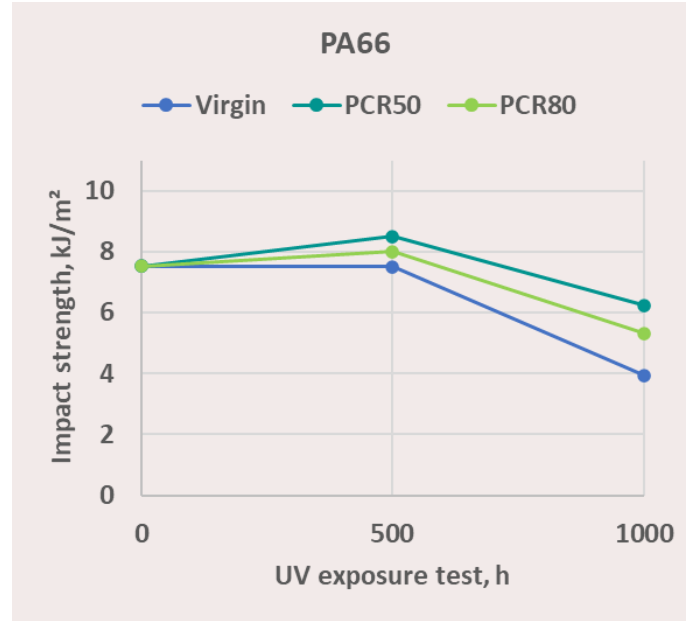
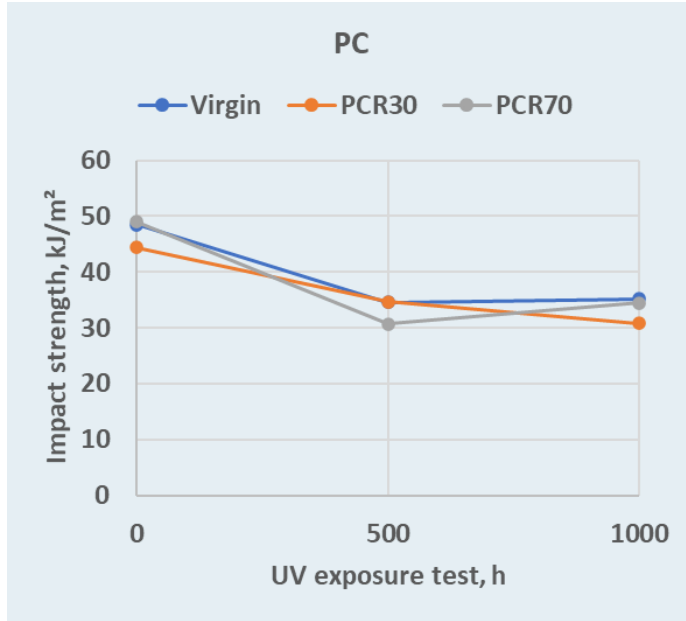
- UL 746C, the Standard for Polymeric Materials – Use in Electrical Equipment Evaluations, Sec. 57, ASTM G155 daylight filter
- ASTM D638 tensile strength test



Source: UL Solutions

Effect of UV exposure on impact strength

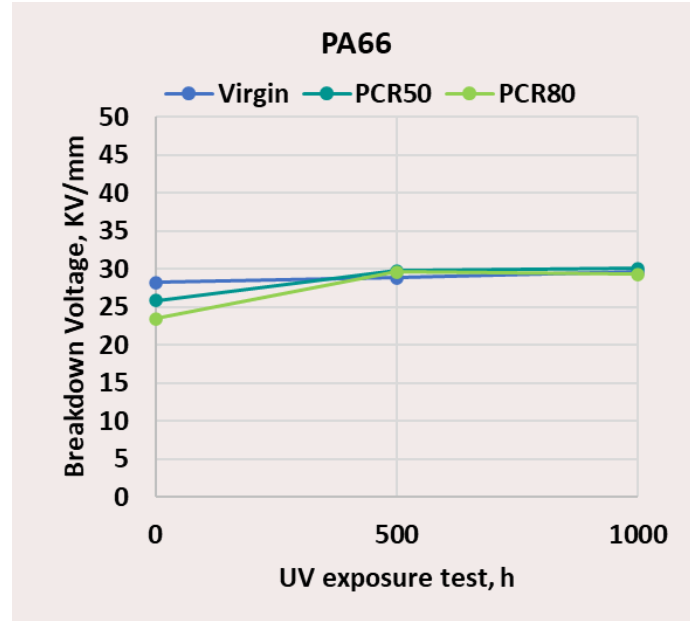
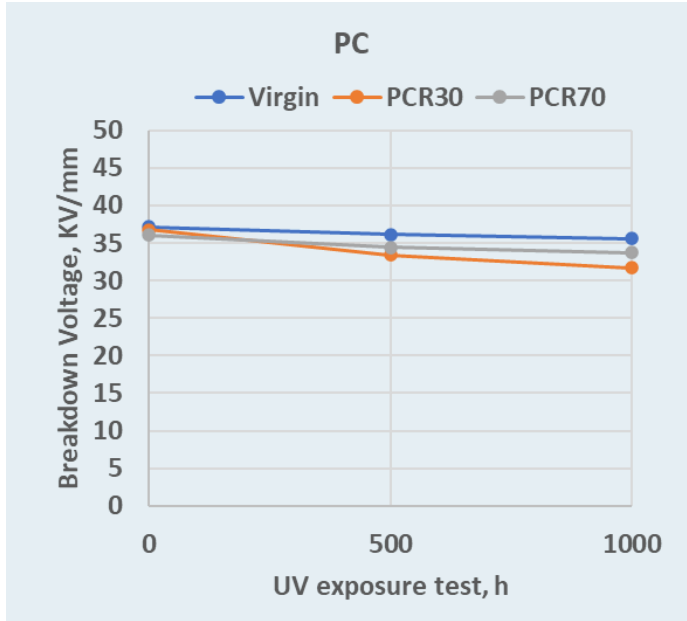
- UL 746C, Sec. 57, ASTM G155 daylight filter
- ASTM D256 Izod impact test



Source: UL Solutions

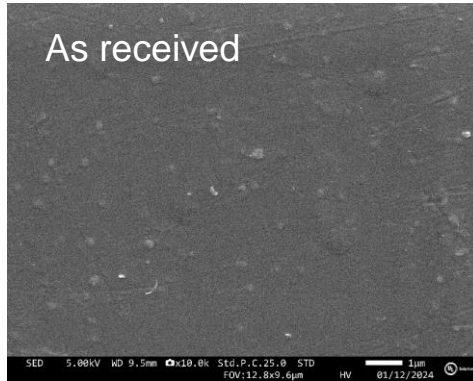
Effect of UV exposure on dielectric strength

- UL 746C, Sec. 57, ASTM G155 daylight filter
- ASTM D149 dielectric strength

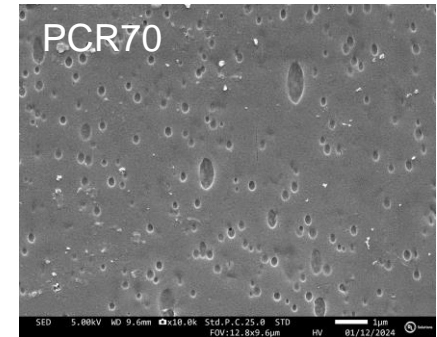
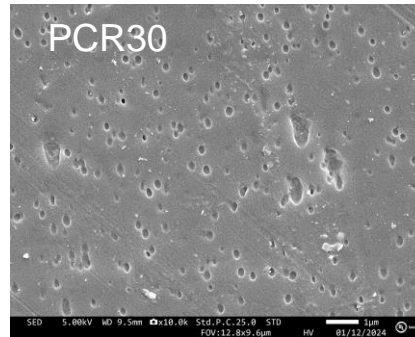
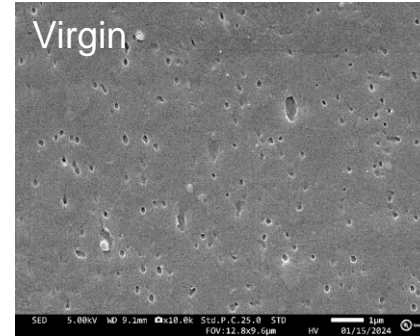


Source: UL Solutions

Surface of PC specimens after UV exposure

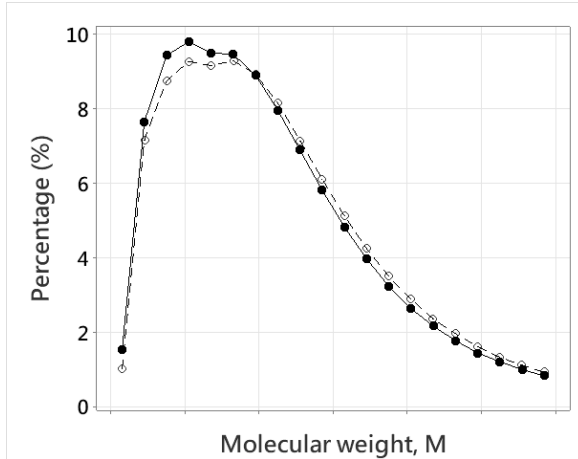


ASTM G155
UV exposure test,
1,000 hours



Source: UL Solutions

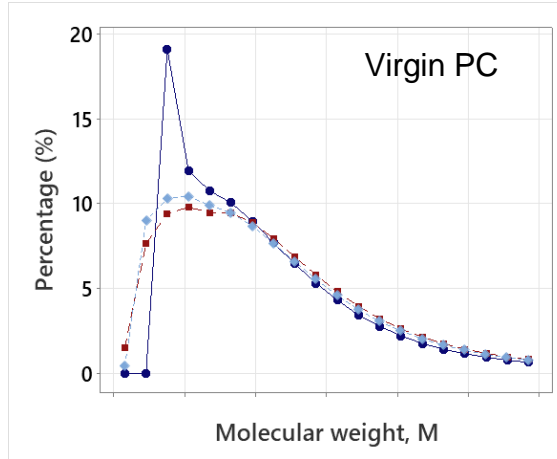
Molecular weight analysis by static light scattering



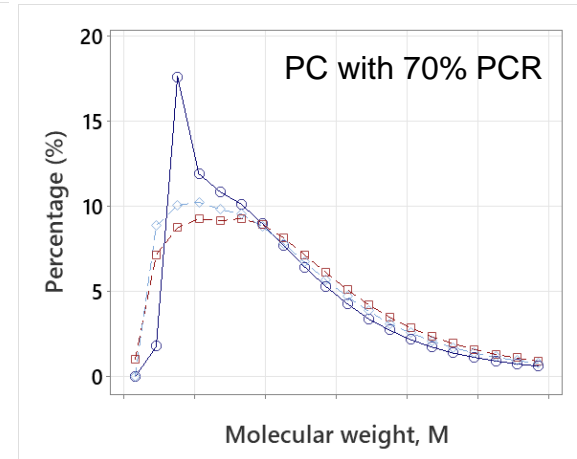
- Virgin PC
- PC with 70% PCR

Please note:

- The molecular weight scale on the X-axis is hidden.
- The left graph compares virgin and recycled materials, showing comparable distribution with slightly higher molecular weight in recycled material.
- The middle and right graphs demonstrate similar aging effects (heat, UV) on both materials, indicating consistent performance under environmental stress.



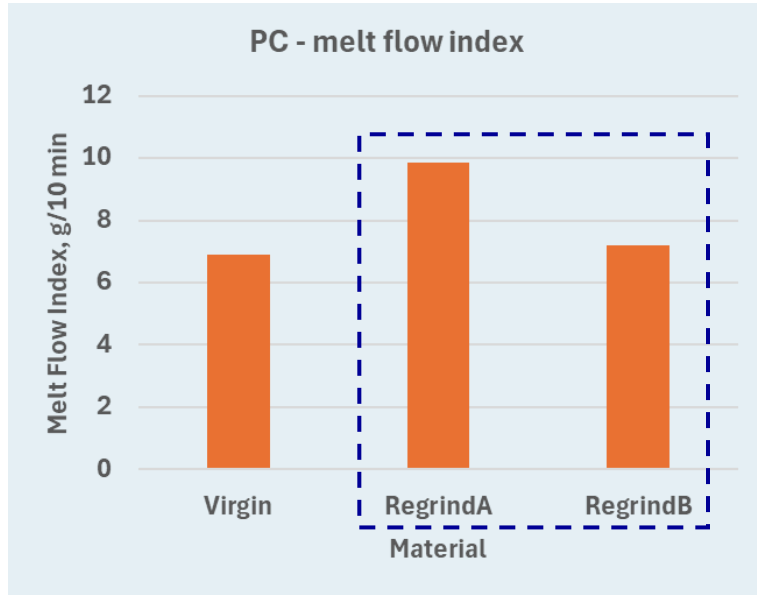
- As-received PC*
- Post-heat aging*
- Post-UV exposure*



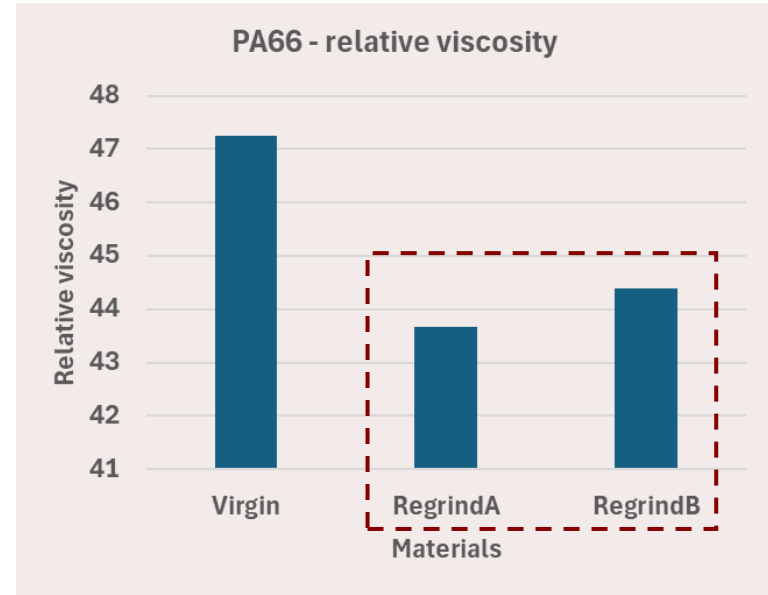
Source: UL Solutions

Effect of regrinding process

ASTM D1238

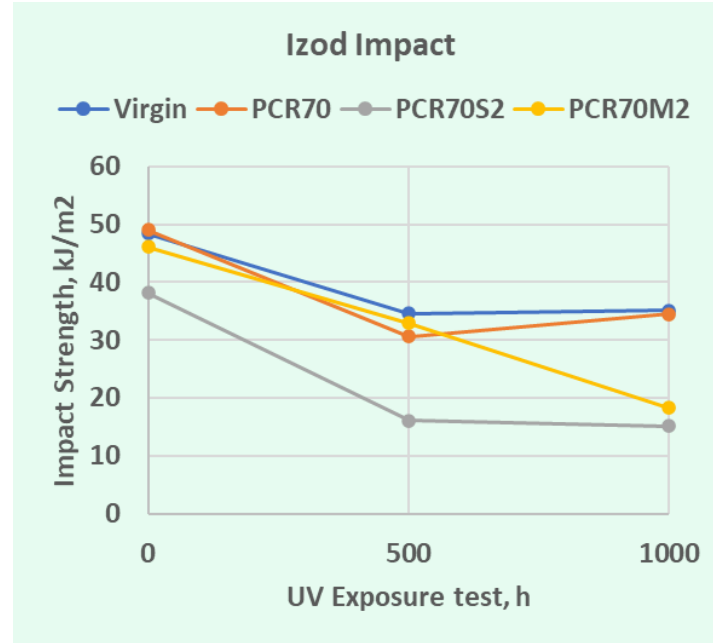
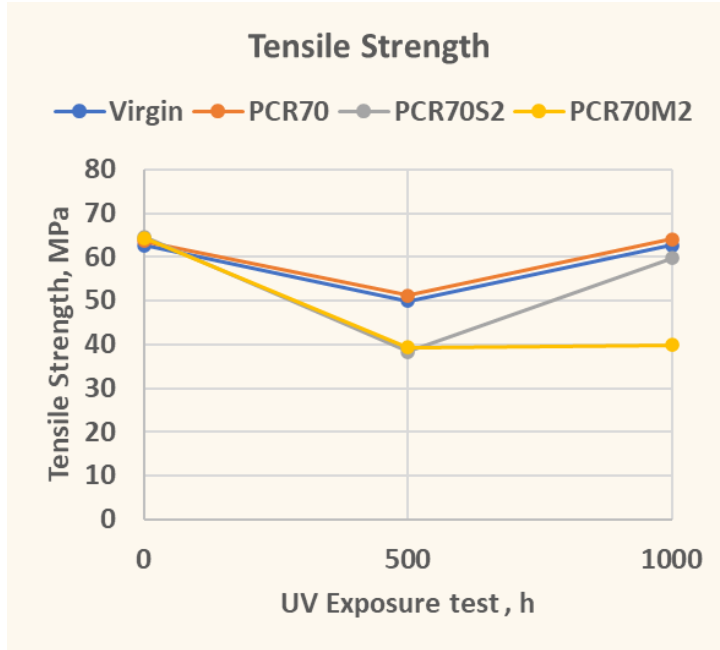


ASTM D789



Change of PCR source or additive

- UL 746C, Sec. 57, ASTM G155 daylight filter











Source: UL Solutions

Summary of study on mechanical recycling

- Effect on material's properties and endurance
 - Flammability, resistance to ignition and mechanical properties are more likely affected by the recycled content.
 - PCs with recycled materials are more susceptible to long-term thermal and UV exposure, even though the property retentions are comparable to virgin material to some extent. The breakdown of PCR content can be observed using delicate tools.
 - PA66 with recycled content shows less degradation in aging tests.
- Effect on polymer structure and flow – Changes in melt flow or viscosity can be detected after the regrinding process.
- Source control and compatibility with virgin plastics – The PCR source and formulation of additives (modifiers) are crucial to the material's safety performance. A systematic screening procedure and verification process will be beneficial to the quality control of recycled materials.

UL 746S* recycled plastics program

Single source (traceable)		Multiple sources (untraceable)	
 <p>Example: Discarded monitors using the same material for enclosure, recalled product of same model from field</p>		 <p>Example: Mixture of post-consumer products</p>	
<p>Single formulation:</p> <ul style="list-style-type: none"> Control is easier Confirmed by analytical tests (infrared spectroscopy (IR), thermogravimetric analysis (TGA), differential scanning calorimetry (DSC)) 		<p>Multiple formulations:</p> <ul style="list-style-type: none"> Control is more challenging Analytical tests do not compare 	
	<p>Three batches: Flammability (UL 94), analytical tests (UL 746A: IR, TGA and DSC)</p>		<p>Five batches: Flammability (UL 94), critical short-term properties (UL 746A)</p>
	<p>One batch: Short-term properties (UL 746A), Outdoor (UL 746C)</p>		<p>Three batches: All additional short-term properties (UL 746A)</p>
	<p>One batch: Outdoor (UL 746C), long-term properties (UL 746B)</p>		<p>One batch: Outdoor (UL 746C), long-term properties (UL 746B)</p>
<p>Quality assurance program Follow-up (flammability, identification)</p>		<p>Quality assurance program Follow-up (flammability, critical short-term properties)</p>	

Goal: Consistency in production batches

*UL 746S, the Standard for Evaluation of Sustainable Polymeric Materials for Use in Electrical Equipment

UL Solutions services for sustainable plastics

Safety certification



- **UL 746S** – Certification for mechanically recycled plastics (E&E)
- **UL 746D, the Standard for Polymeric Materials – Fabricated Parts** – Certification for regrind
- **UL 746A/B**
 - Certification for chemically recycled plastics
 - Certification for bio-based plastics

Sustainable claim validation

- **UL 2809-2, Environmental Claim Validation Procedure (ECVP) for Recycled Content** – Material or product validation
- **UL 2809-3, Environmental Claim Validation Procedure (ECVP) for Ocean Plastics and Ocean Bound Plastics** – Material or product validation
- **UL 9798, Environmental Claim Validation Procedure (ECVP) for Biobased Content** – Material or product validation





Thank you

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