Elastollan® TPU Thermoplastic Polyurethane

Material Considerations for Railway Engineering

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BASF Touchpoints in Rail

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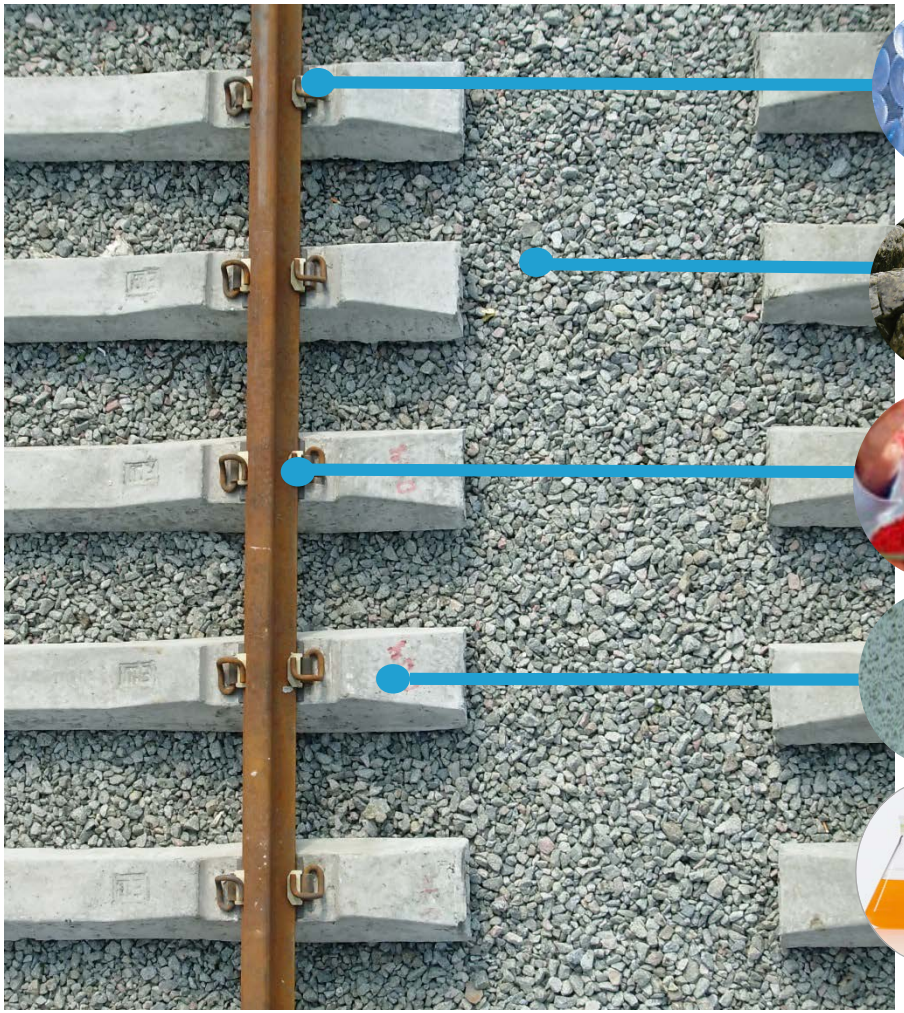


Elastollan ® Thermoplastic Polyurethane

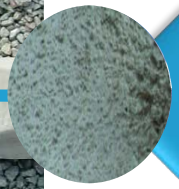
Excellent abrasion resistance, compressive strength, and mechanical properties

Elastotrack ® Ballast Binder

Reinforces and stabilzes loose bulk ballast

Ultramid® Polyamides

High strength and abrasion resistant insulators



MasterGlenium ® and MasterSure ®

Concrete admixtures designed for fast wetout and extended workability

Urethane Raw Materials and Additives – rail seat repair, tie plugs

Complete integration across value chain

Outline

- What's an elastomer?
- Value proposition
- Properties of Interest
  - Abrasion resistance
  - Hardness
  - Aging
  - Polyether vs. Polyester
  - Vs. Rubber
  - Mechanical properties
  - Summary

Elastollan® TPU
Engineered by BASF for the Toughest Applications

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- Elastollan® TPU is a

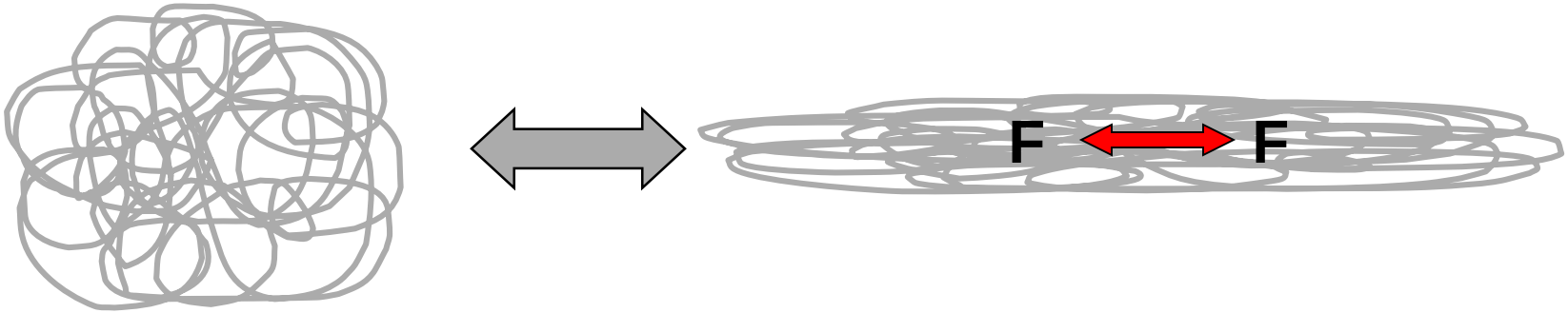
  TPE material characterized by:

  - Rubbery Nature (flexible)
  - Excellent Abrasion Resistance & Mechanical Properties (both compression and in tension)

Rubber Elasticity

- **What makes elastomers special is that they can be stretched to many times their original length, and can bounce back into their original shape without permanent deformation.**

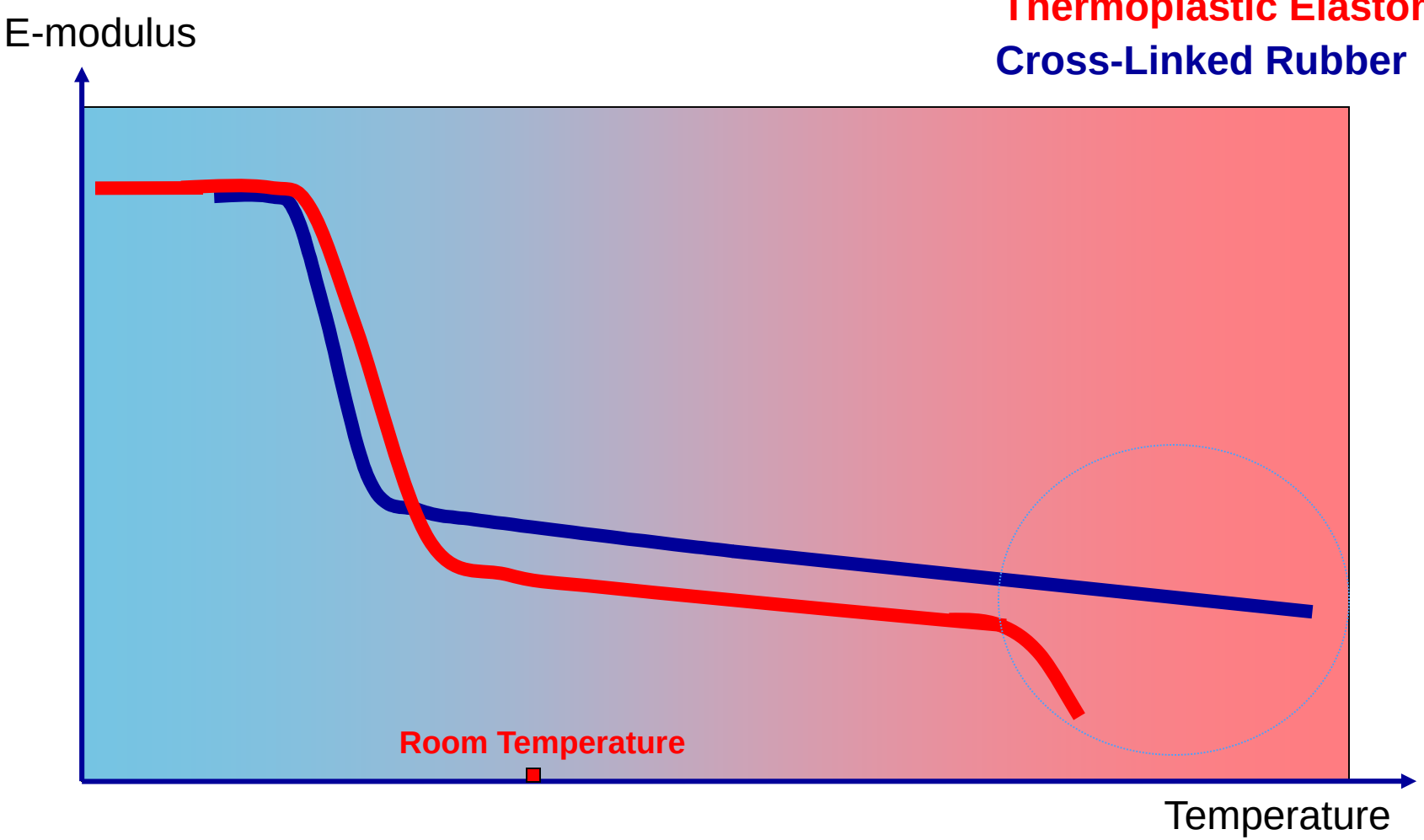
PUTTING ENTROPY TO WORK



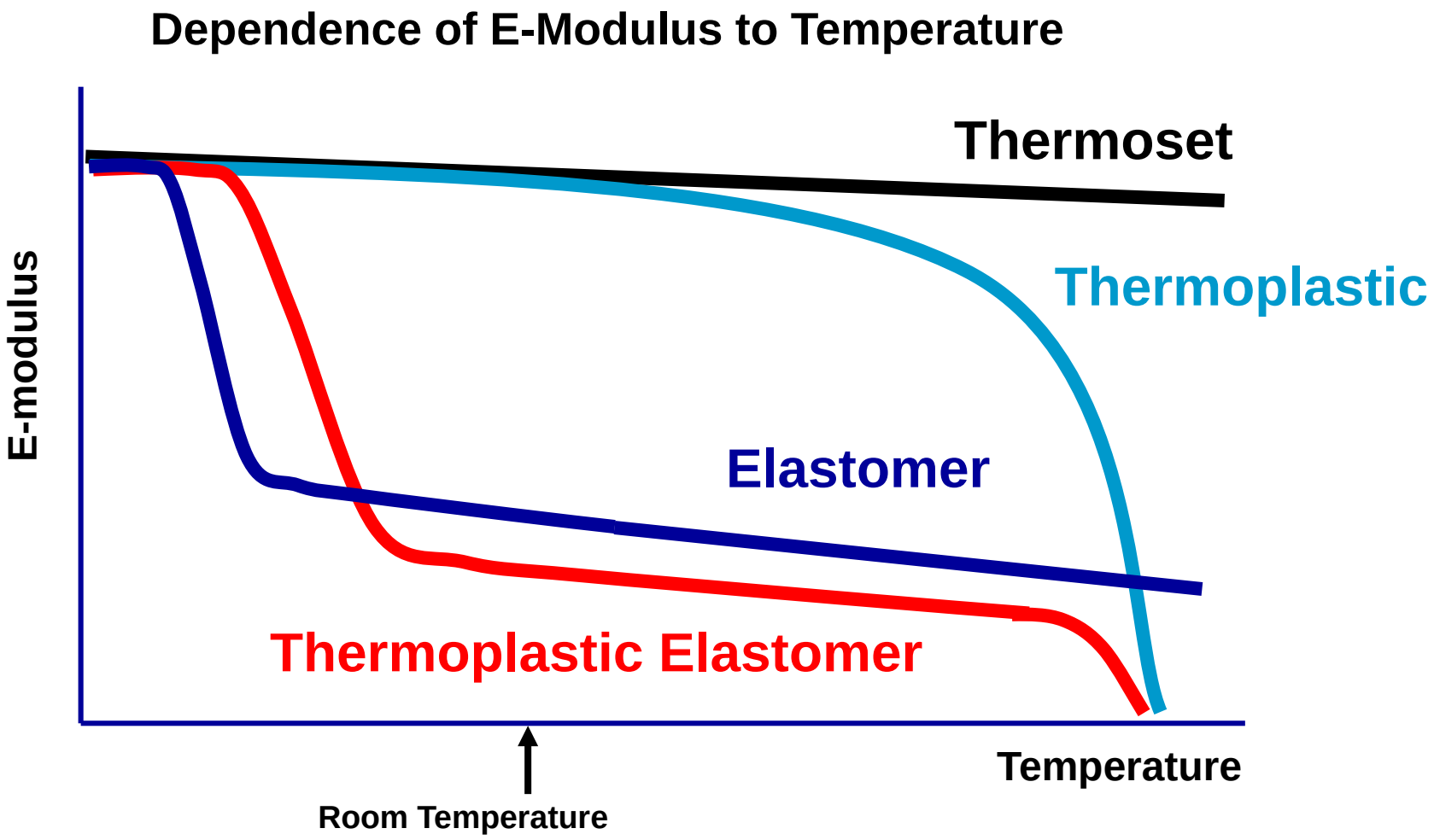
High Entropy

Low Entropy

Modulus vs. Temperature - Elastomers



Modulus vs. Temp – Thermoplastics & TPEs



Bridging the Gap Between Elastomers and Plastics

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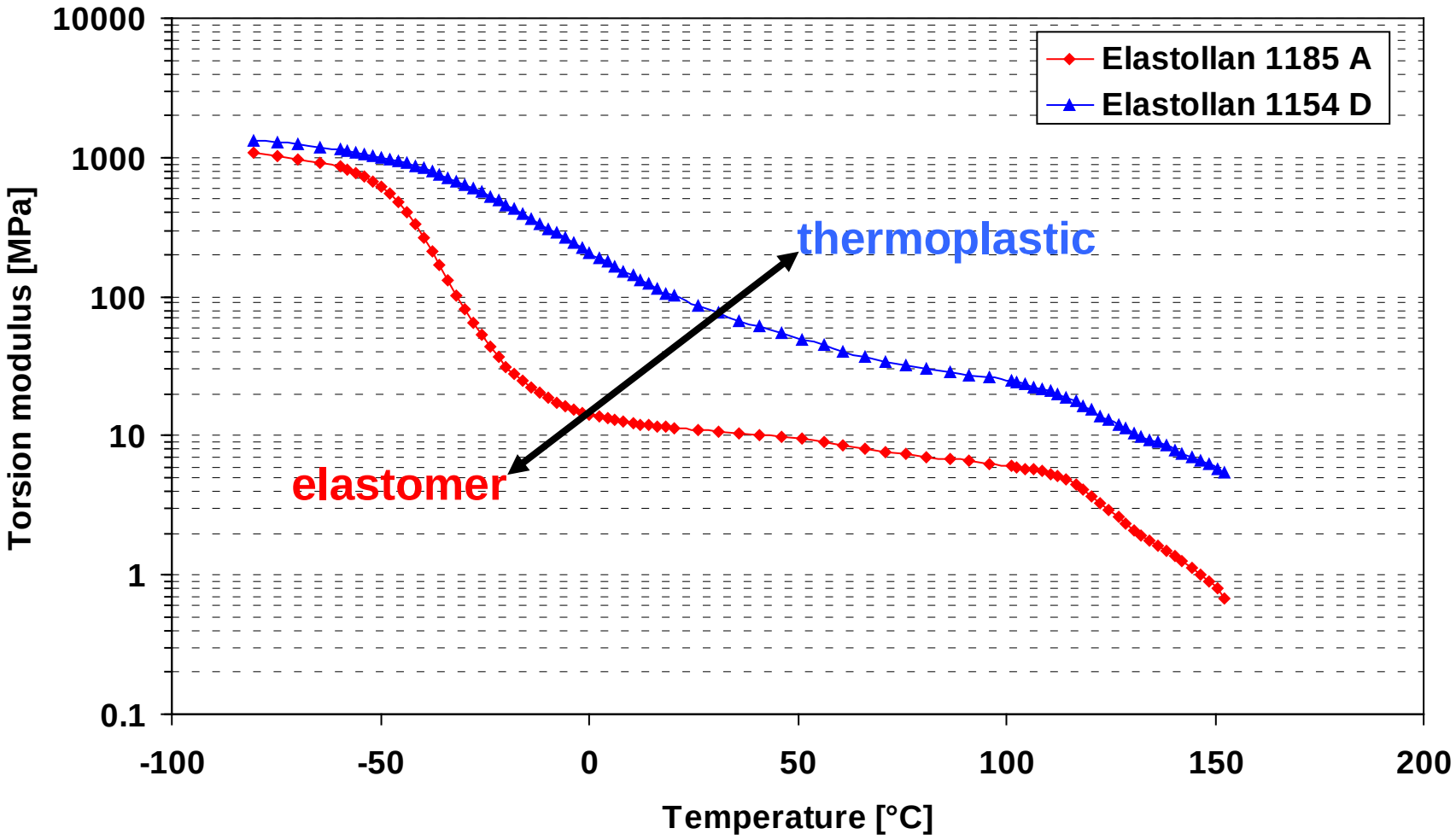
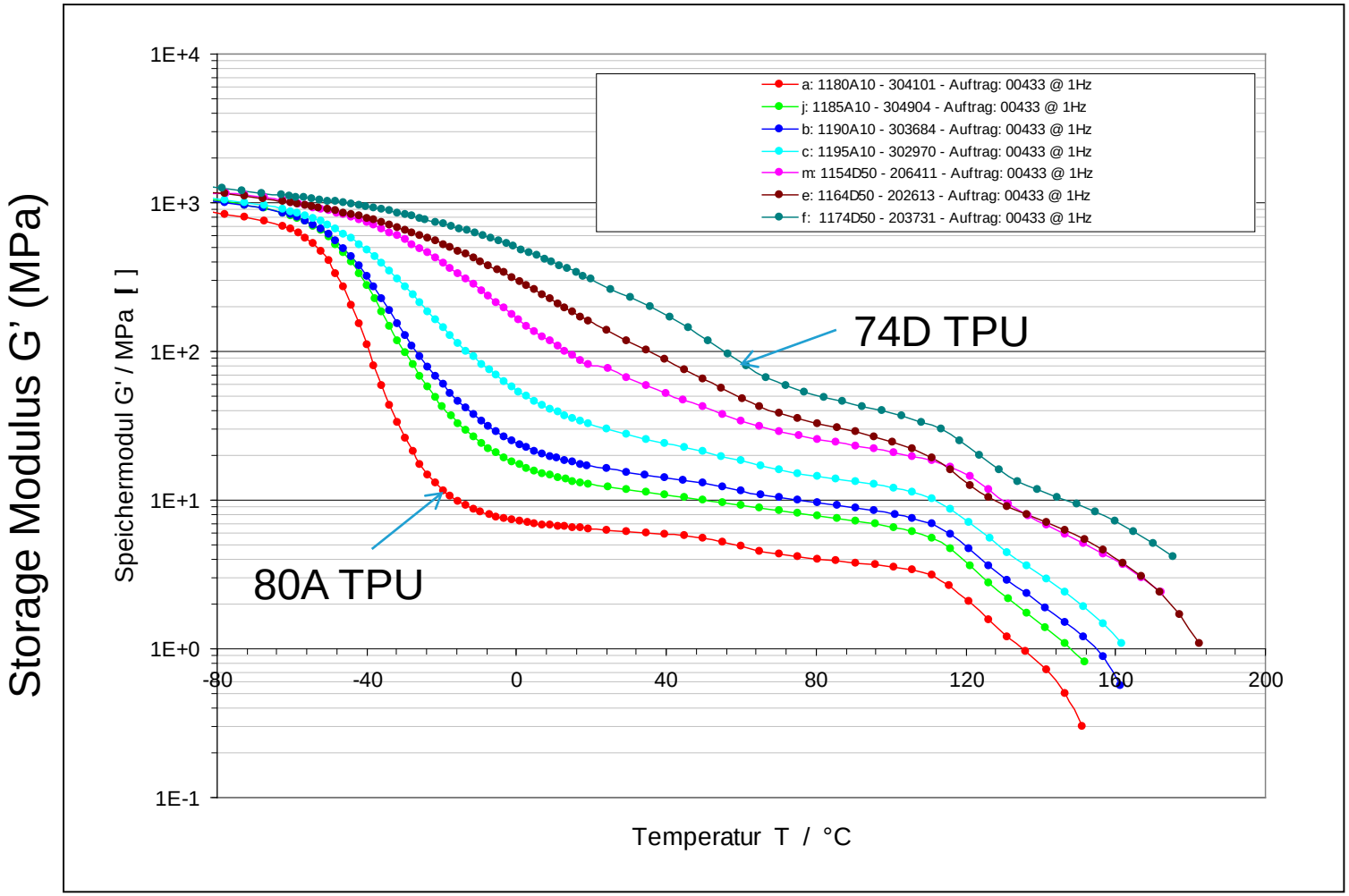
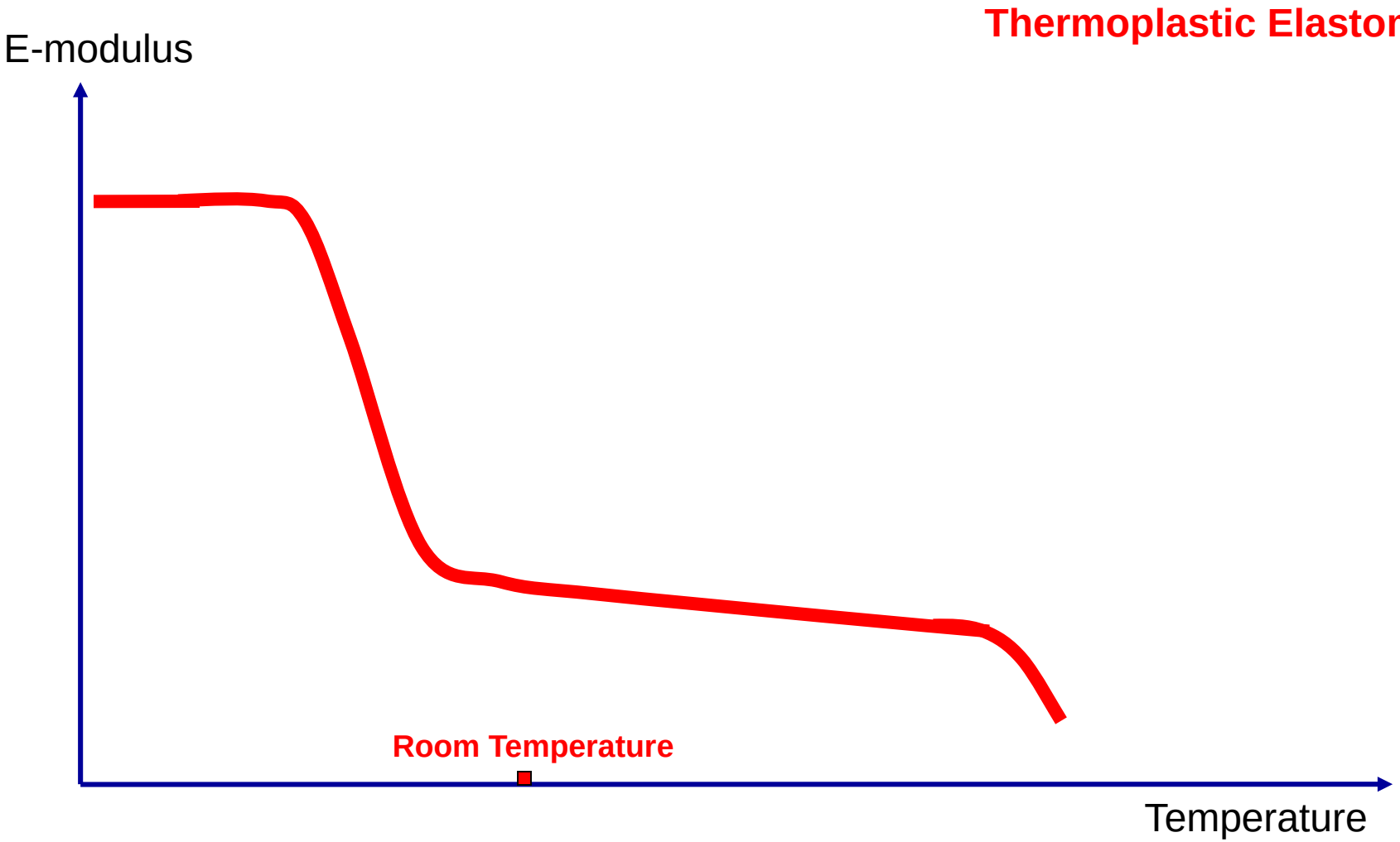


Dynamic Mechanical Analysis
G’ (Storage Modulus)



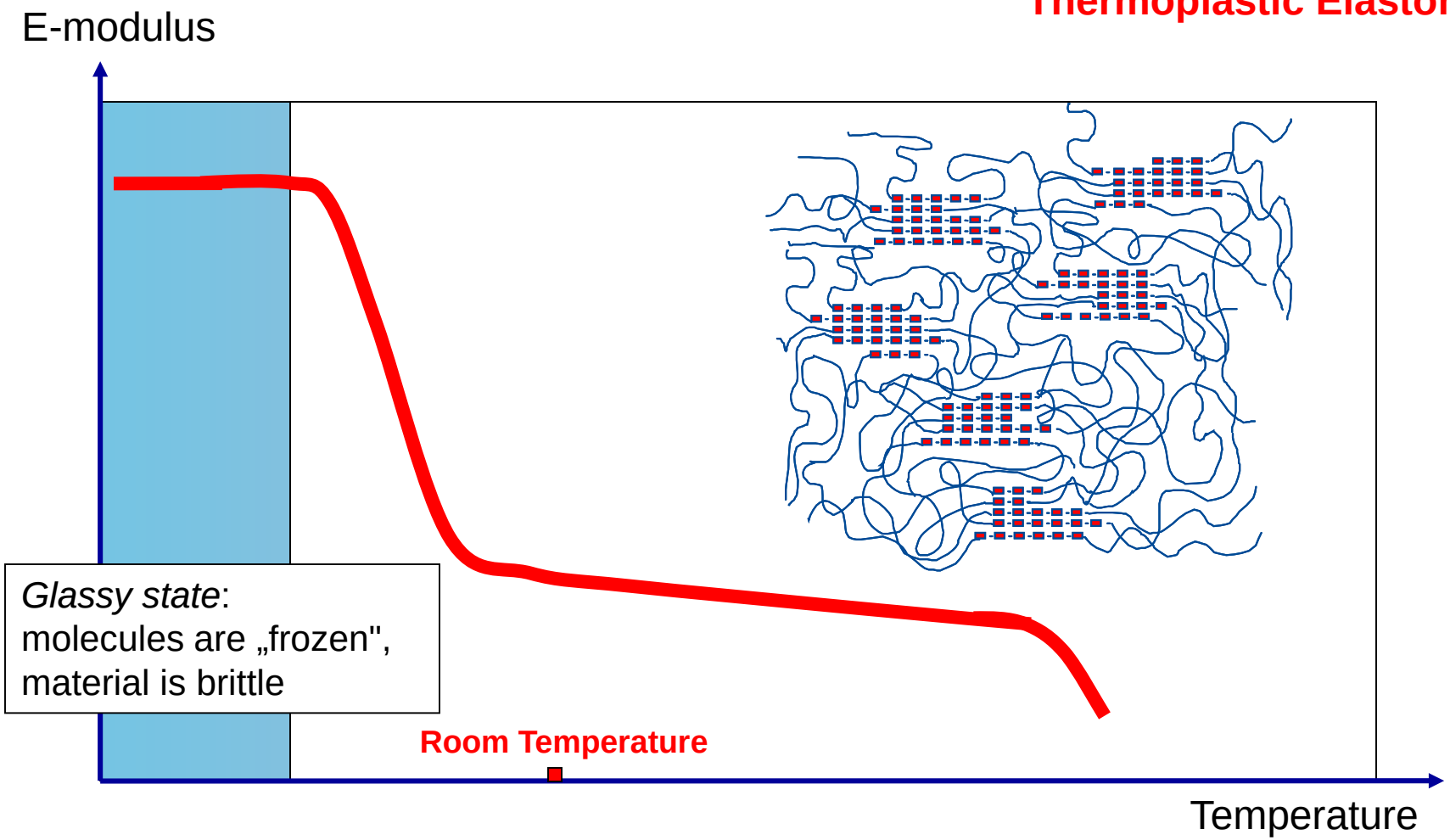
Temperature (°C)

E Modulus and Temperature



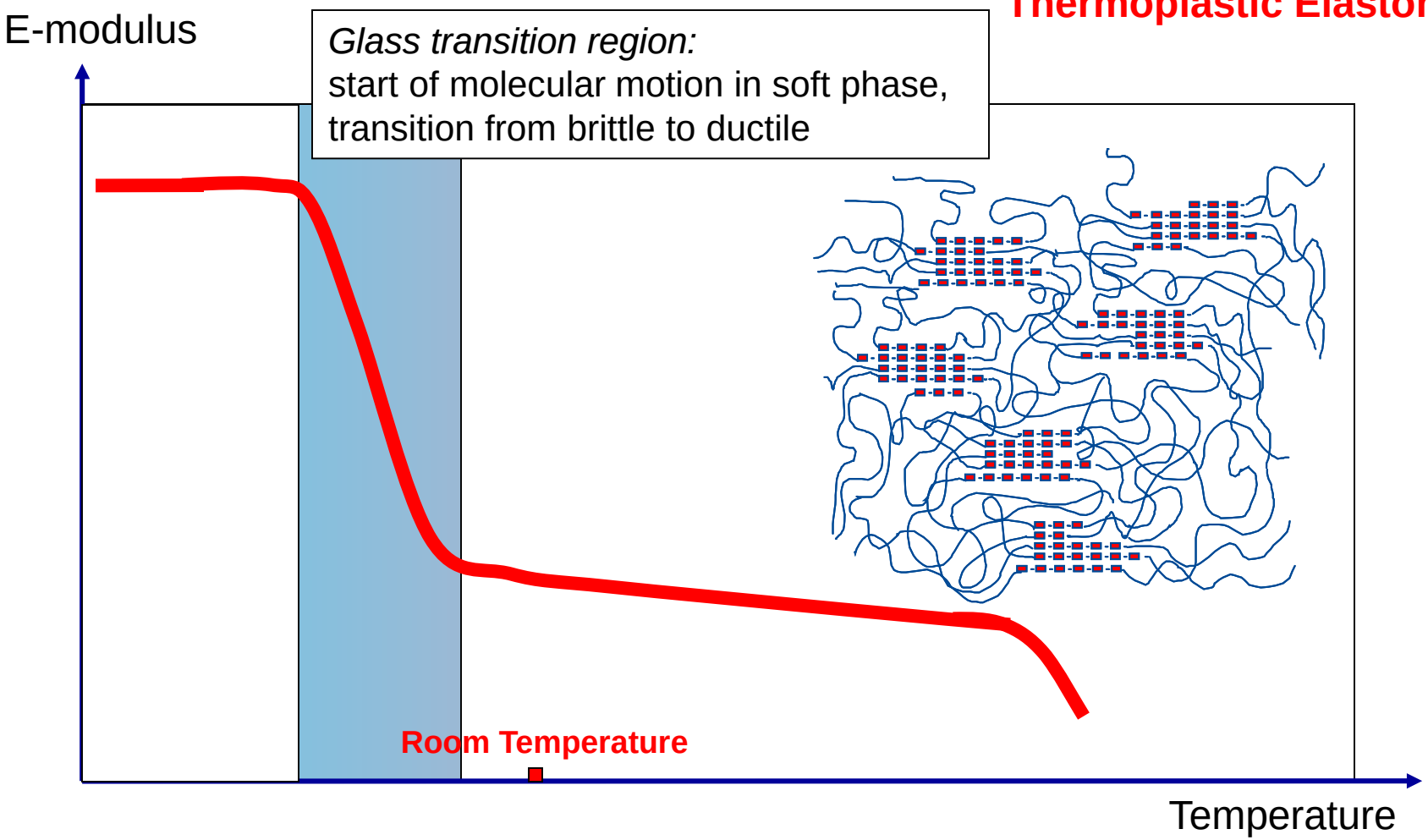
Glassy State

Thermoplastic Elastomer



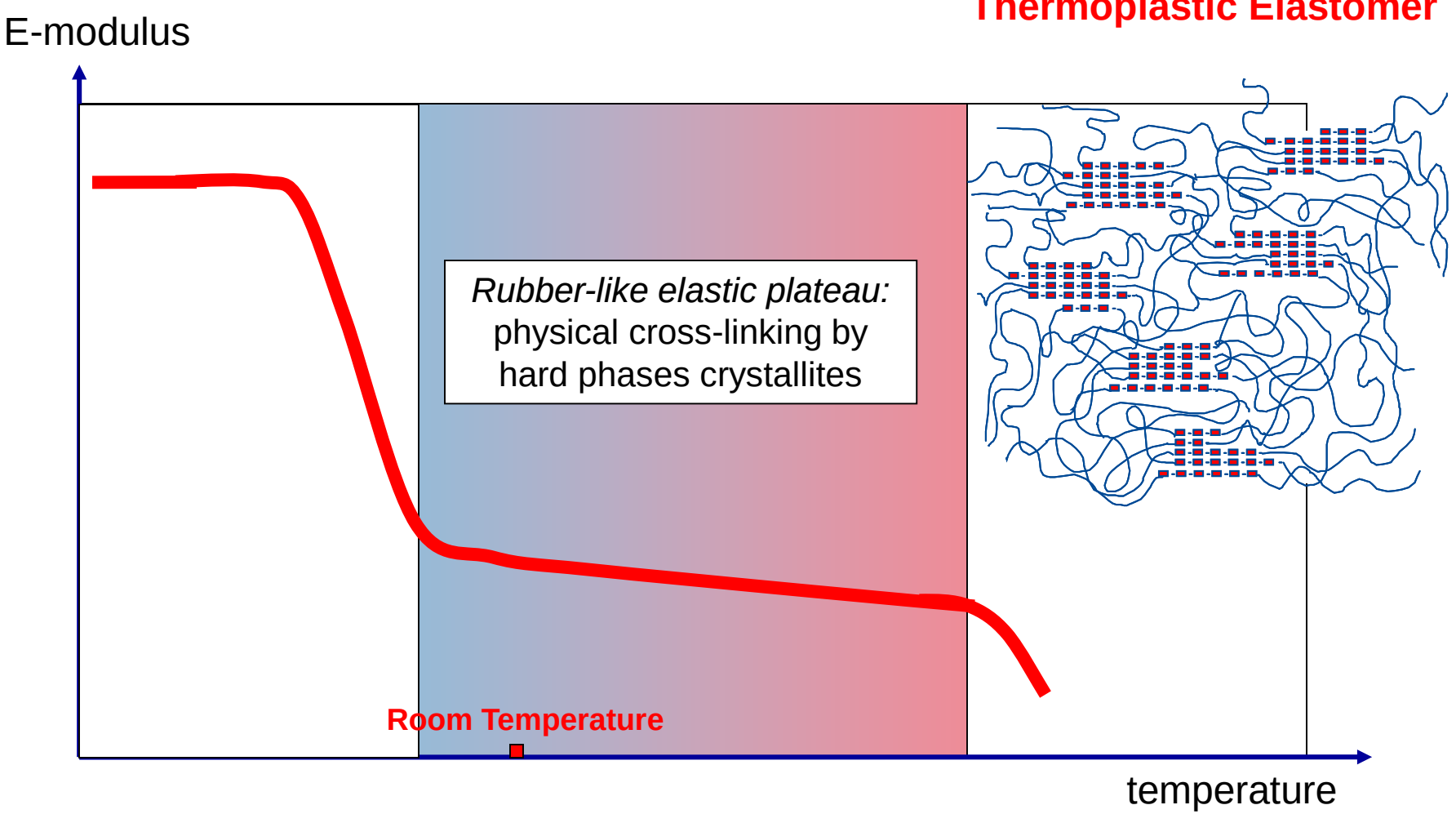
Molecular Movement

Thermoplastic Elastomer

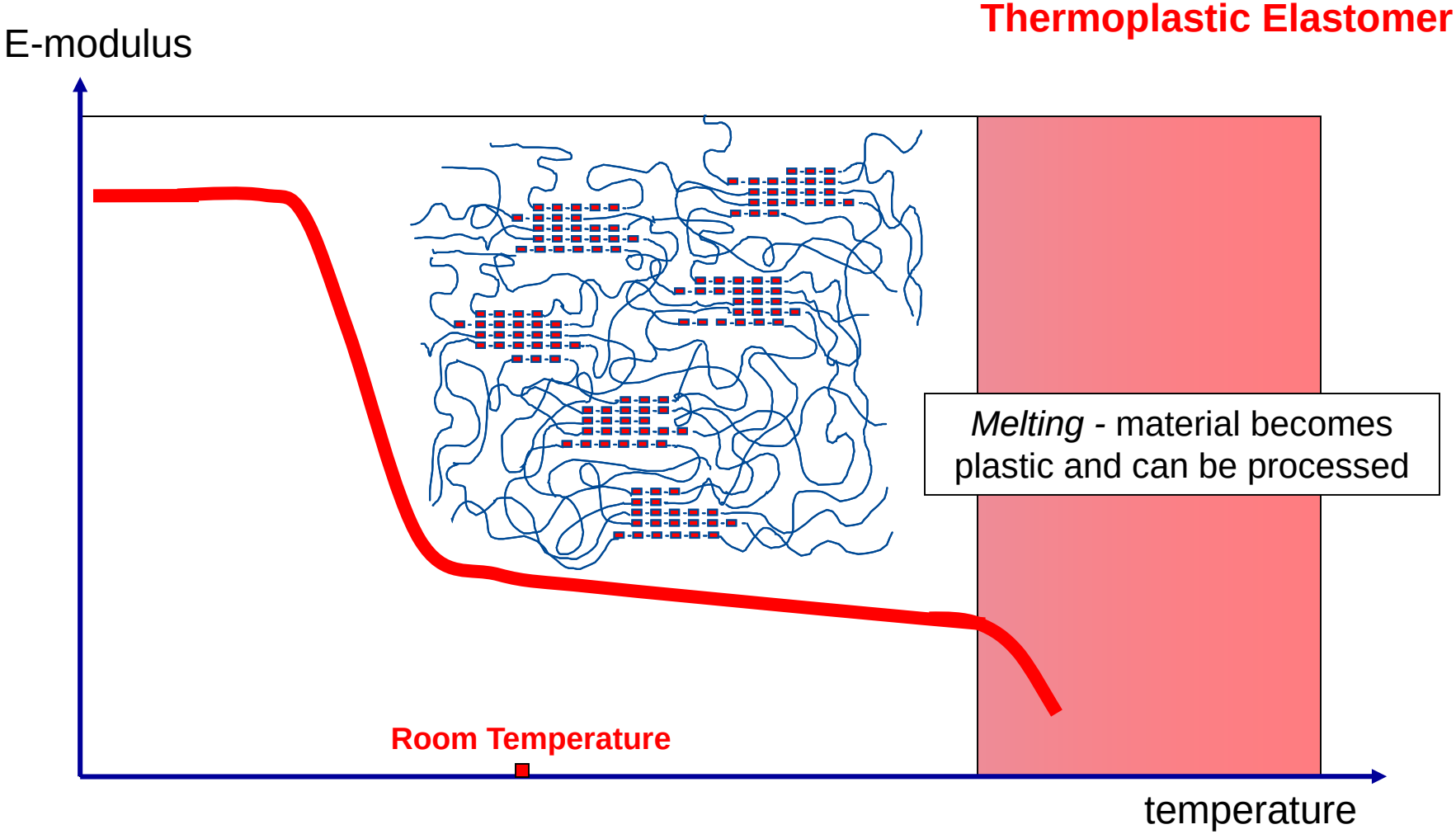


Elastic Region

Thermoplastic Elastomer



Melting

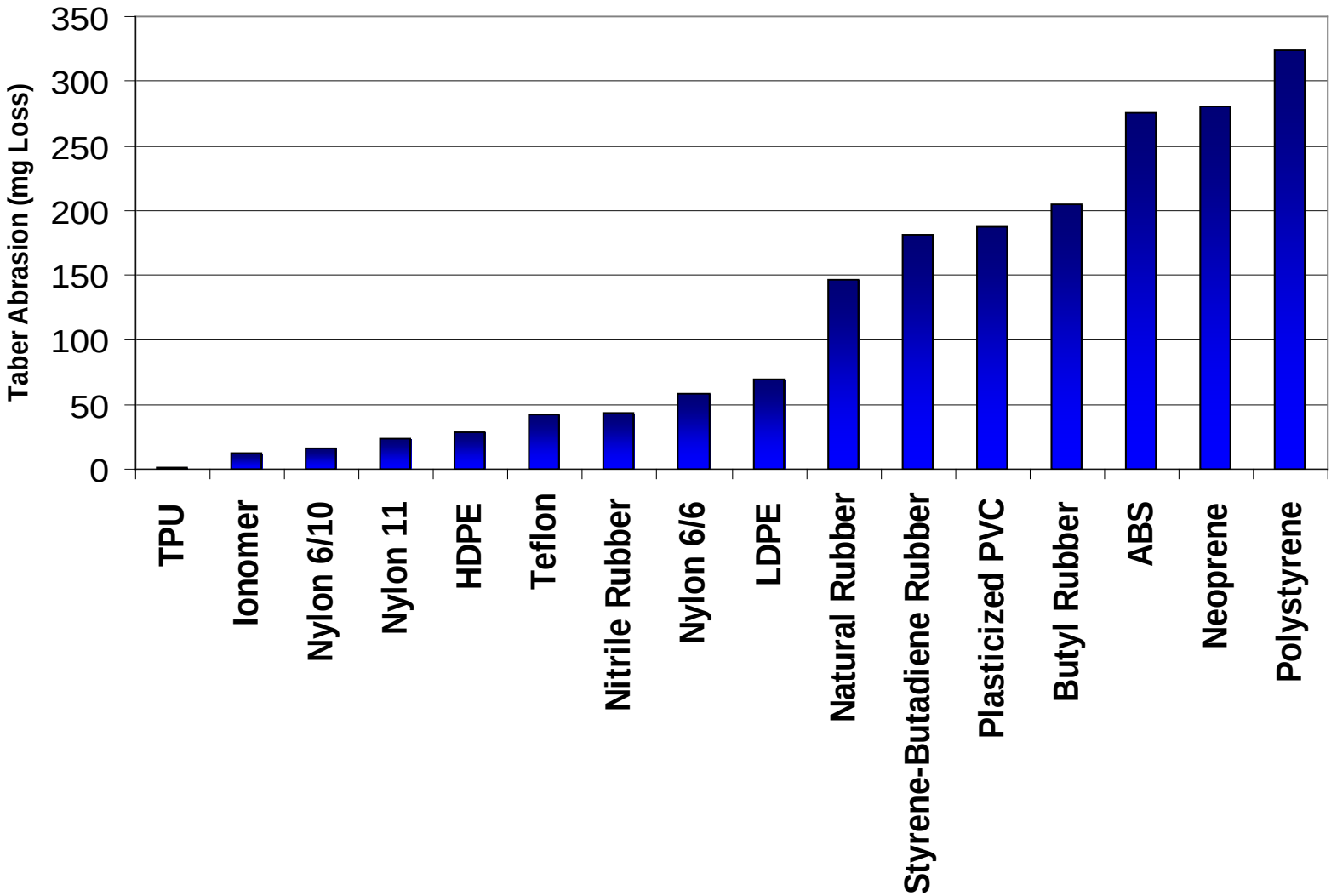

Thermoplastic Elastomer
E-modulus
Melting - material becomes plastic and can be processed
Room Temperature
temperature

Elastollan® Properties

TPU Value Proposition

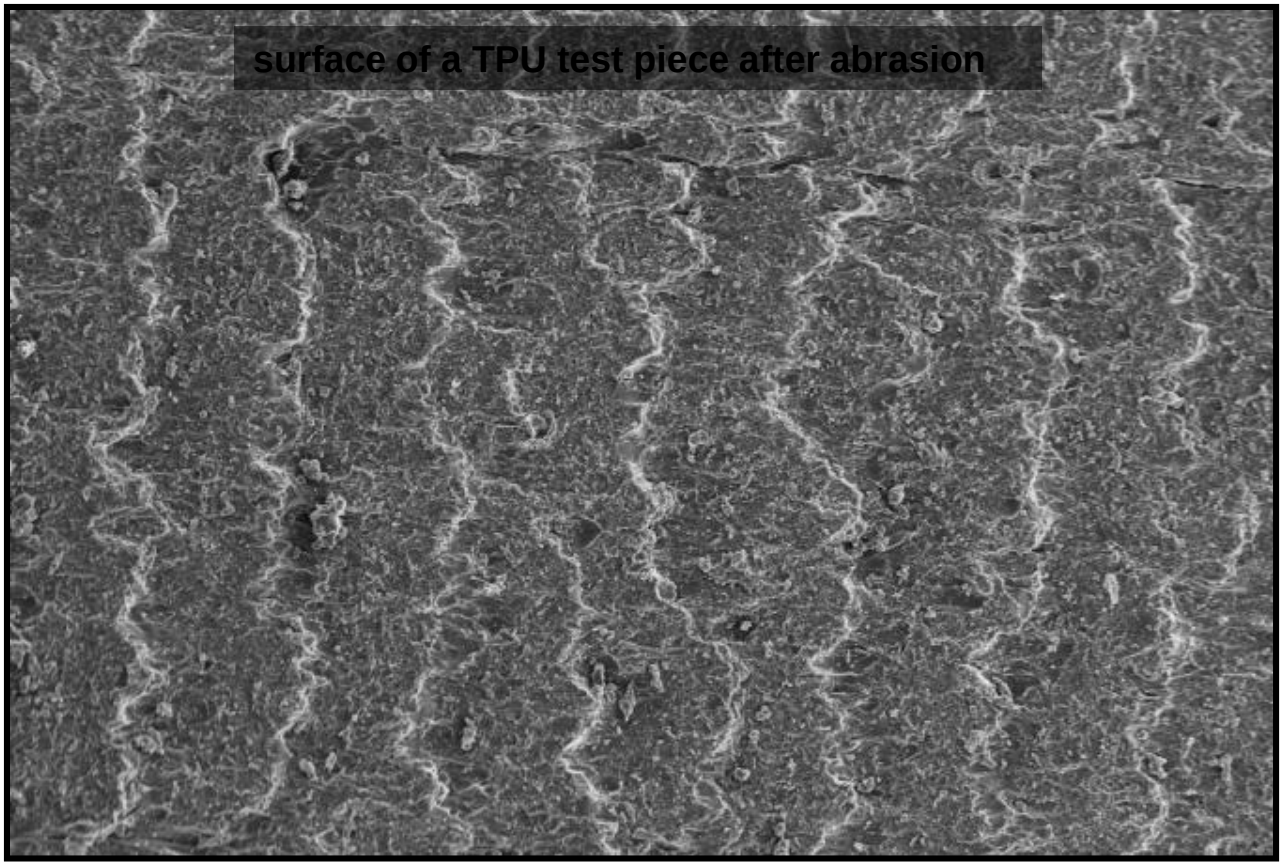
- Abrasion Resistance
- Elasticity and Resilience
- Tear Strength
- Compressive Strength (load bearing)
- Low Compressive Set
- Low Temperature Flexibility
- Low Temperature Impact Resistance
- Resistance to Fuels and Oil
- Transparency (some grades)
- Chemical Adhesion to Most Engineering Plastics
- Material is Processed via Conventional Extrusion and Injection Molding Techniques

Abrasion Resistance of Materials

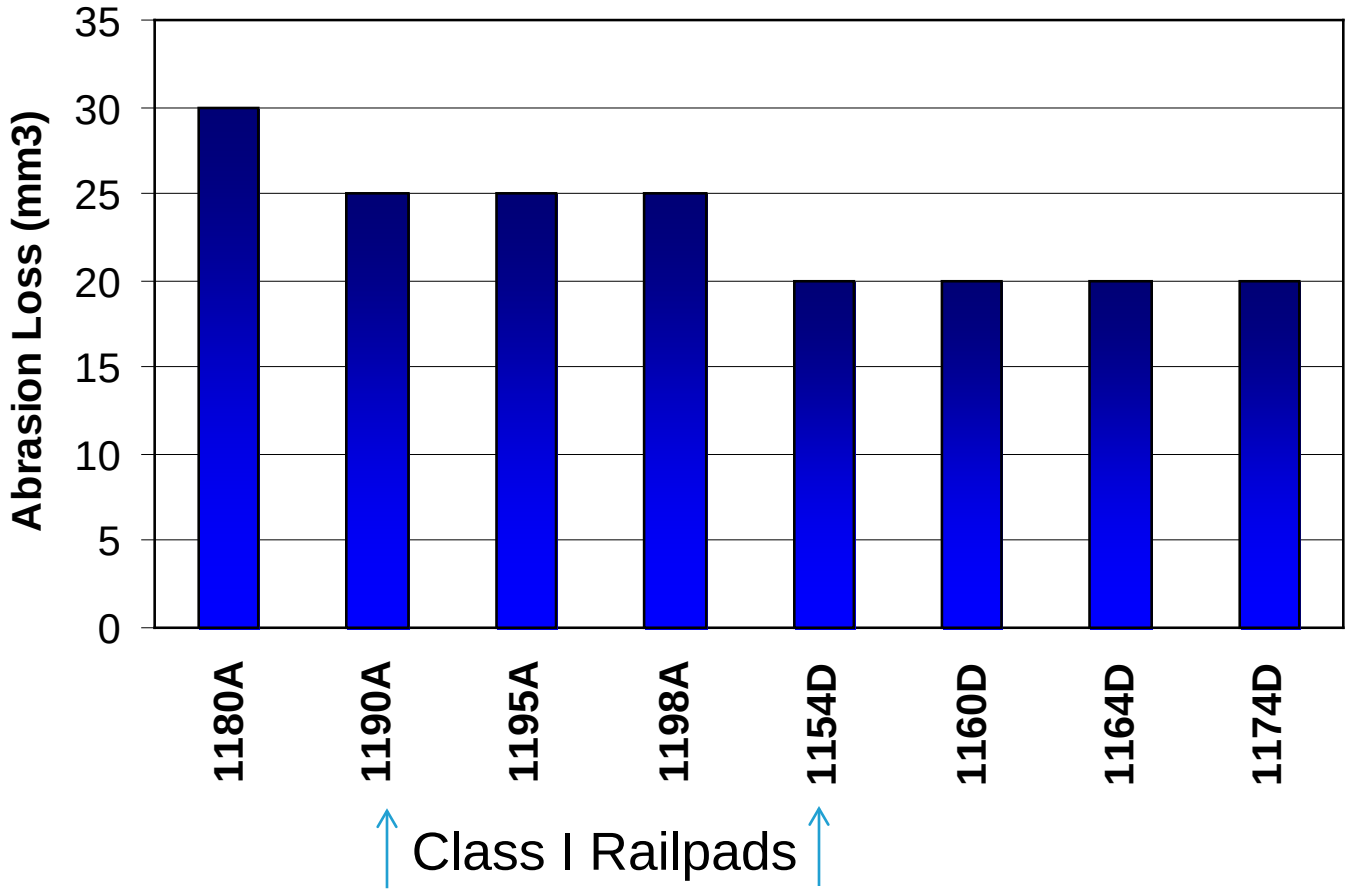


Abrasion Resistance

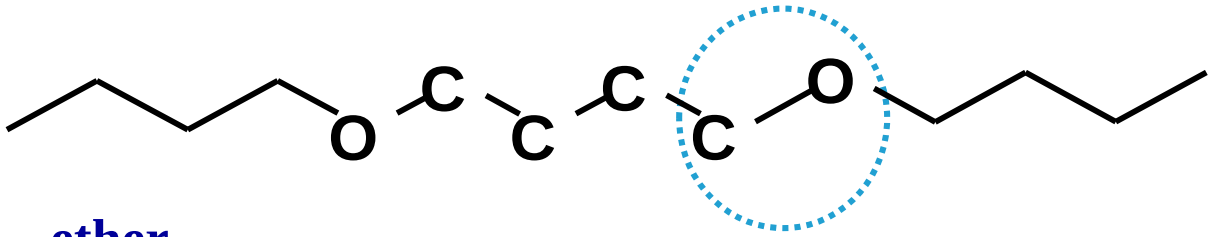
high tensile strength + high elasticity = high abrasion resistance



Effect of “Hardness” on Abrasion loss

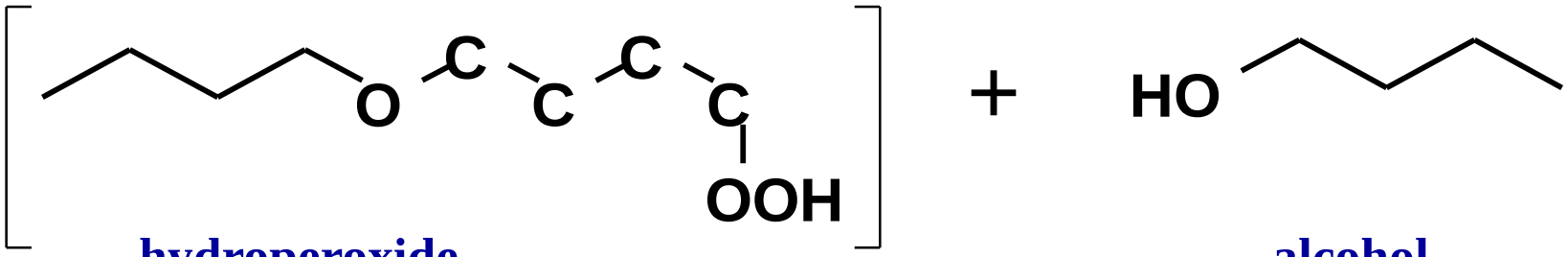


TPU Heat Ageing (Ether)



ether

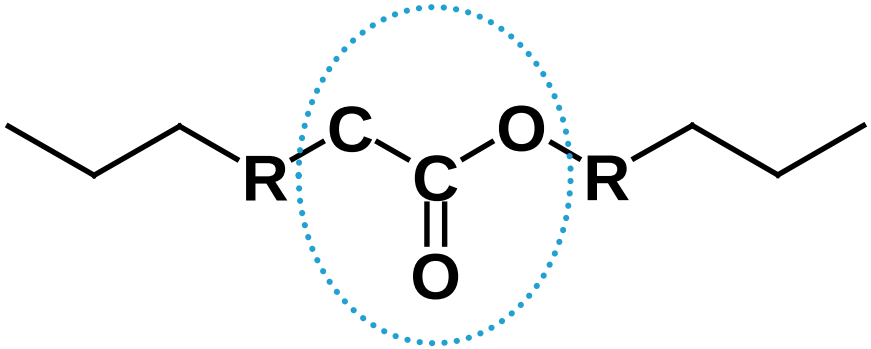
O_2



hydroperoxide

alcohol

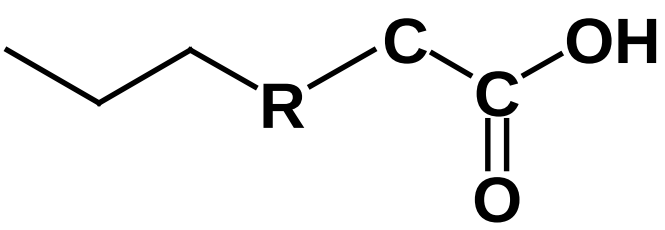
TPU Hydrolysis (Ester)



ester

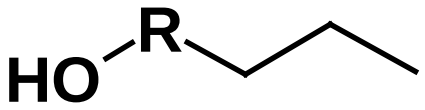
H^+

H_2O



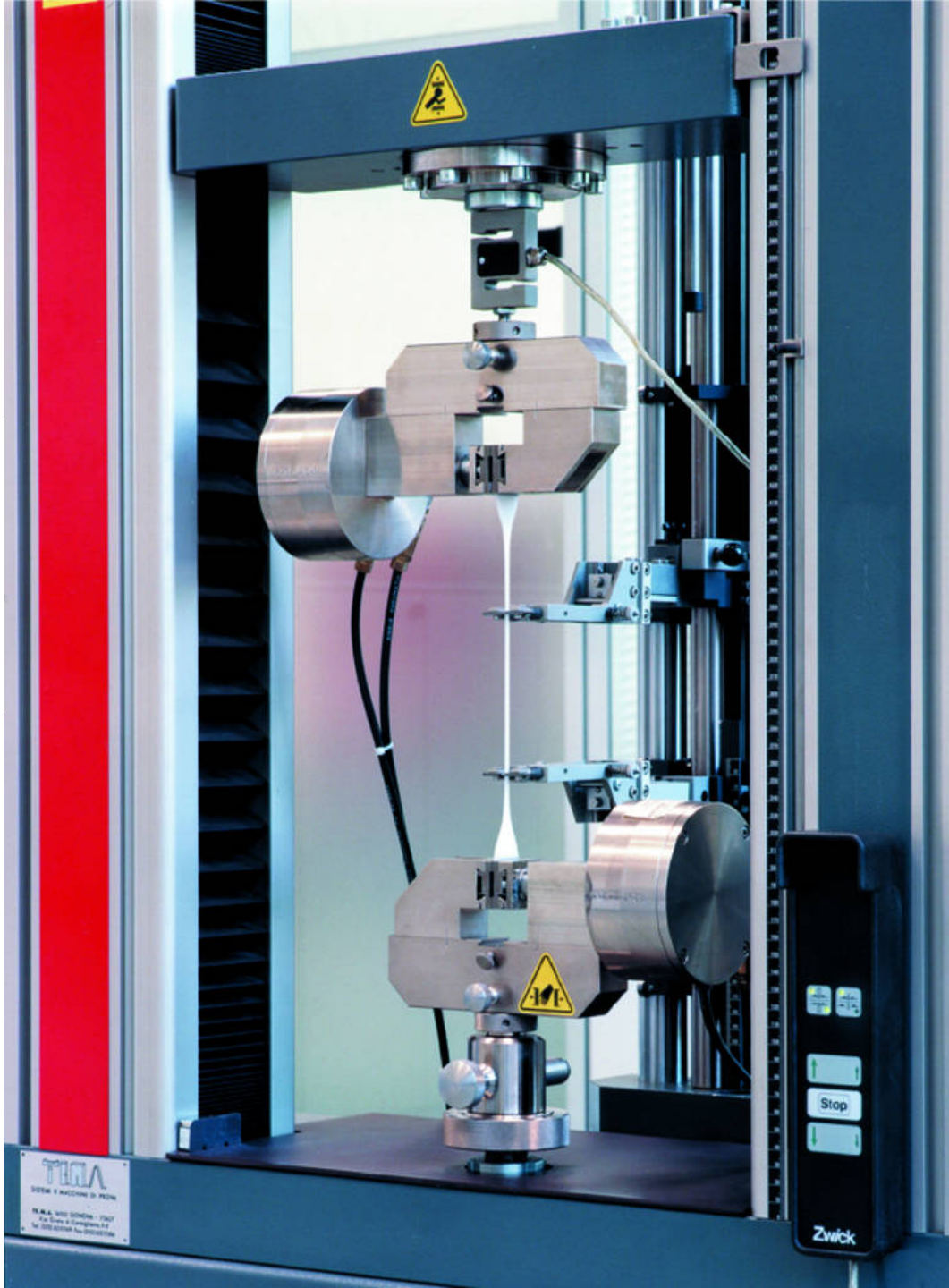
acid

+



alcohol

Important Properties of Elastollan® TPU



Polyether vs. Polyester TPUs

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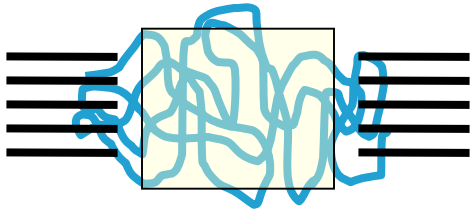
Polyether TPU

- Hydrolysis Resistance
- Microbe Resistance
- Cold Temperature Flexibility
- Low Temperature Impact Resistance

Polyester TPU

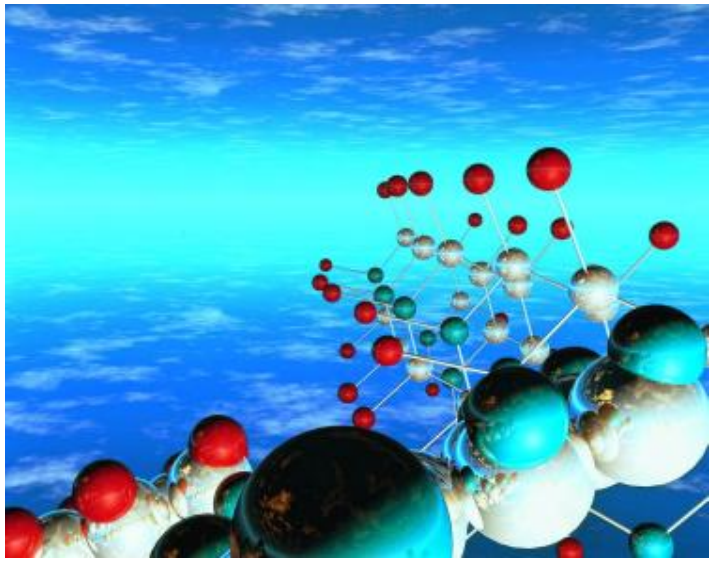
- Heat Stability
- Mechanical Strength
- Oil Resistance
- Polarity
- Stability to Radiation



TPU vs. Rubber –

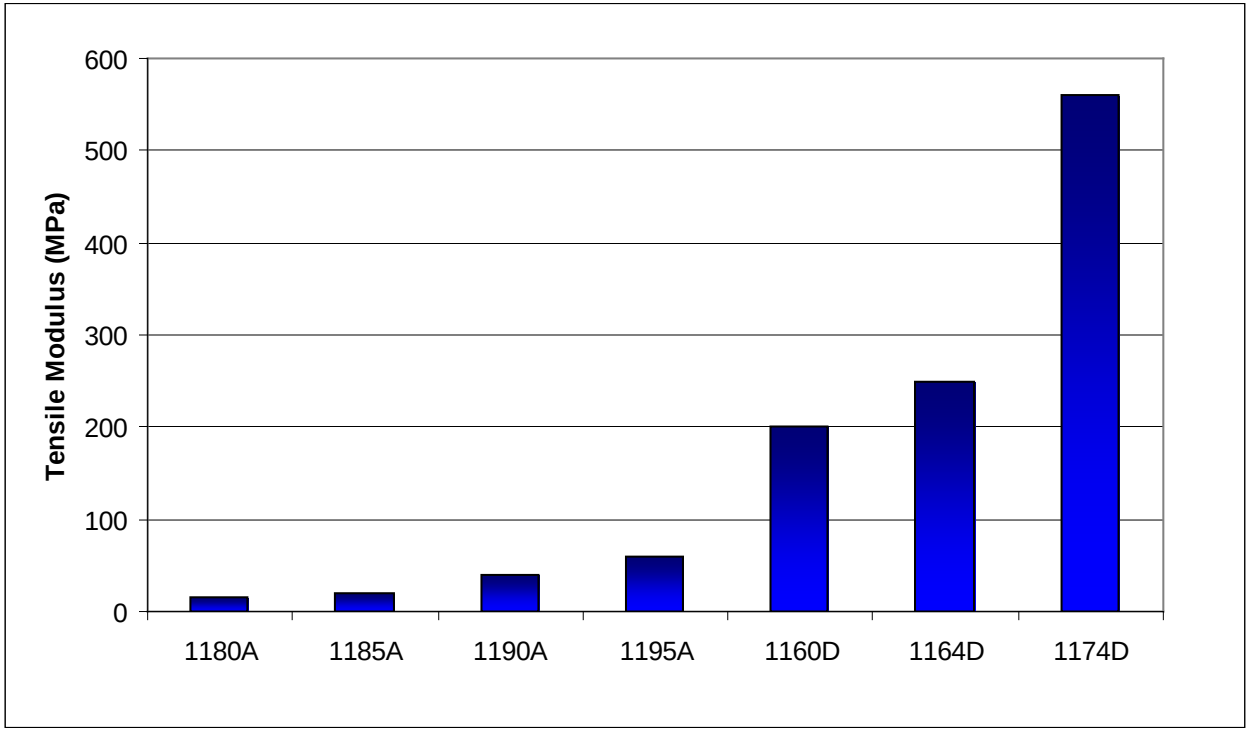
- **Advantages (of TPU)**:
  - Processing methods are similar to thermoplastics
  - Shorter fabrication times
  - No compounding necessary
  - Reusable scrap
  - Low energy consumption
  - Holding low tolerances
  - Lower density than conventional rubber

- **Disadvantages**:
  - Melting at elevated T
  - Limited number of low hardness TPEs (less than 50A)
  - Drying prior to processing

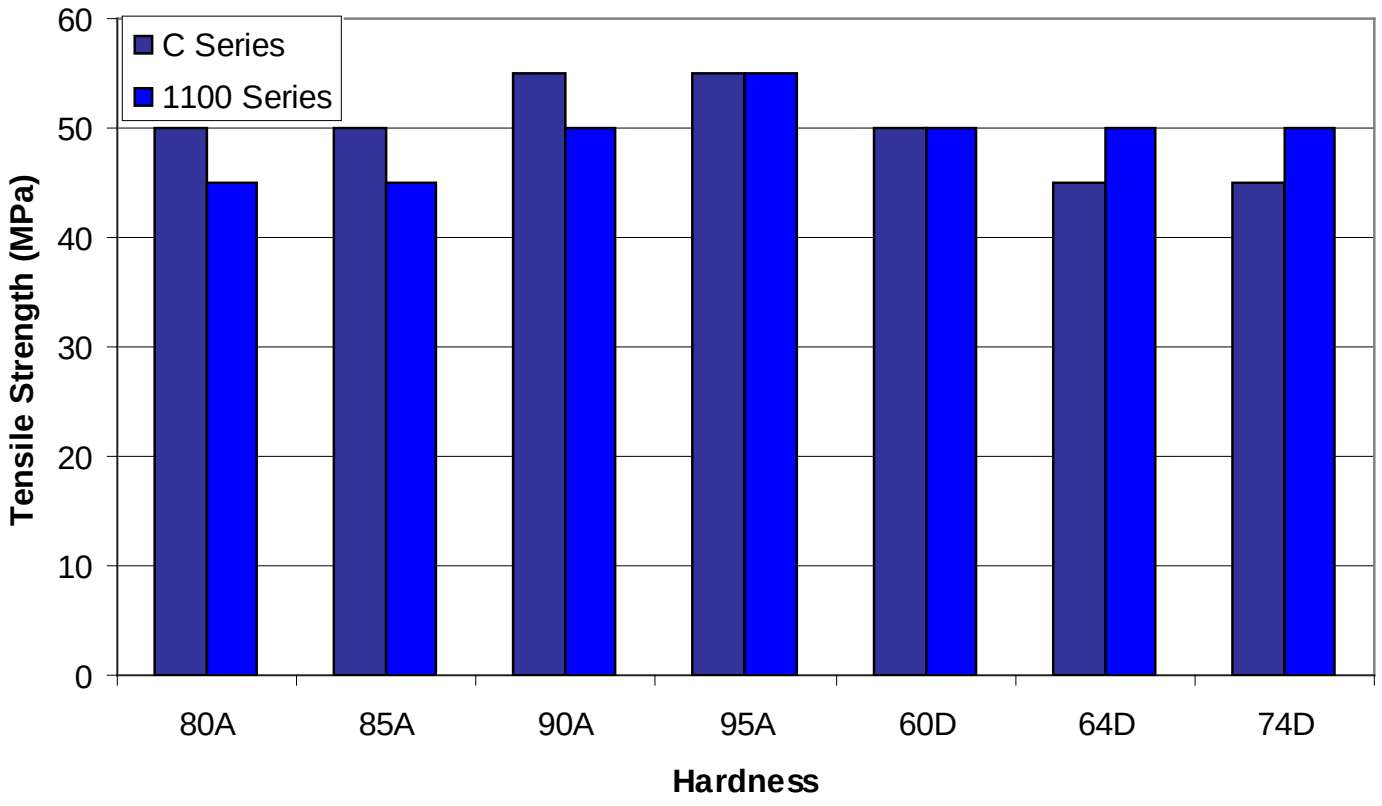


Modulus (Tensile)

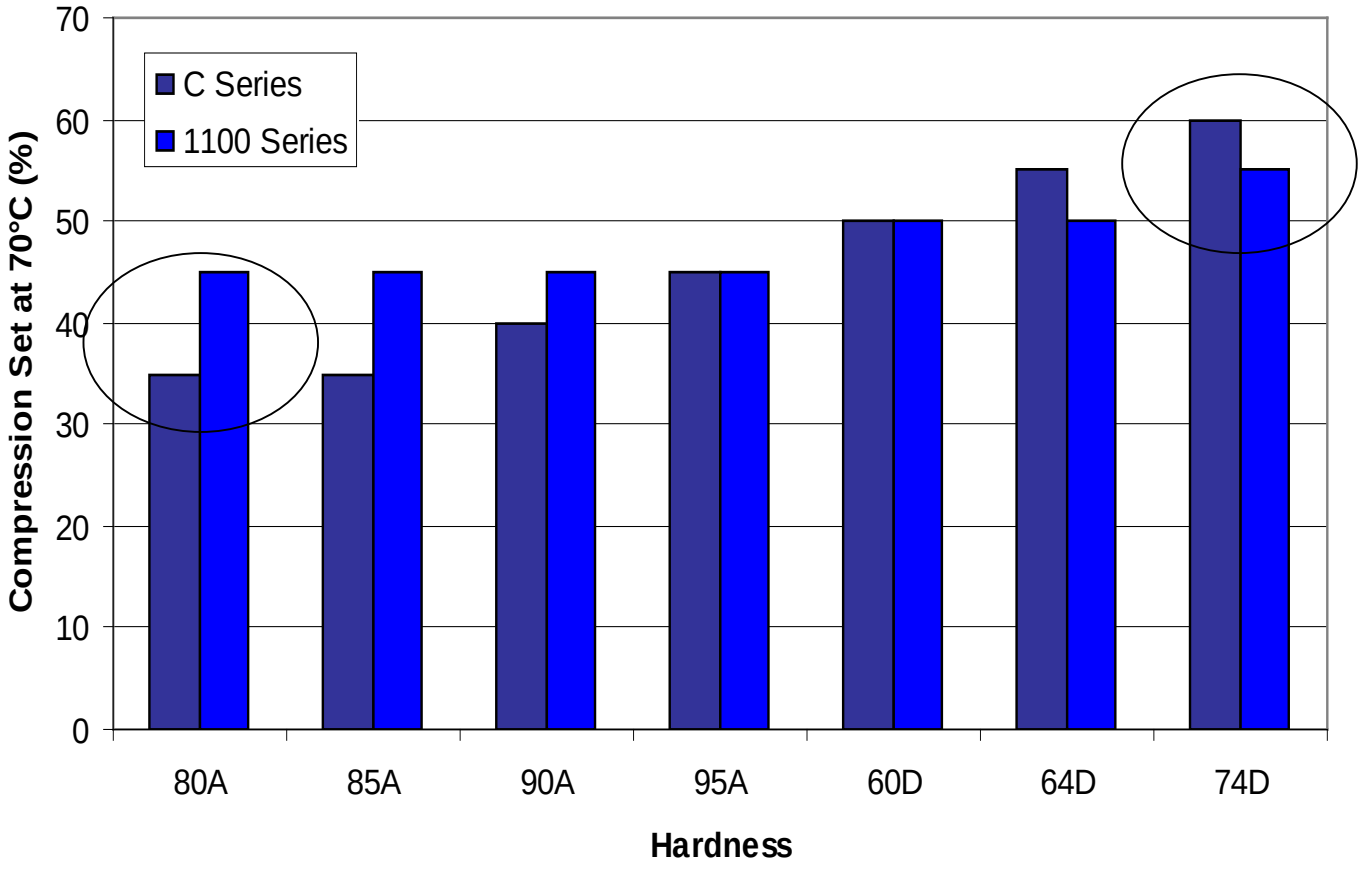
- The tensile and other mechanical properties of TPU vary with the hardness.
- “Hardness” and “Stiffness” can be considered as one



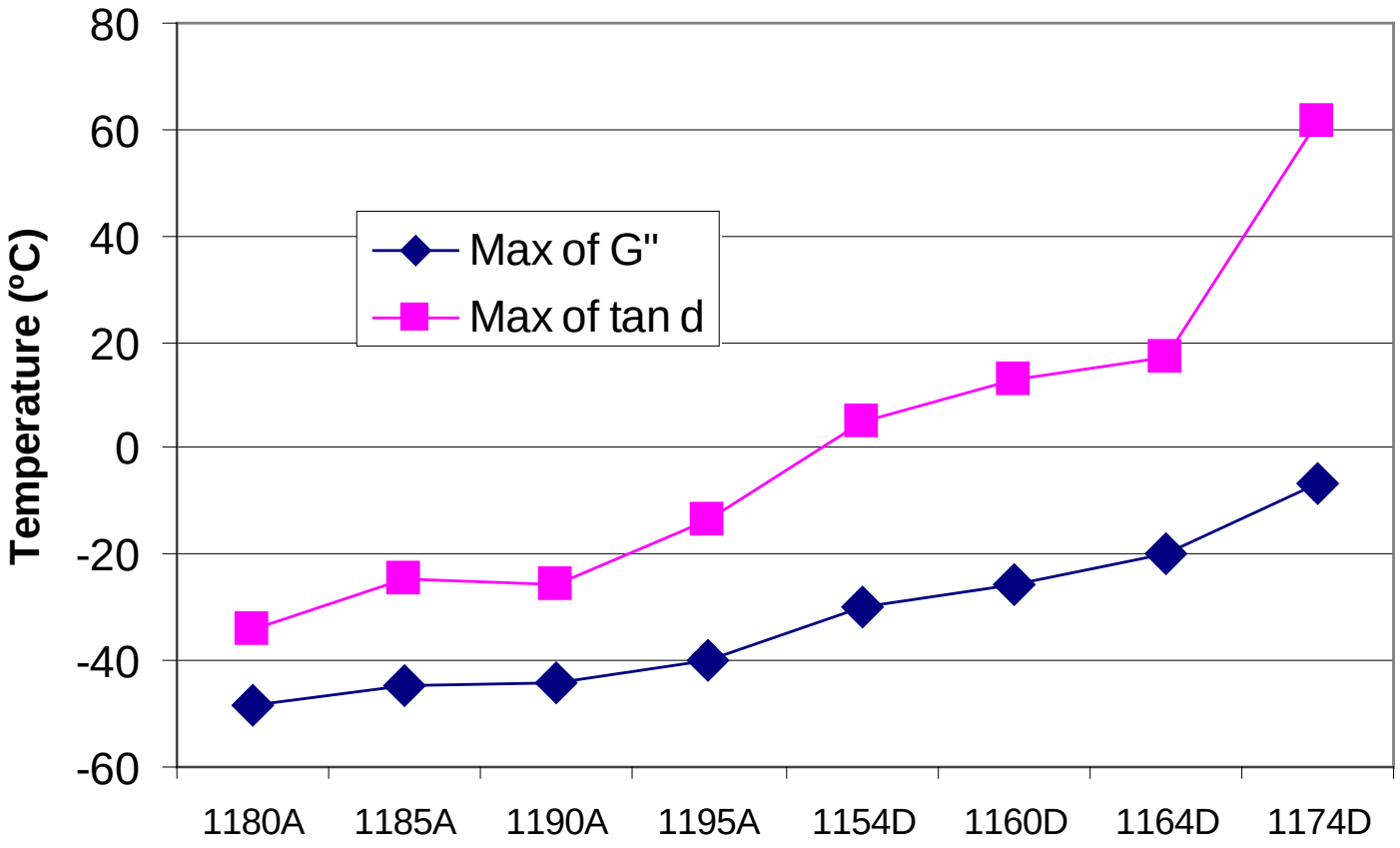
Tensile Strength (at Break) v. Hardness



Compression Set v. Hardness

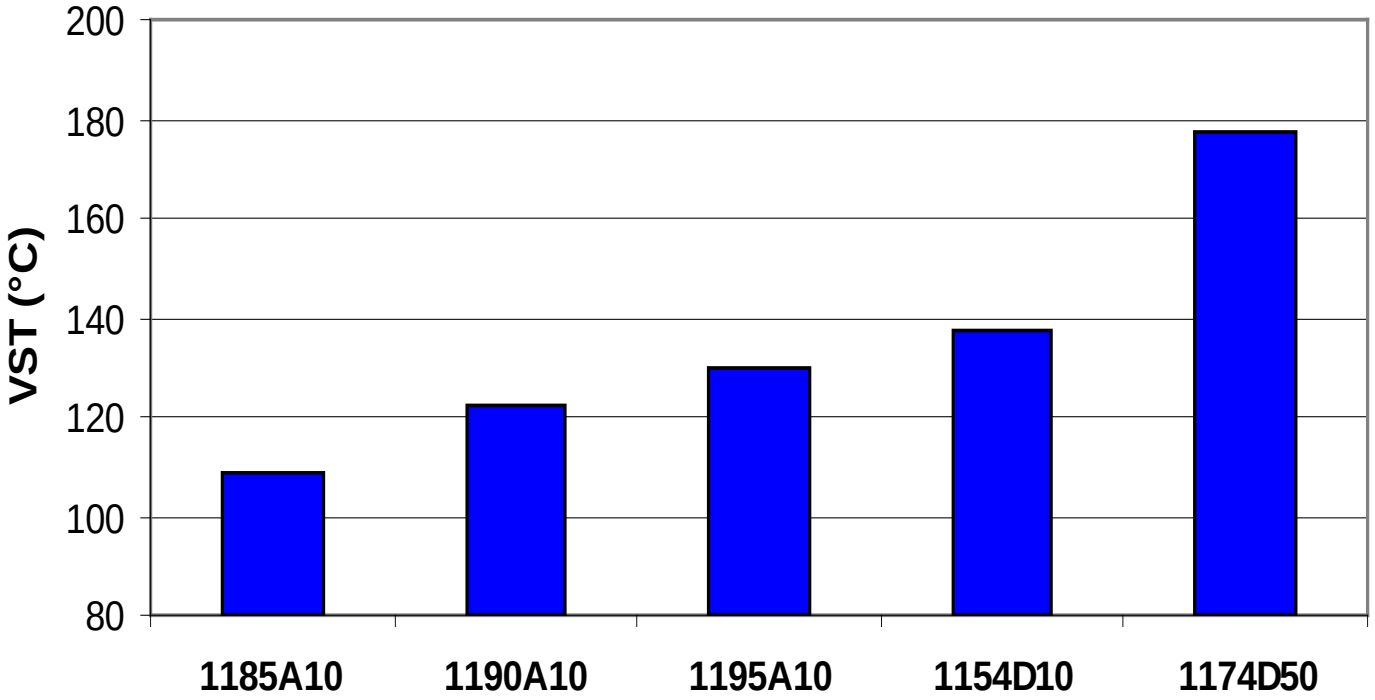


“glass temp” vs Hardness



Softening Temp (Vicat) v. Hardness

Method: DIN ES IS 306 with 120ºC/h and 10N



Cold Temp Impact v. Hardness

DIN EN ISO 175 (kJ/m²)

		Elastollan®						
	Temperature	1175 AW	1185 A	1185 A FHF	1195 A	1154 D	1154 D FHF	1164 D
Unnotched	- 40 °C	NF	NF	NF	NF	NF	48	NF
	- 50 °C	NF	NF	NF	NF	NF	37	NF
Notched specimen	- 10 °C	NF	NF	NF	NF	163	9	29
	- 20 °C	NF	NF	NF	NF	168	5	13
	- 30 °C	NF	NF	37	180	14	3	9
	- 40 °C	NF	NF	8	24	11	3	9
	- 50 °C	NF	NF	4	12	9	3	7

Elastollan® TPU by BASF –
Excellent Properties for Demanding Applications

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TPU for Rail Infrastructure - Summary

- TPU's modulus vs. temp behavior similar to rubber
- Major benefit of Elastomers - flat modulus across temp range
- TPUs for heavy haul in North America - range from 90A – 55D
- Harder materials/grades
  - less rubbery
  - Behave more 'plastic', almost 'metal like' in terms of modulus and dynamic mechanical properties
- Compression Set % – increases with hardness
- Tensile Strength at break – unaffected by hardness

TPU for Rail Infrastructure - Summary

- Softer grades = higher abrasion loss vs harder grades
- Softer grades = more elastic (lower modulus)
- Softer grades – higher damping, absorb more energy than harder grades
- Harder grades are significantly stiffer, are thus less elastic (have higher modulus)
- Harder grades – higher load bearing, less energy absorption
- Is there a limit? – as hardness increases, glass temp, cold flexibility, impact strength, damping, comp set are all affected and should be considered
- If harder TPUs are considered (to counteract increased track loads) – please factor all this into the design, seek BASF's assistance

Elastollan® TPU - Production Sites

BASF develops, produces and markets Thermoplastic Polyurethane elastomers (TPU) under the trade name Elastollan® in all major economic regions globally

More than just products

BASF
We create chemistry

Engineering, simulation and material consulting expertise

Material Consulting

- World-class technical service
- Over 10,700 employees worldwide involved in R&D
- Around 3,000 research projects
- R&D spending €1.8 Bn

Parts testing

Simulation Competence

Processing technologies

Questions