

RESOMER®: An Overview

Isometric / Evonik workshop

September 12th, 2024

Thiago Borges.

Head of Services, Business Management

Health Care

Evonik Corporation



Introducing Evonik

A Global Specialty Chemicals Leader

What we do

more fuel saving



CAR TIRES

fluffier



TOWELS

more elastic



MATTRESSES

healthier



NUTRITION

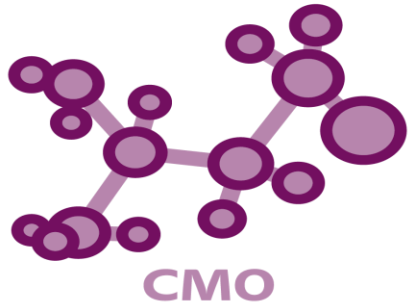
more effective



TABLETS

Evonik Health Care

An enabling development partner and solutions provider to the health care industry



APIs, HPAPIs & Intermediates



Oral drug delivery



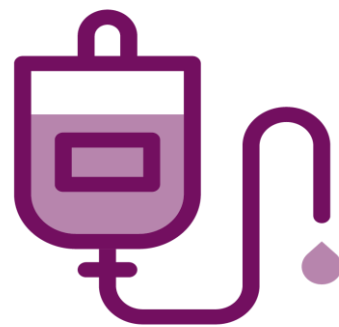
Complex parenteral



Nutraceuticals



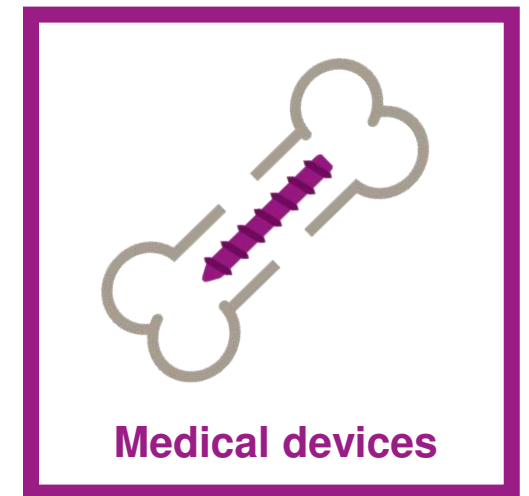
Pharmaceutical ingredients



Amino acids



Cell culture



Medical devices

Medical Device Solutions

Your strategic solution provider for medical device applications

High value system solution offerings along the value chain

Advanced Technologies with strong IP background

Manufacturing Solutions

Application Technology and value-added services: A global network of regional labs and competence centers

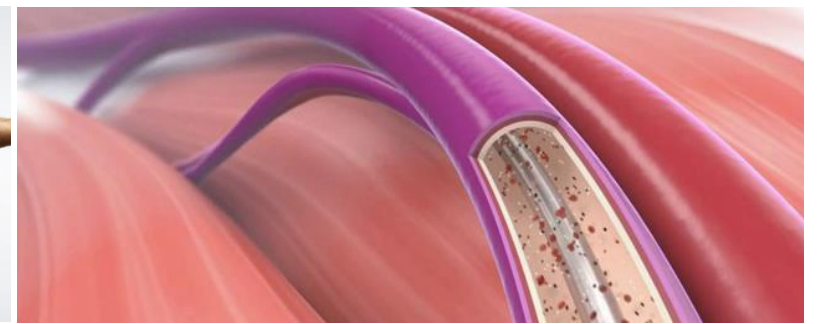
Synthetic bioresorbable polymers
RESOMER®



Natural identical biomaterials
Biocellic® | Vecollan®



Surface modification Technology
Endexo®



Vecollan®

A recombinant collagen that is safe,
sustainable and scalable



A major biotech breakthrough: Evonik's new collagen platform for life science applications

1.

A **recombinant collagen** that mimics many of the attributes of natural human collagen

2.

Highly soluble, biocompatible and **processable** for efficient interaction with our cells and tissues

3.

Fermentation-based, highly pure process for **scalability** and **batch reproducibility**

4.

Highly sustainable, effectively substituting the use of animal-derived collagen

5.

Ready to commence **product sampling, feasibility studies** and **development programs**



Vecollan[®]

Biosynthetic Cellulose



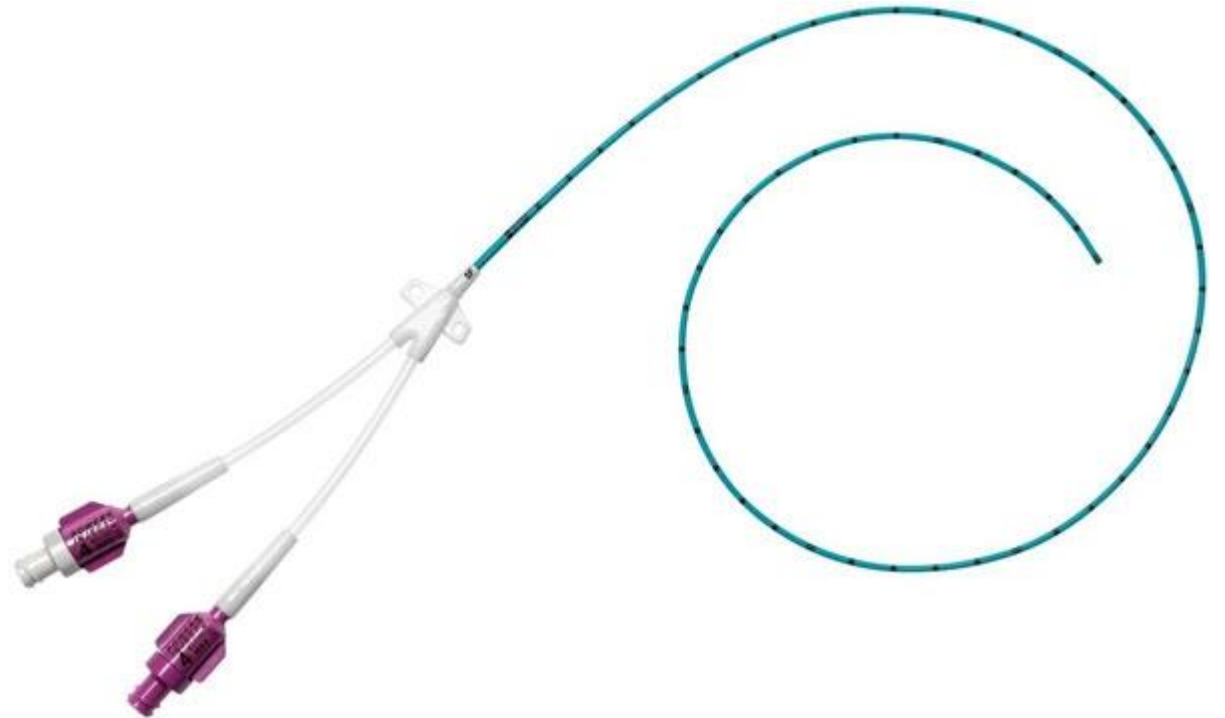
Superior biosynthetic cellulose for wound care and dermatology

1.	Chemically pure cellulose, highly biocompatible
2.	Pharma-grade raw materials, fermentation-based, non-animal derived
3.	High batch to batch reproducibility
4.	Homogenous network structure and high fluid absorption and donation capacity
5.	Ready to commence product sampling, feasibility studies and development programs



Endexo[®] Surface Modification

Anti-thrombotic and
anti-fouling additives



Endexo® Surface Modification

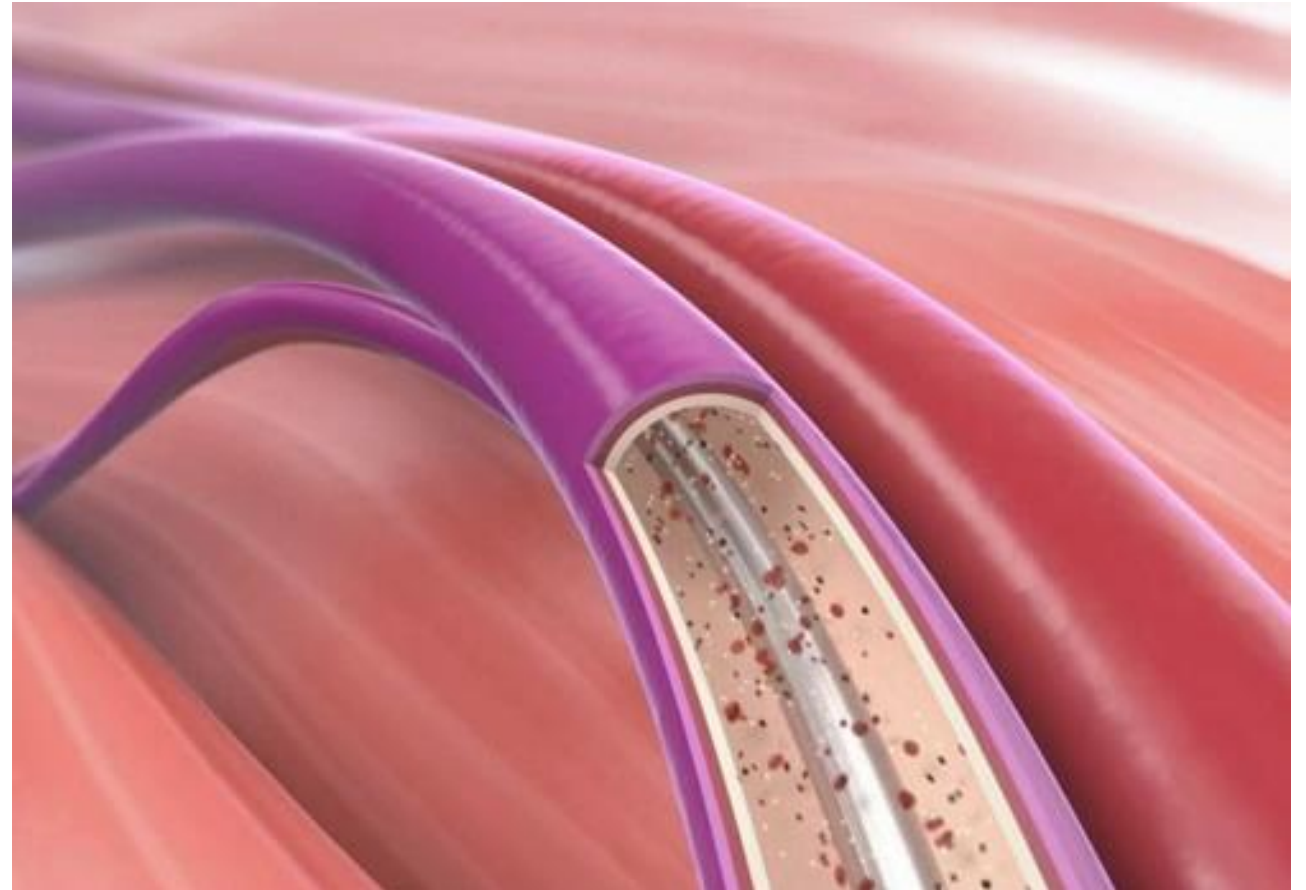
A best-in-class solution for medical device applications

Highly versatile platform of anti-thrombotic and anti-fouling additives

Passive, stable, uniform and durable surface protection with no elution

Compatible with a range of base polymers and standard manufacturing processes

Clinically proven across multiple applications over more than 10 years of commercial use



RESOMER® Portfolio

The versatility you need.
Backed by the safety, biocompatibility
and supply security you demand.



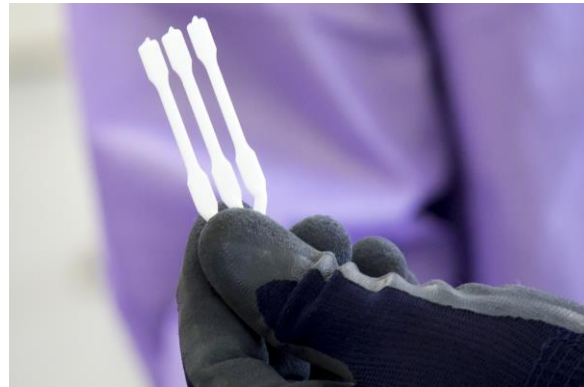
Introducing RESOMER®

The world's leading portfolio of standard, custom and specialized bioresorbable polymers



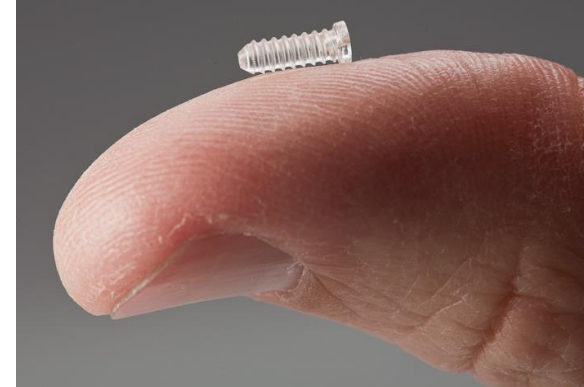
The broadest portfolio

Match our polymer properties and characteristics to specific application requirements



Highly customizable

The world's leading brand of custom-made bioresorbable polymers, made to order



30 yrs. of quality & safety

For reliable biocompatibility, efficacy, safety, quality and supply security at any scale



Best-in-class services

Modern labs with technical experts in the U.S., EU & Asia to reduce scale-up risk

Global Network of Manufacturing Facilities and Application Labs

For customer proximity and supply security

Birmingham, USA



- cGMP cleanroom production of RESOMER® / RESOMER® Select/ Endexo®
- MD Competence Center (MDCC) and Application lab
- Regulatory support

Shanghai, China



- MD Application lab
- Regulatory support

Darmstadt, Germany

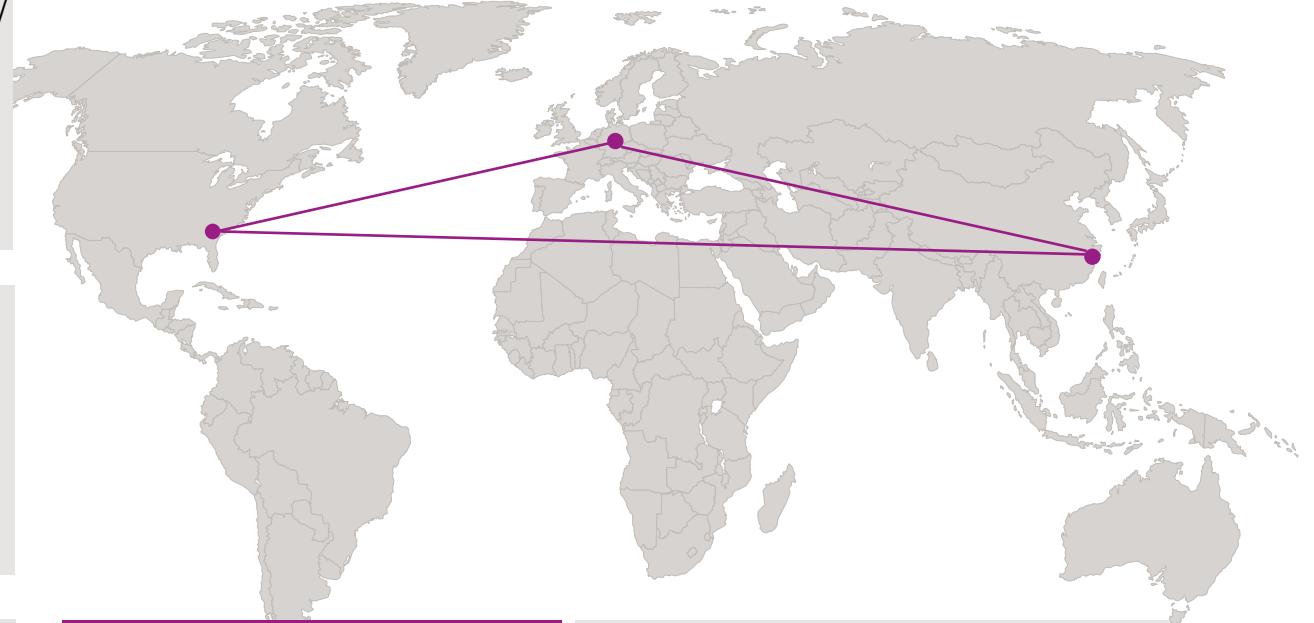


- cGMP cleanroom production of RESOMER® / RESOMER® Select
- MD Application lab
- Regulatory support

Jena, Germany



- cGMP cleanroom production of Epicite®, Biocellic®
- Biocellic Application lab
- Regulatory support



RESOMER® Portfolio of Bioresorbable Polymers

RESOMER®
catalog



20-plus standard high and low molecular weight PLG polymers

RESOMER®
Select



Highly customizable options to address your specific needs

RESOMER®
Composites



Safety, biocompatibility and osteo-conductivity for bone fixation devices

RESOMER®
Powder



Micronization platform for customized particle size distribution

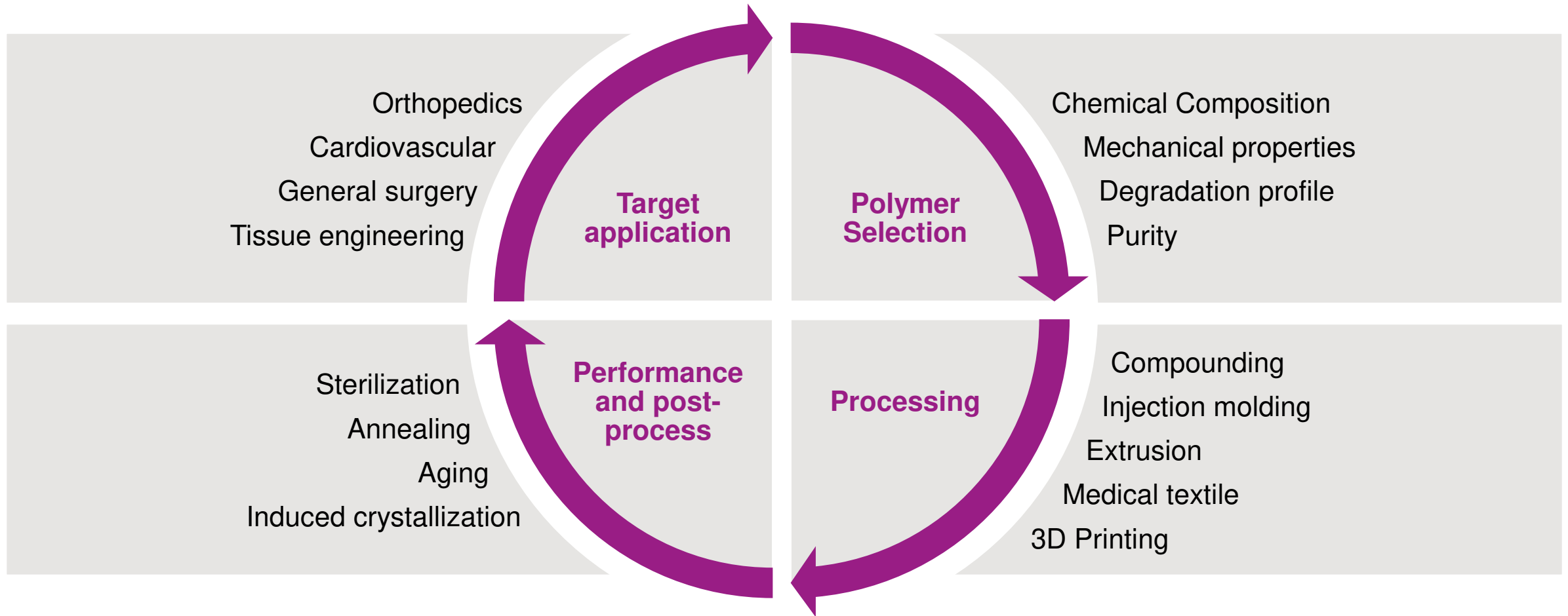
RESOMER®
for 3D Printing



High resolution 3D printed parts on FFF and SLS equipment

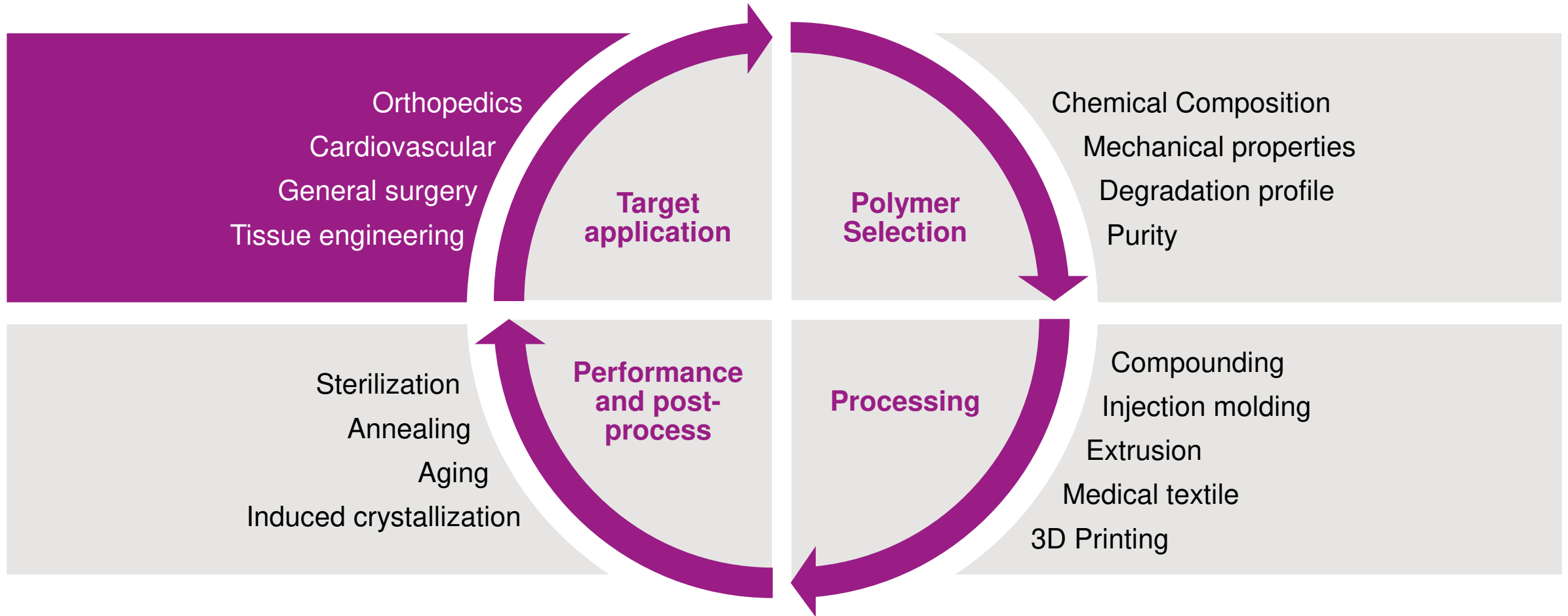
Application Technology for RESOMER®

Material and processing considerations for successful medical device performance



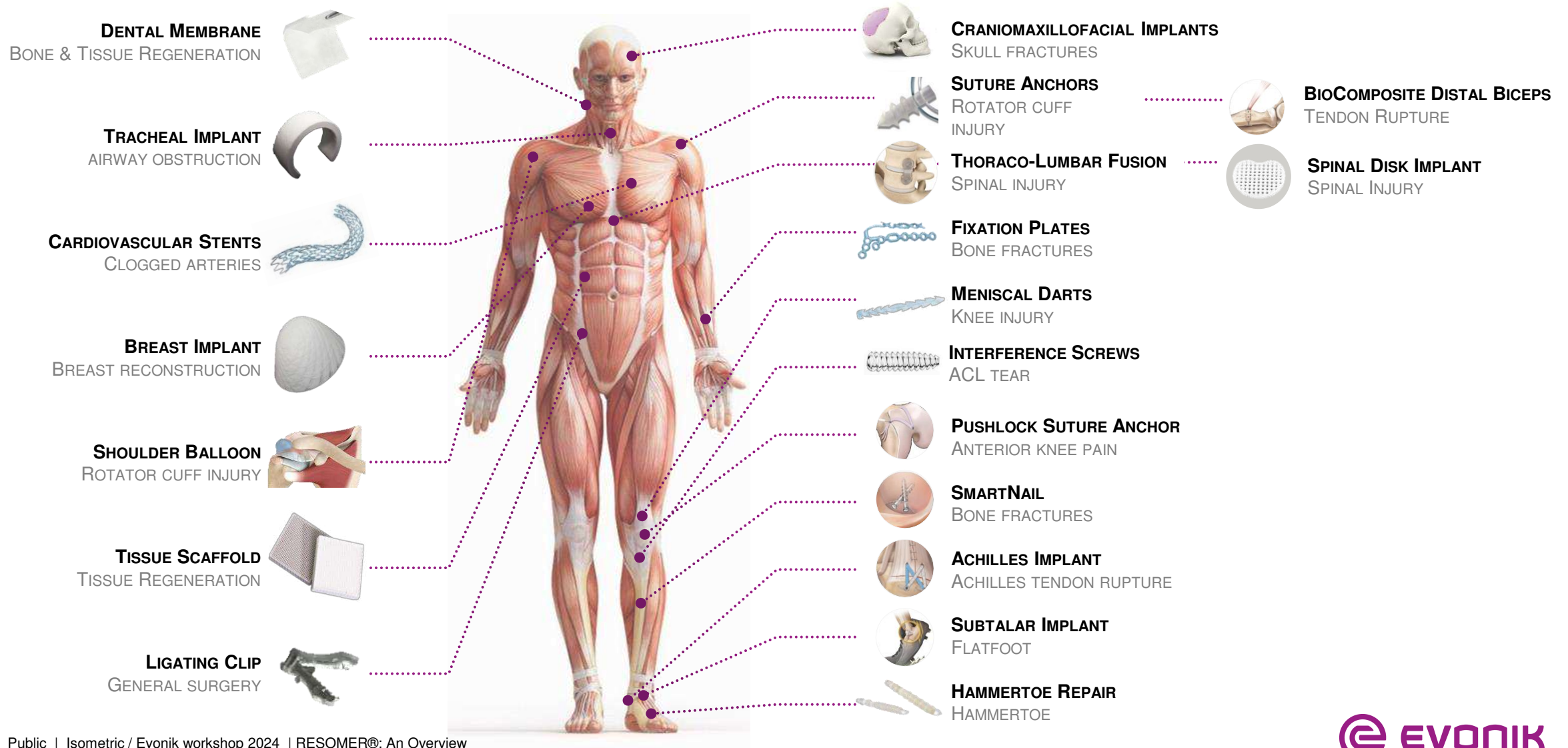
Application Technology for RESOMER®

Material and processing considerations for successful medical device performance



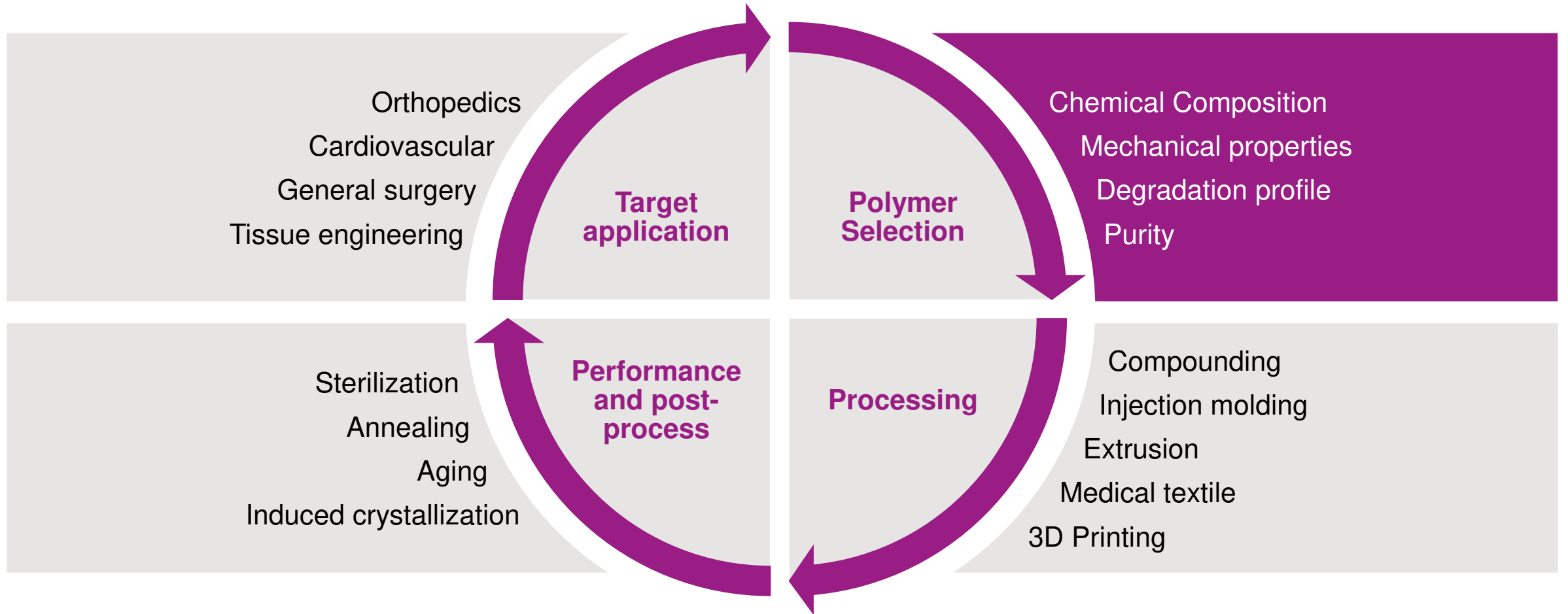
The RESOMER® portfolio

The breadth and versatility to match virtually any application requirement



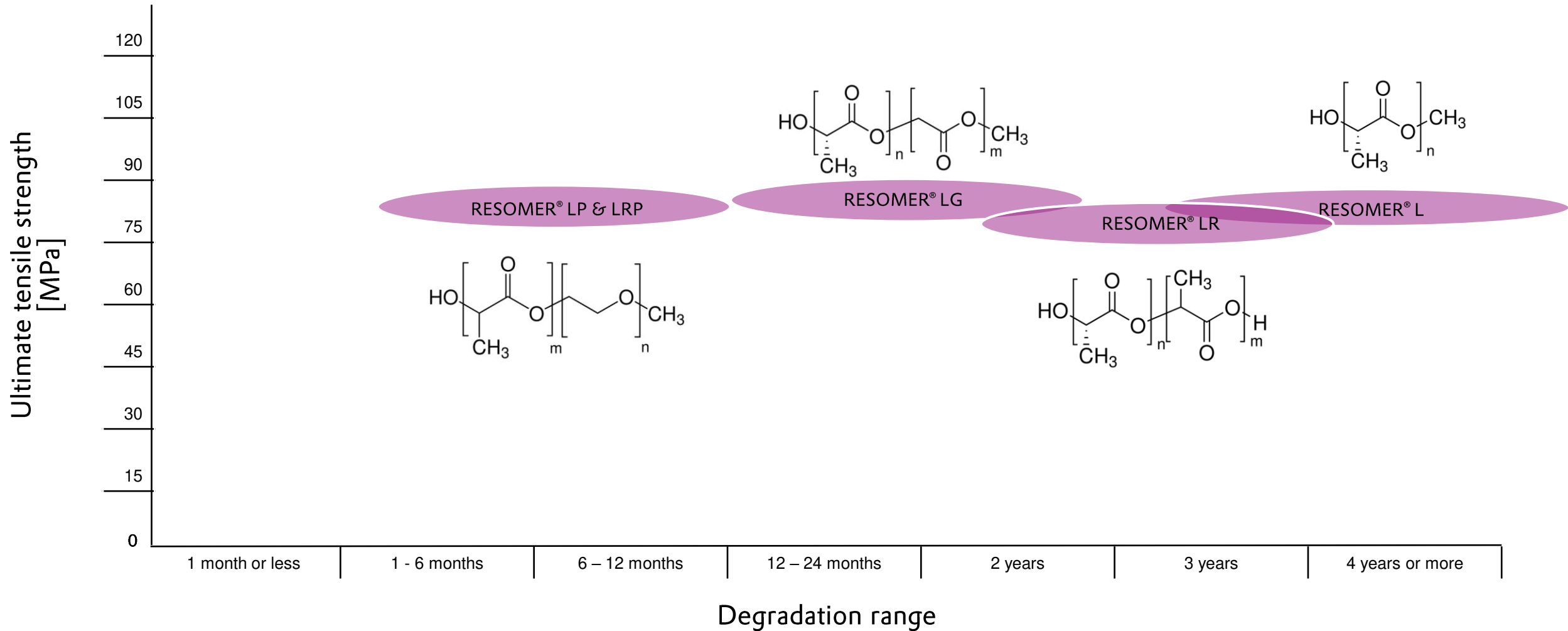
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Material and processing considerations for successful medical device performance



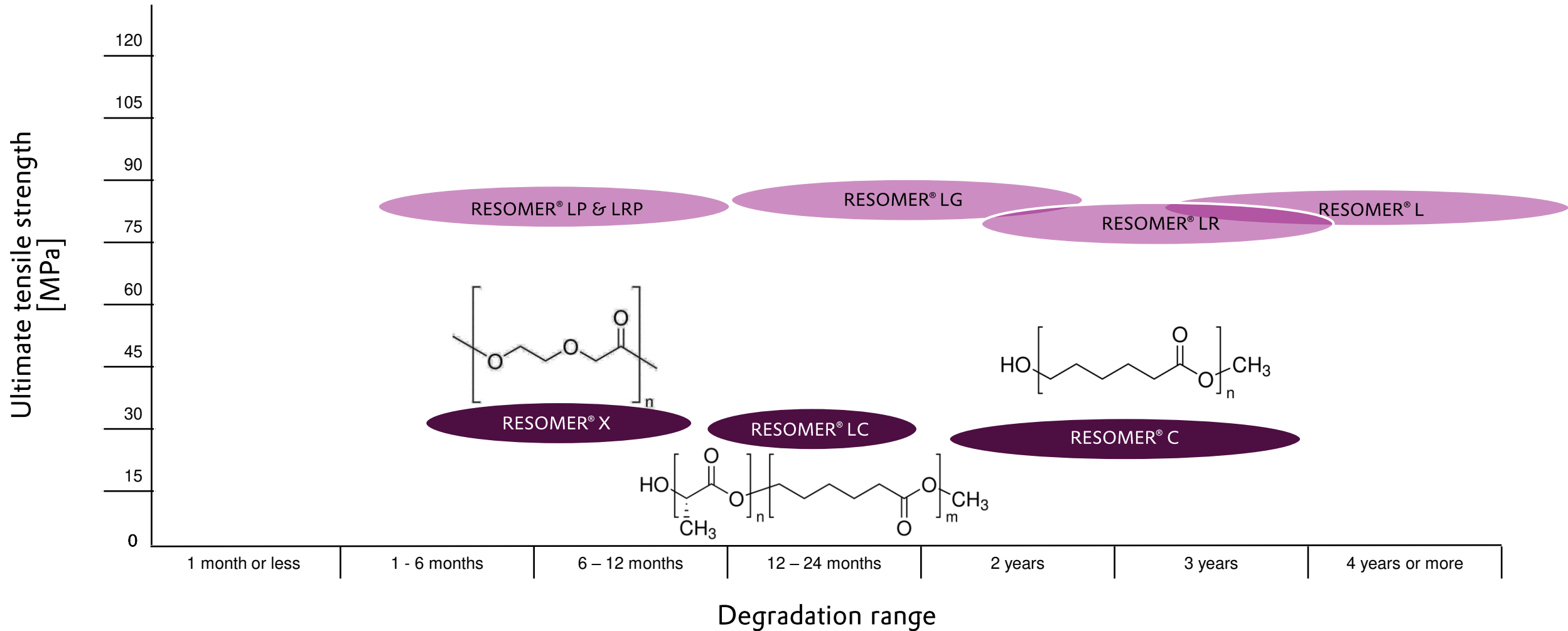
The RESOMER® portfolio

Degradation times ranging from few weeks to four years or more



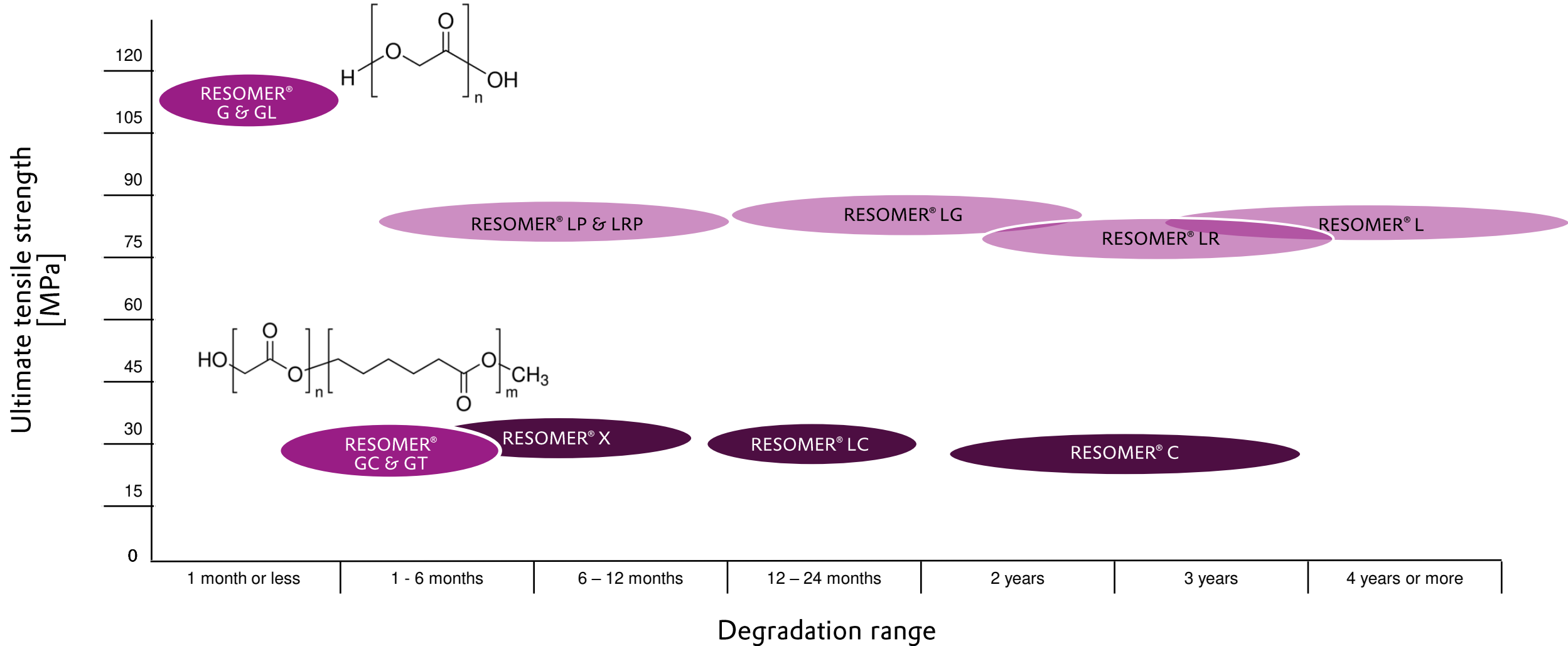
The RESOMER® portfolio

Degradation times ranging from few weeks to four years or more



The RESOMER® portfolio

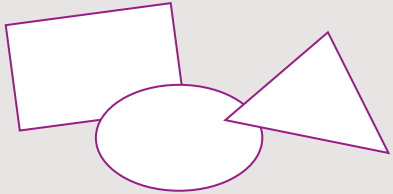
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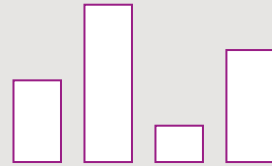
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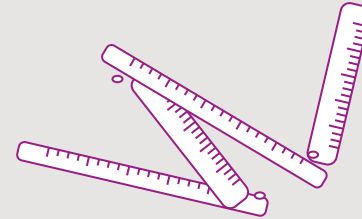
Monomer Selection



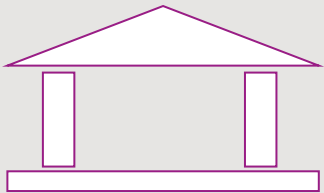
Monomer Composition



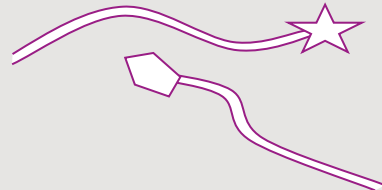
Molecular Weight



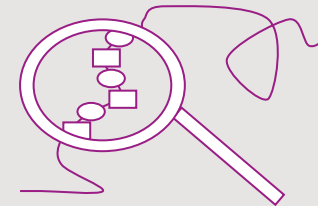
Polymer Architecture



End Groups



Polymer Microstructure



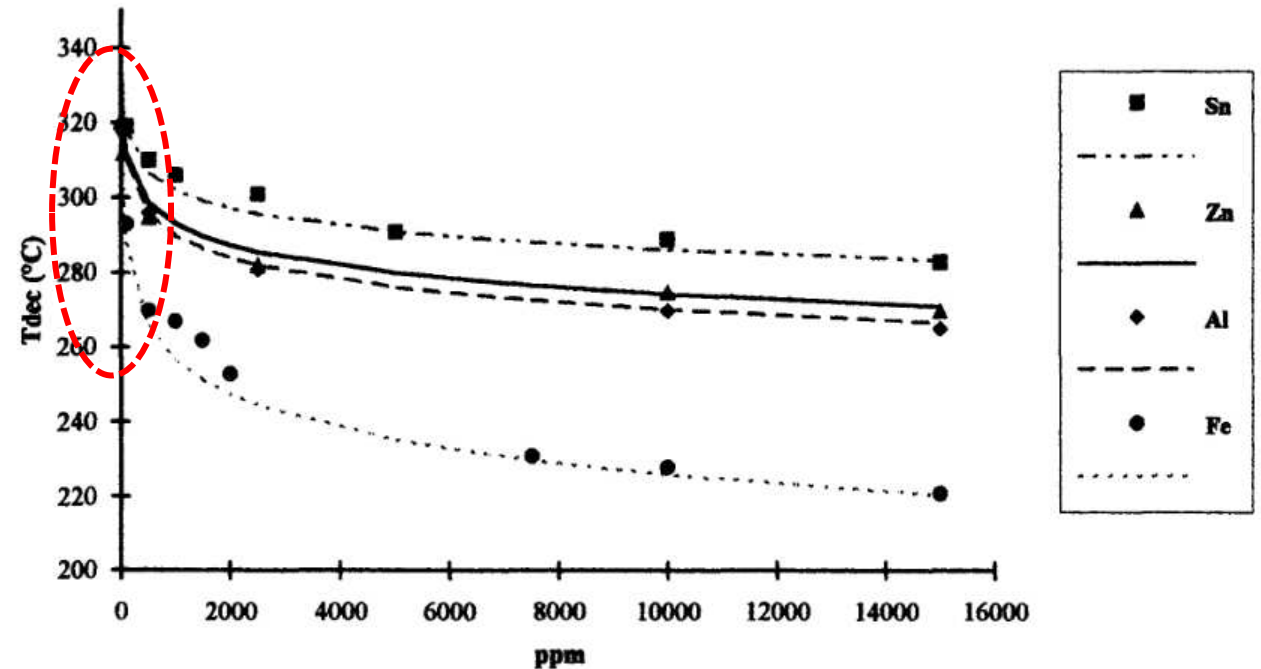
RESOMER® & RESOMER® Select

- The world's leading brand of standard and custom-made bioresorbable polymers
- Flexibility to meet specific customization needs
- Batch sizes from lab to production scale

Impurities on resorbable materials

Effect of residual catalyst

- Increasing the concentration of catalyst reduces the melting and decomposition temperatures.
- Concentrations of catalysts on GMP materials are significantly lower than industrial grade. Recommended concentration in resins and surgical implants is $\leq 100 \text{ ppm}^{(1)}$ or $\leq 150 \text{ ppm}^{(2)}$

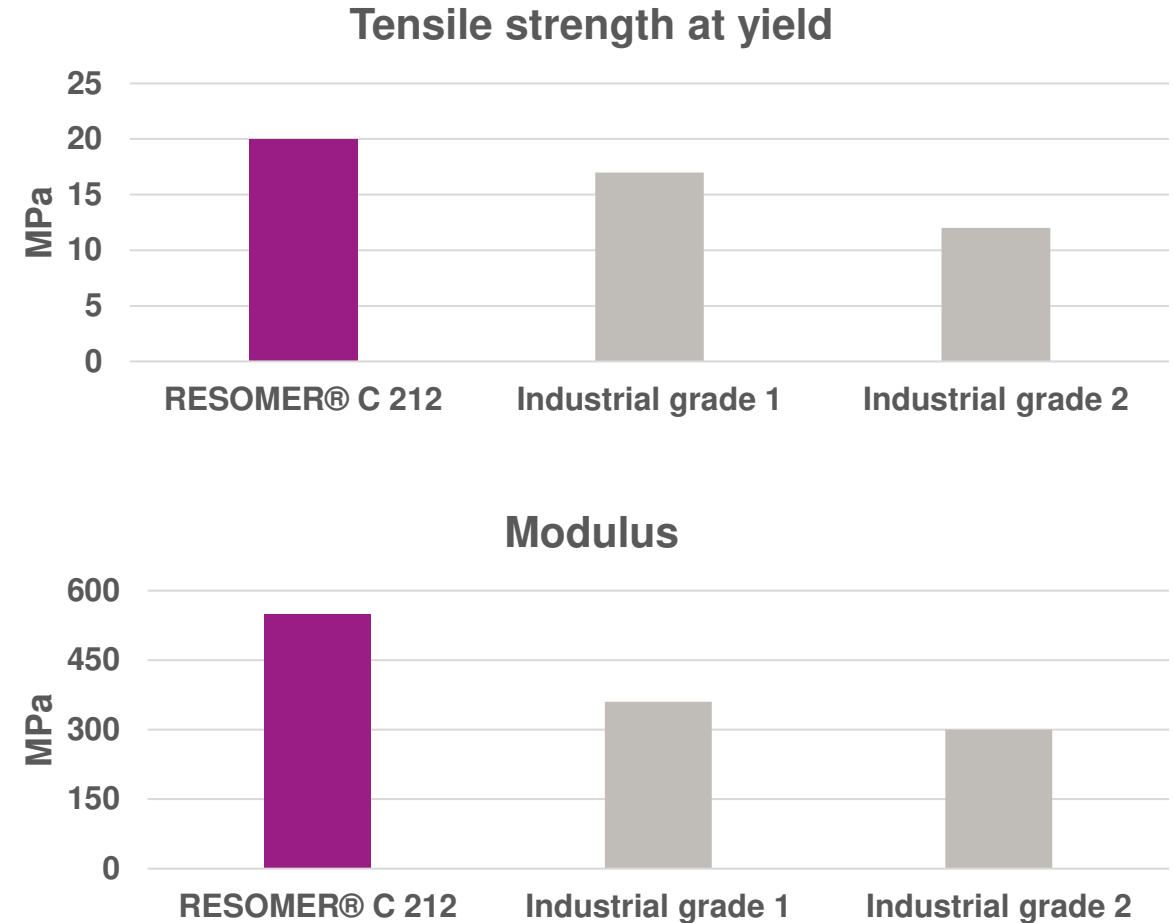


Effect of residual catalyst presence on PLA thermal degradation, reported by Cam and Marucci⁽³⁾

Impurities on resorbable materials

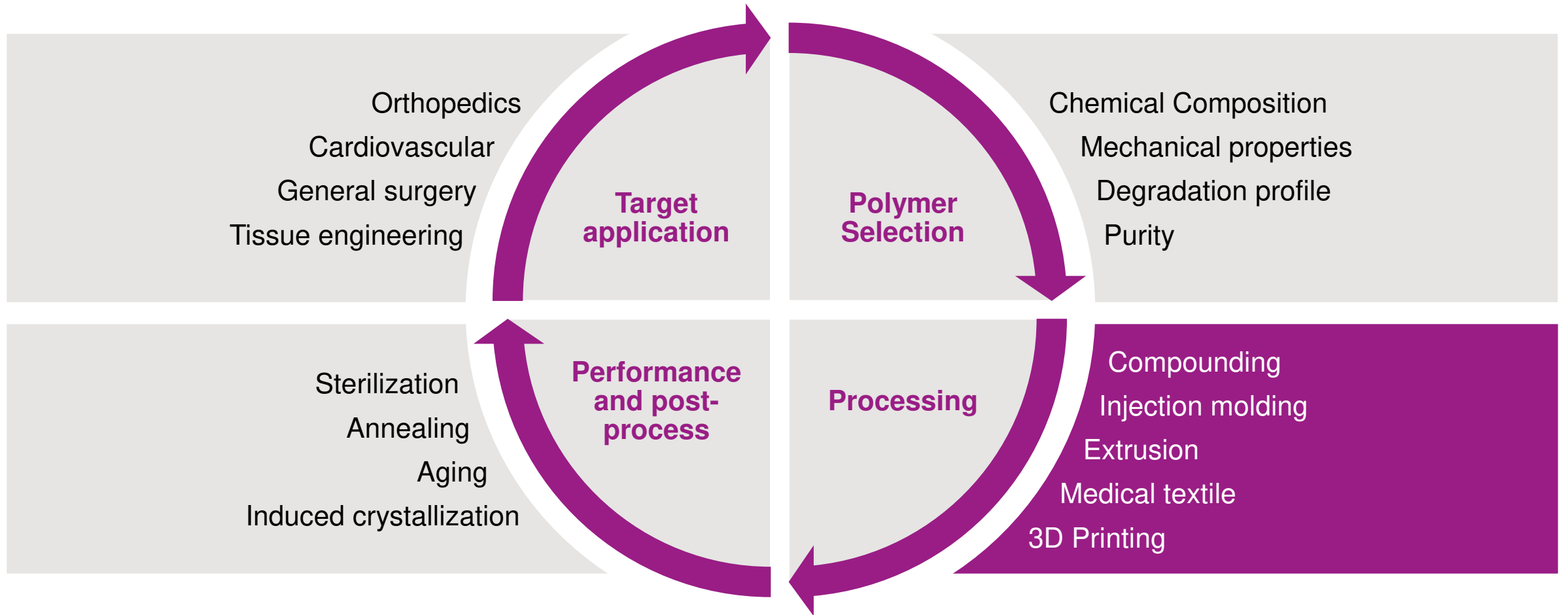
Effect of residual monomer

- Residual monomer acts as a plasticizer, reducing processing temperatures and mechanical properties
- Concentrations of residual monomer on GMP materials are significantly lower than industrial grade. Recommended concentration in resins and surgical implants is $< 2\%$ ⁽¹⁾



Application Technology for RESOMER®

Material and processing considerations for successful medical device performance



Processing of RESOMER®

Compatibility with advanced processing technologies

Injection molding



- Finished devices
- Prototypes

Compounding



- Composite
- Blends

Medical textile



- Yarns
- Meshes
- Non-woven

Extrusion



- Tubes
- Filaments
- Films

3D printing



- Finished devices
- Prototypes

Processing of RESOMER®

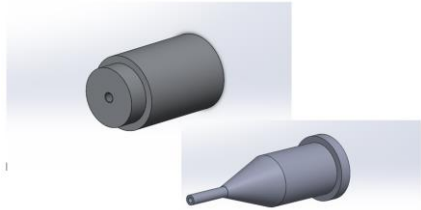
Key Points to Consider

Material Handling



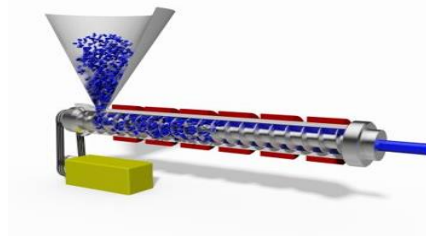
- Moisture control
- Contamination control

Tooling Design



- Dimensions
- Tolerances

Processing



- Temperature Profile
- Residence time

Post Processing



- Annealing
- Sterilization

Testing



- Mechanical properties
- Analytical methods

Processing of RESOMER®

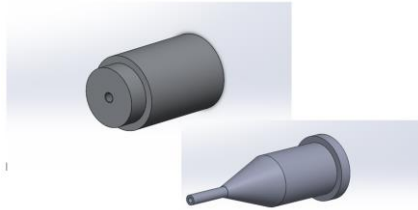
Key Points to Consider

Material Handling



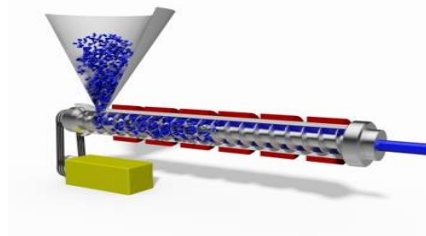
- **Moisture control**
- Contamination control

Tooling Design



- Dimensions
- Tolerances

Processing



- Temperature Profile
- Residence time

Post Processing



- **Annealing**
- **Sterilization**

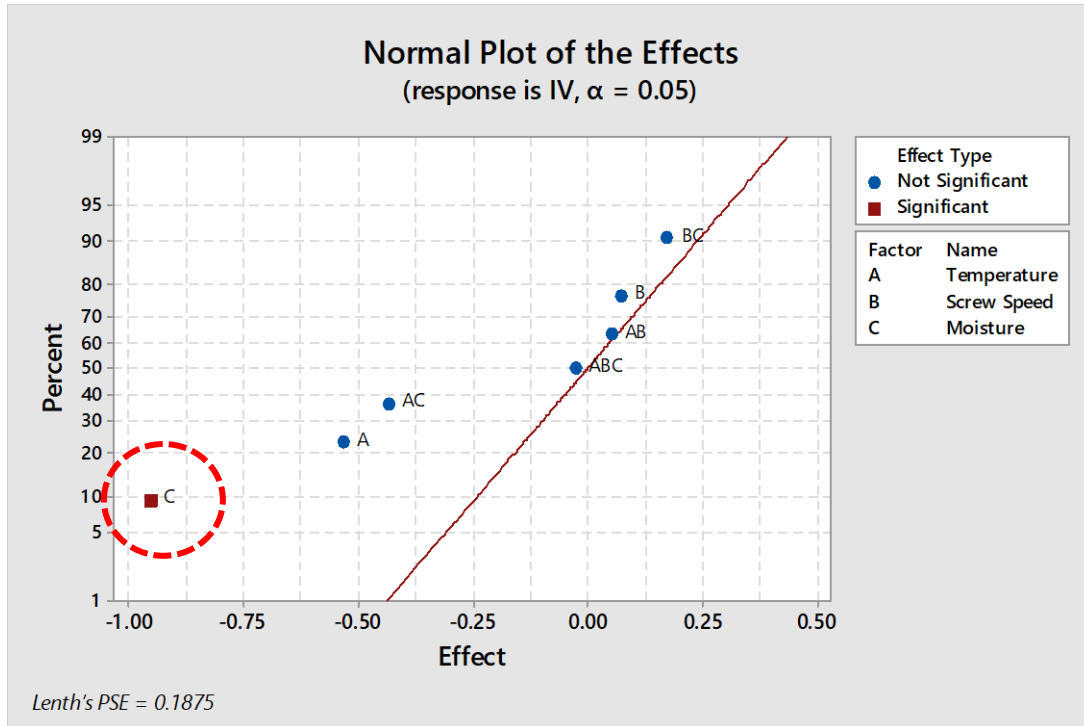
Testing



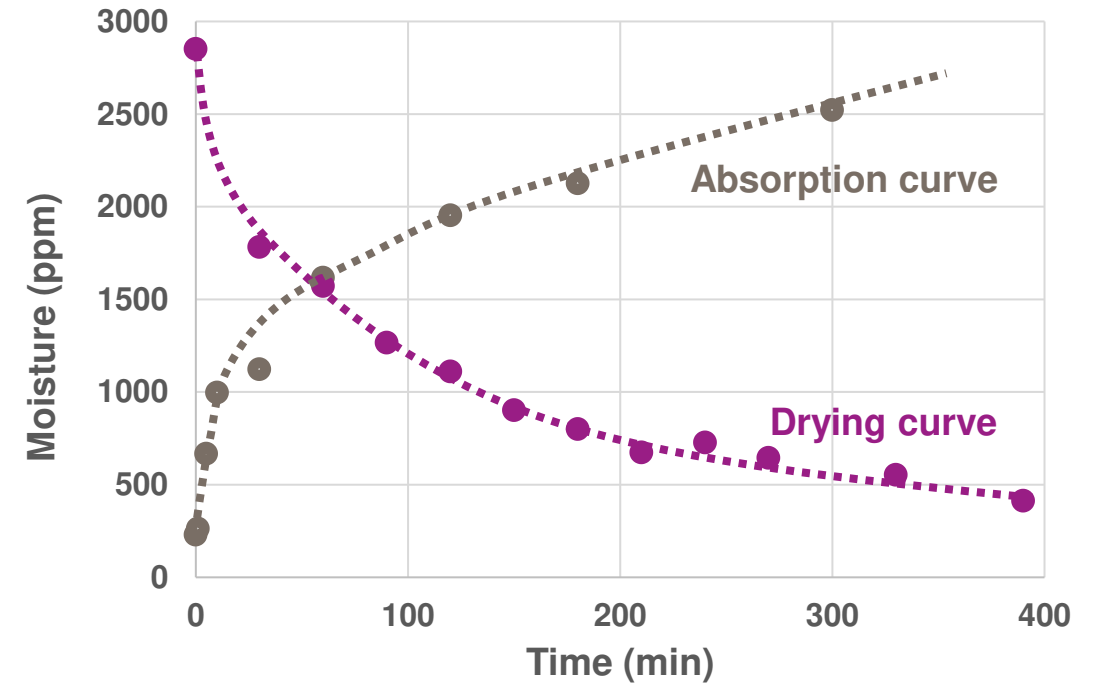
- Mechanical properties
- Analytical methods

RESOMER® – Extrusion Processing

Importance of drying the material



Example of a normal plot for analyze factorial design of an extruded RESOMER® component

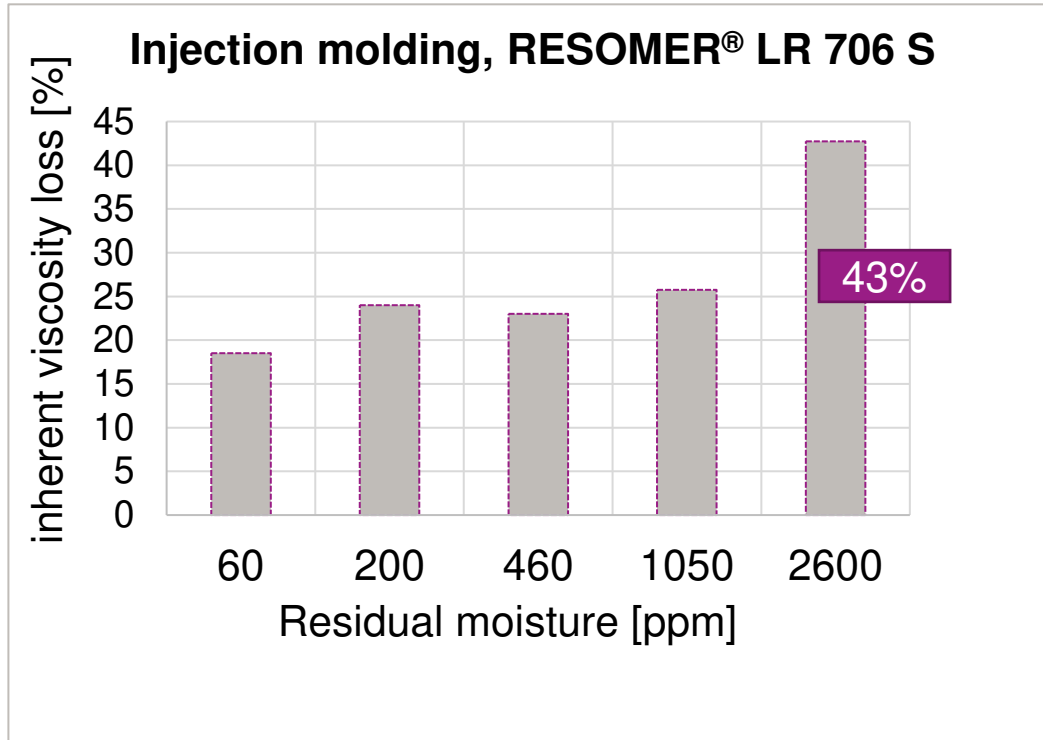


Example of drying and moisture absorption curve of RESOMER®

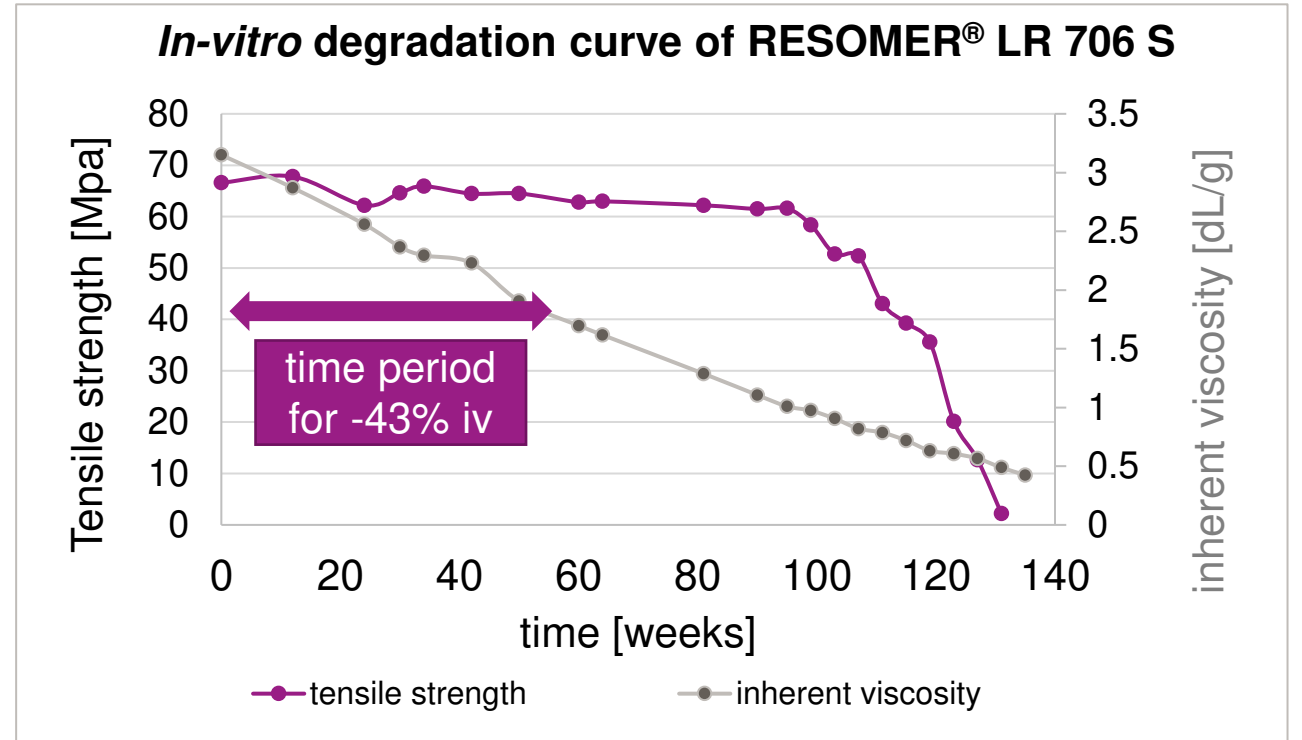
Moisture content is a critical parameter and must be controlled through out the entire process

RESOMER® – Extrusion Processing

Importance of drying the material



Effect of moisture content on degradation of RESOMER® LR 706 S (PDLA) during injection molding of tensile specimens.

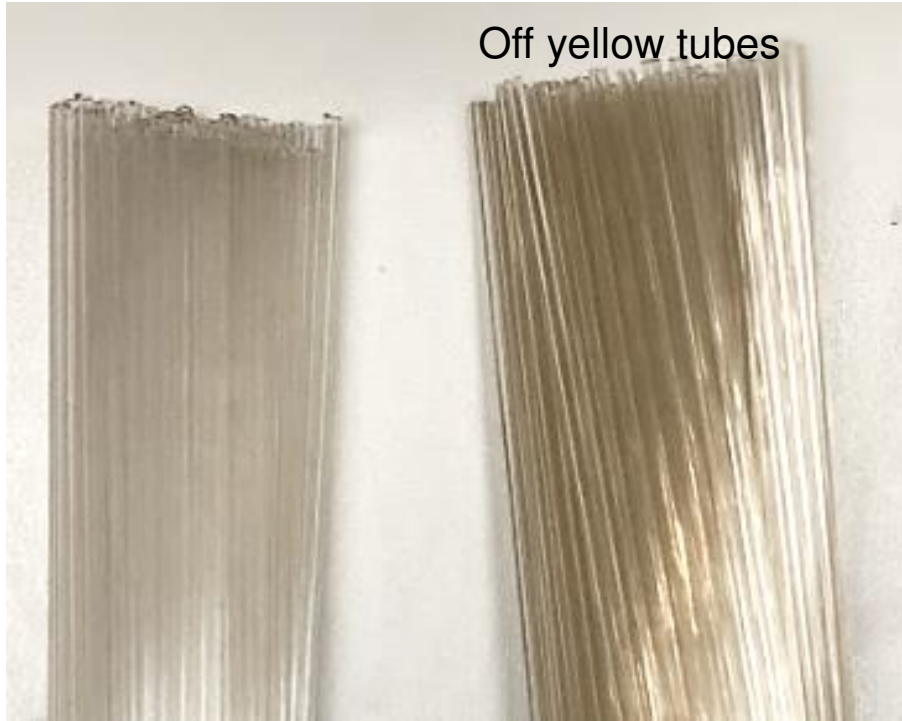


In-vitro degradation curve of RESOMER® LR 706 S (PDLA)

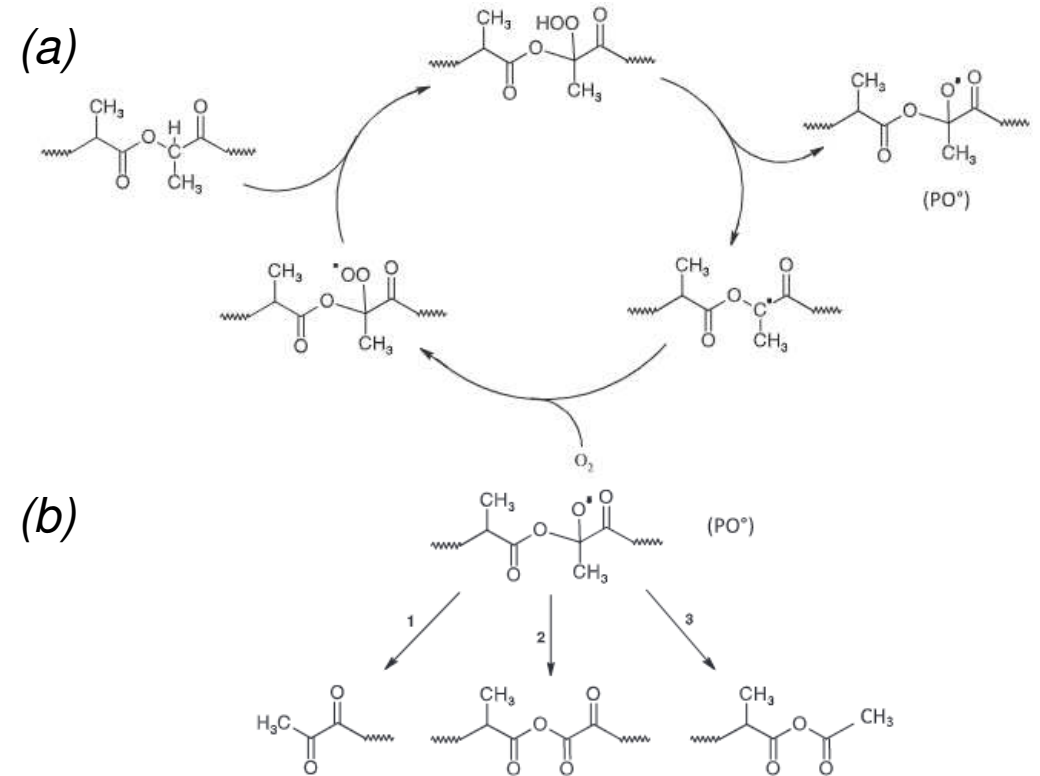
High moisture content can cause degradation via hydrolysis during process

RESOMER® – Extrusion Processing

Importance of drying the material



Polylactide tubes produced with optimal (left) and low (right) moisture content.

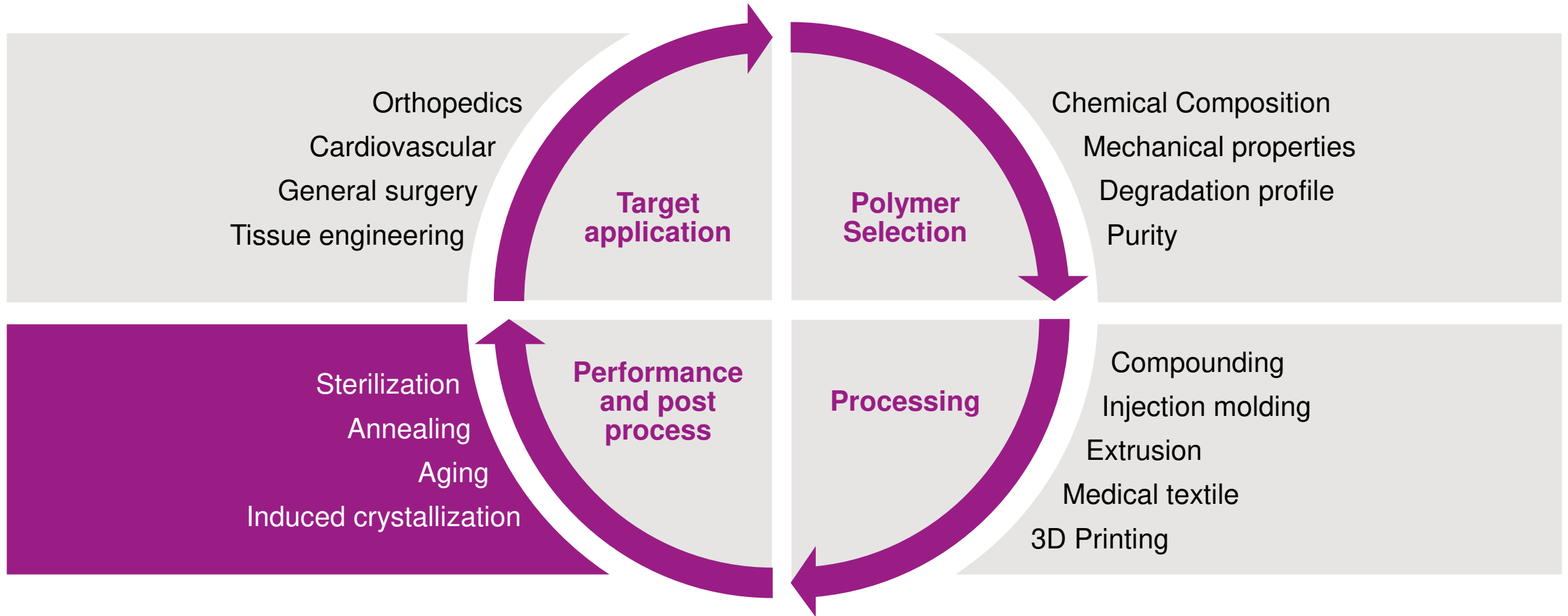


(a) Polylactide oxidation mechanism and (b) possible β -scissions of the PO^\bullet radical, reported by Rasselet, et al.¹

Low moisture content can cause oxidative degradation and increase residual monomer

Application Technology for RESOMER®

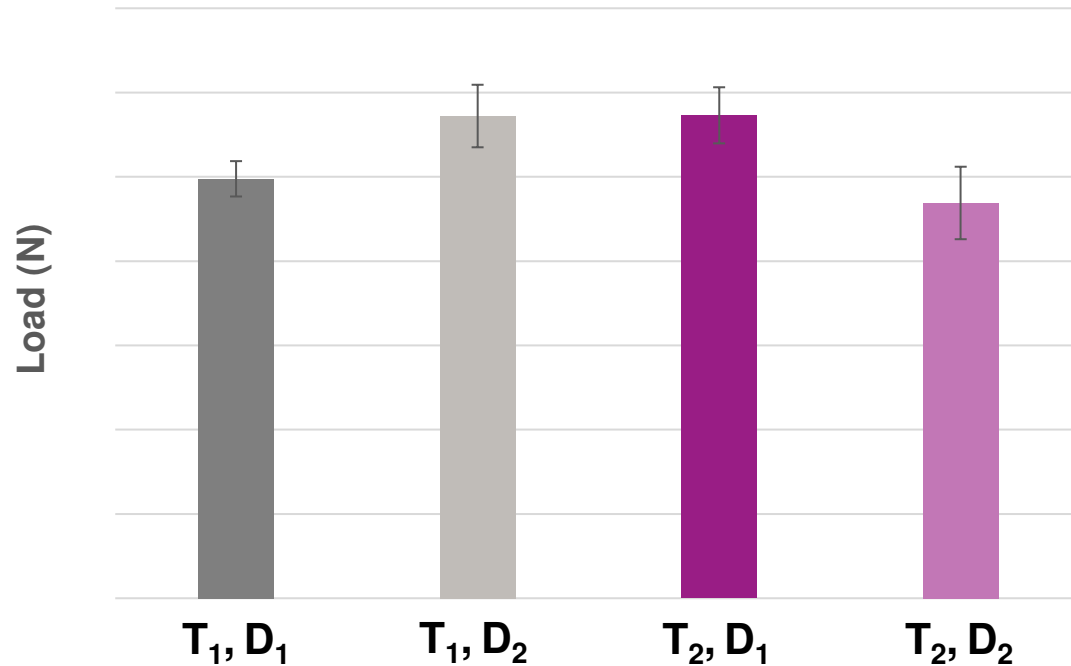
Material and processing considerations for successful medical device performance



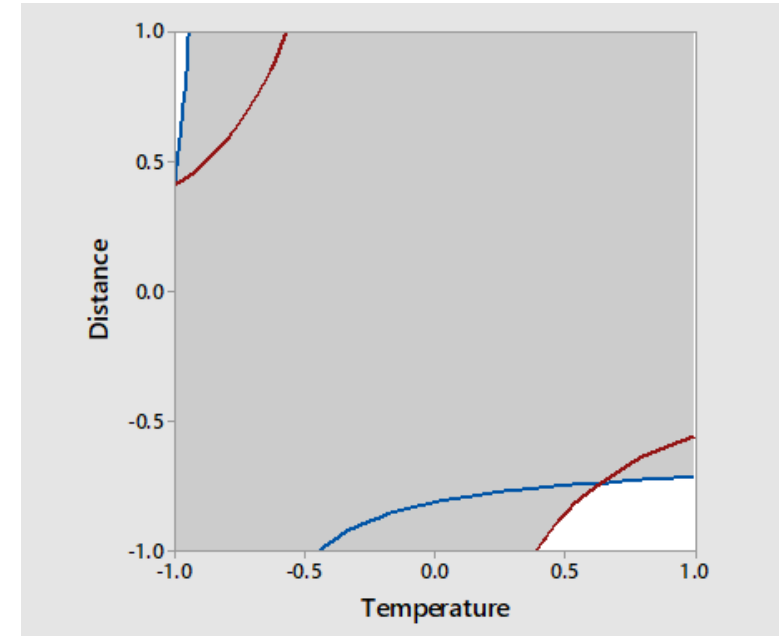
RESOMER® – Extrusion Processing

Impact of annealing on mechanical properties

Crush Resistance



Effect of temperature and distance of water tank on crush resistance of RESOMER® Tubes



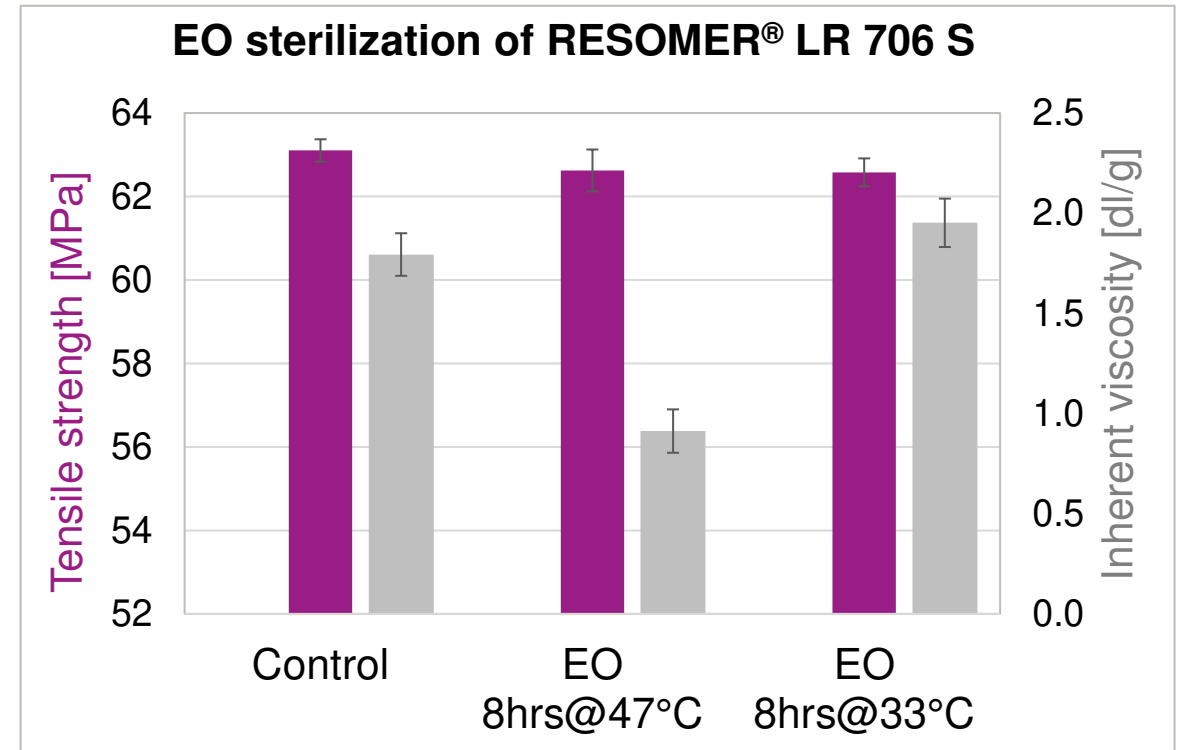
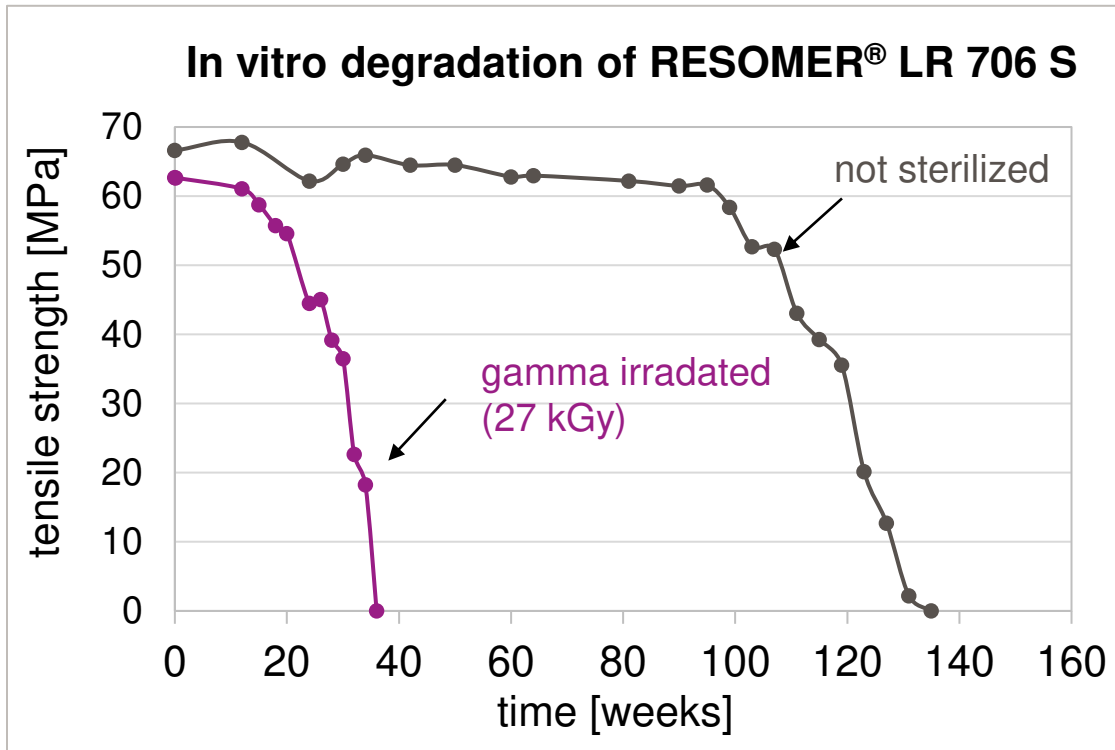
Example of contour plot for crush resistance of RESOMER® Tubes.

Without an optimal cooling control, mechanical properties of RESOMER® cannot be optimized

Sterilization of RESOMER®

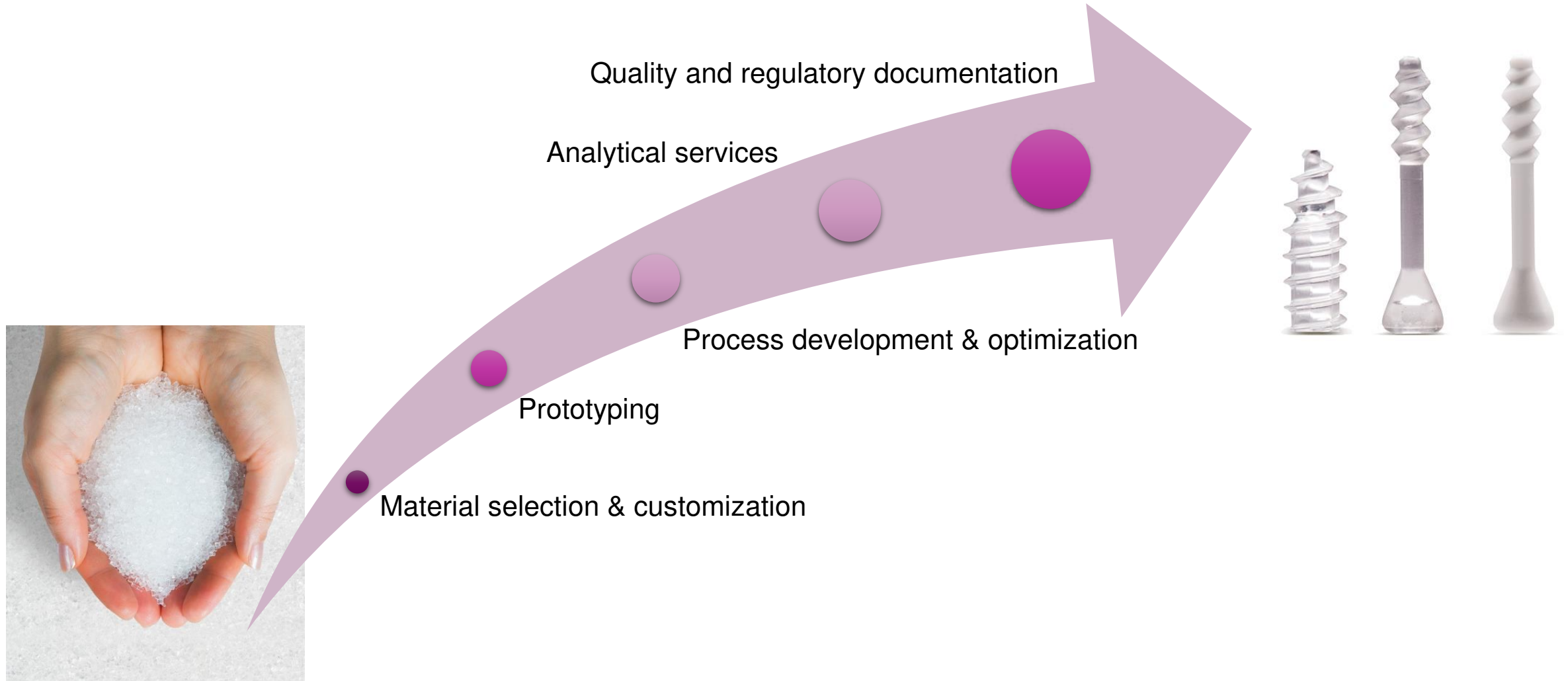
Effect of sterilization on degradation and mechanical properties

- RESOMER® polymers are compatible with EtO sterilization, gamma irradiation, e-beam irradiation and chlorine dioxide*.
- The sterilization method and/or dosage may impact the degradation profile



RESOMER® Products & Services

Services and process development support for faster commercialization





EVONIK

Leading Beyond Chemistry