TAILORING THE MECHANICAL PROPERTIES OF THE IMPLANTABLE POLYURETHANES BY VARIATION IN THE CHAIN STRUCTURES

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TOKMIS:
Treating Osteoarthritis in Knee with Mimicked Interpositional Spacer
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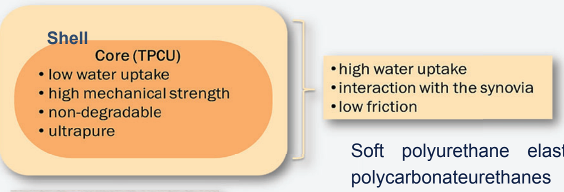
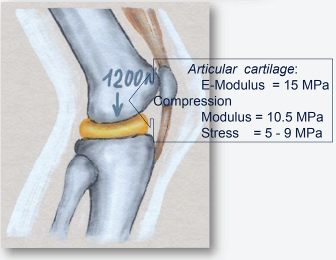
MOTIVATION

How can a material for Knee Spacer be designed to
a) have a very low water uptake and high strength
b) simultaneously interact with the synovia to reduce friction?

But: Water uptake reduces the strength of a material and causes biodegradation ⇨ ***Core-Shell-Structure of the Material***.





Soft polyurethane elastomers, primarily polycarbonateurethanes (PCU), have significant advantages as a basis to fabricate biostable soft orthopedic devices of a new generation [1-3]

⇩

Mechanical properties of TPCU-elastomers are highly dependent on the macrodiol structure (soft segment, SS) and hard-segment (HS) content.

⇩

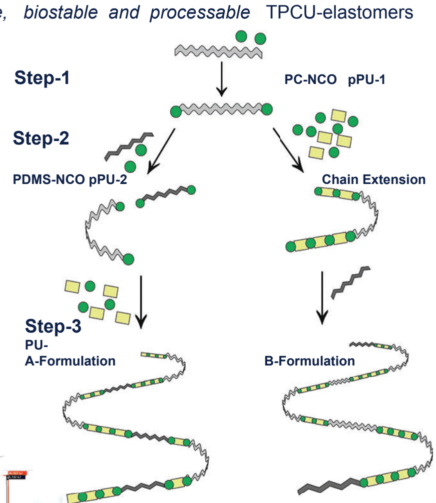
A combination of MDI-based polycarbonate urethane core surrounded with long polydimethylsiloxane (PDMS) chains could be elastic enough to avoid irreversible mechanical deformations under long-term physiological loadings and simultaneously reduce the fluid adsorption of a core material.

Experimental design for the preparation of PC-PDMS-MDI-BD-block copolymers *via*
- ✓ HS content / Concentration of the urethane groups
- ✓ PDMS concentration / position in the polymer chain (A, B) / type and Mw
- ✓ Presence of the urea-groups

SYNTHESIS OF TPCU-BASED CORE MATERIAL

Experimental design

to have *soft, elastic, biocompatible, biostable and processable* TPCU-elastomers



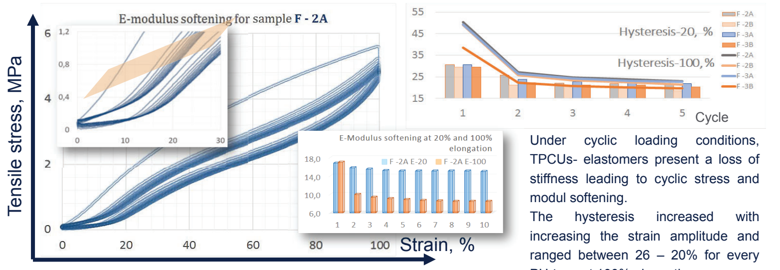
Real-time Monitoring of *multistep* Polymerizations **in catalyst free** systems *via*
- ✓ React-FT IR- Spectroscopy
- ✓ React-Calorimeter RC1 with RT-Cal

❖ The extrusion and injection molding techniques are used for processing

CYCLIC TENSILE / COMPRESSIVE RESPONSES OF THE SELECTED CORE-MATERIALS *hysteresis test*

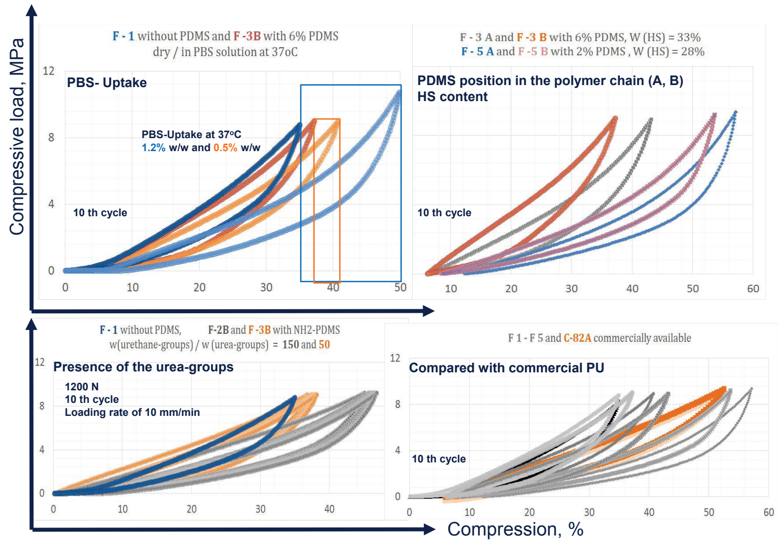
The fatigue performance of biocompatible elastomers were tested in physiological conditions to optimize efficiently the composition design of new materials as well as to evaluate commercial biomaterials for orthopedic applications [4,5].

Tensile response at 100% elongation



Under cyclic loading conditions, TPCUs- elastomers present a loss of stiffness leading to cyclic stress and modul softening.
The hysteresis increased with increasing the strain amplitude and ranged between 26 – 20% for every PU-type at 100% elongation

Compressive response at applied pressure load of 1200 N



A different viskoelastic behavior of the TPCUs with a wide variety of compositional variables is affected by:
- ❖ Volumes of HS-domains and their distribution within a soft matrix ⇨ Degree of phase separation
- ❖ Molecular packing of the constituents within HS- and SS-phases ⇨ Density of hydrogen bonds

- ✓ Several specialized tests on the new urethane elastomers have been conducted under simulated physiological compressive loading (1200 N), temperature (37 °C) and liquid environment for knee spacer applications.
- ✓ Elastic moduli for all materials range from 6 MPa to 16 MPa (Hardness 65 - 82 A Shore). A lack of thermo-mechanical transitions near the body temperature was confirmed using DMA. All materials were in a viscoelastic state over the temperature range tested up to 45 °C and demonstrated the modulus softening at the body temperature.
- ✓ The fatigue behavior of each material was investigated under cyclic compression in a linear elastic range (at 20% of deformation) as well as under physiological loading (1200N) with corresponding compressive deformation 35-57%.
- ✓ The comparison of fatigue responses between novel synthetic meniscal analogs with systematically varied structure improves the understanding of the structure-mechanical response relationship to develop the most promising materials.

REFERENCES

[1] Treharne, R.W., et al. *The case for the use of polycarbonate–urethane in orthopedic implants*, 1. Med-Tech, Spring **2008**, 18–22. [2] John, K.R.S. *The use of polyurethane materials in the surgery of the spine:* a review. Spine J. **2014**, 14(12): 3038-47. [3] Hsu S.H., Lin Z.C. *Biocompatibility and biostability of a series of poly(carbonate)urethanes.* Colloids Surf. B Biointerfaces. **2004**, 36(1):1-12. [4] Shemesh, M., et al. *Viscoelastic properties of a synthetic meniscus implant*, J. Mech. Behav. Biomed. Mater. **2014**, 29: 42-55. [5] Miller, A.T, et al. *Compressive cyclic ratcheting and fatigue of synthetic, soft biomedical polymers in solution*, Mech. Behav. Biomed. Mater. **2016**, 54: 268-82.

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