INSTITUTE FOR MECHANICS OF MATERIALS AND STRUCTURES imws

TECHNISCHE UNIVERSITÄT WIEN Vienna University of Technology

COST Action MP1301 – 1st Workshop

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Research on Biomaterials and Biological Tissues at the Institute for Mechanics of Materials and Structures, Vienna University of Technology

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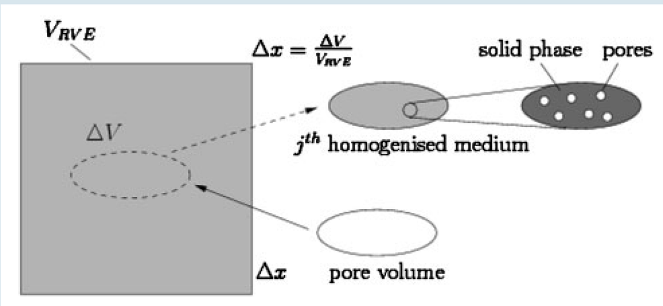
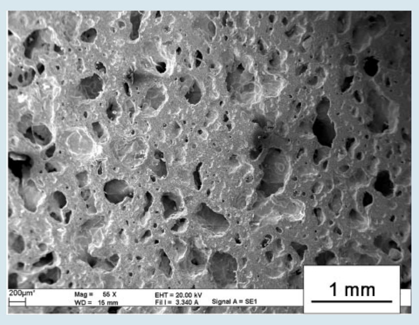
Ceramics-Based Materials: Mechanical Models and Characterization

STIFFNESS AND STRENGTH DETERMINATION of glass-ceramic scaffolds:

Malasoma et al. (2008), *Adv Appl Ceram* 107: 277-286

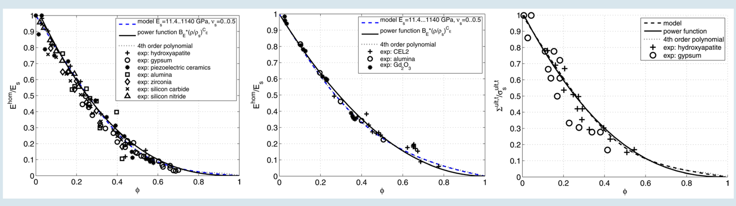
- Prediction via micromechanics-based **homogenization models**
- Sample **characterization** (experimental validation) through **ultrasonics and uniaxial compression tests**



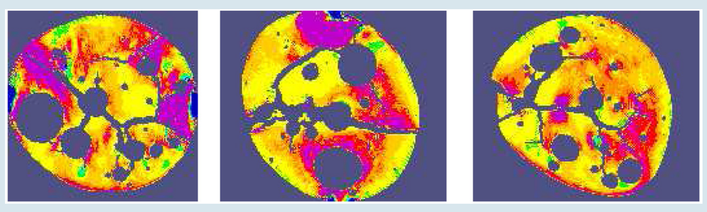


MODELS FOR HYDROXYAPATITE BIOMATERIALS:

- Micromechanical homogenization for **(poro-) elasticity and strength**
- CT-based **elasticity analysis** of hydroxyapatite-based granules

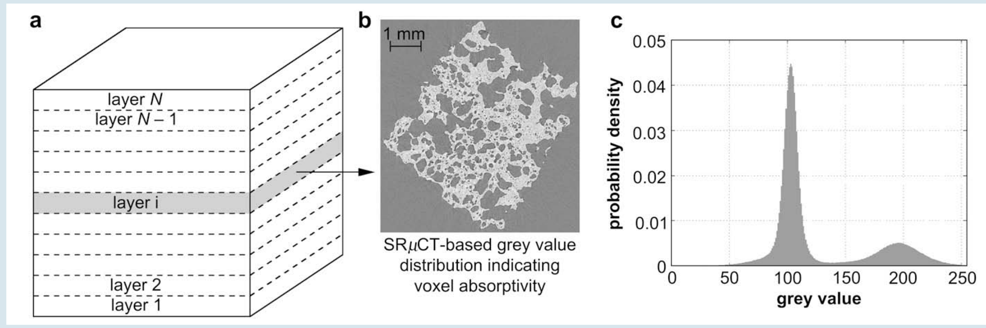


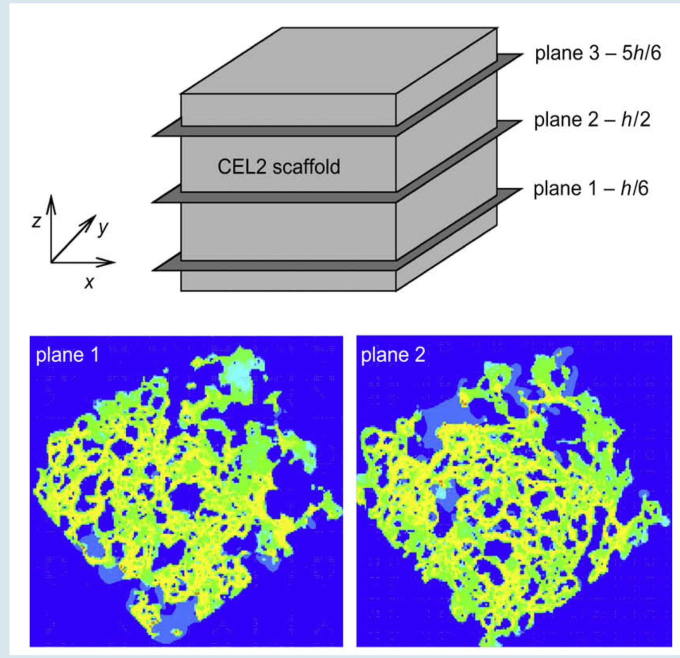
Fritsch et al. (2009), *J Biomed Mater Res A* 88: 149-161; Fritsch et al. (2010), *Philos Trans A Math Phys Eng Sci* 368: 1913-1935; Fritsch et al. (2013), *J Appl Mech* 80: 020905



Dejaco et al. (2012), *J Biomech* 45: 1068-1075

CT IMAGE-TO-STIFFNESS CONVERSION, applied to glass-ceramic scaffolds:





- Retrieval of 3D nanoporosity field from CT image
- Micromechanics-derived 3D stiffness field
- Finite Element simulation of uniaxial compression test
- **Computation of macroscopic sample stiffness**

Scheiner et al. (2009), *Biomaterials* 30: 2411-2419

FURTHER WORKS:

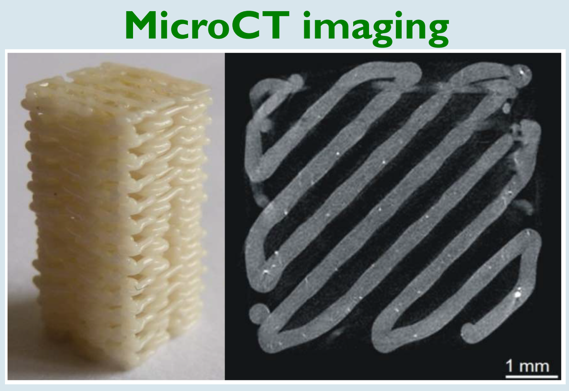
- **Gyspum:** Elasticity and strength homogenization Sanahuja et al. (2010), *J Eng Mech* 136: 239-253
- **Cementitious materials:** (Visco-) elasticity and strength homogenization

E.g. Scheiner et al. (2009), *J Eng Mech* 135: 307-323; Pichler et al. (2011), *Cem Concr Res* 41: 467-476

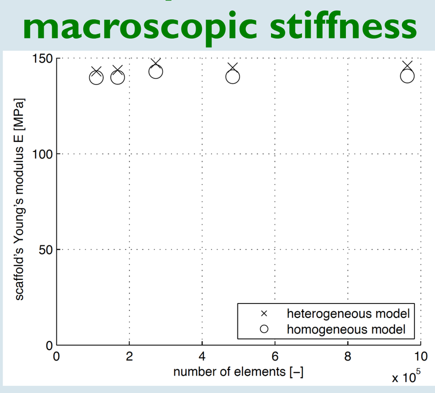
Composite Materials: Mechanical/Metabolic Models and Characterization

STUDIES ON POLYMER-BASED COMPOSITE MATERIALS:

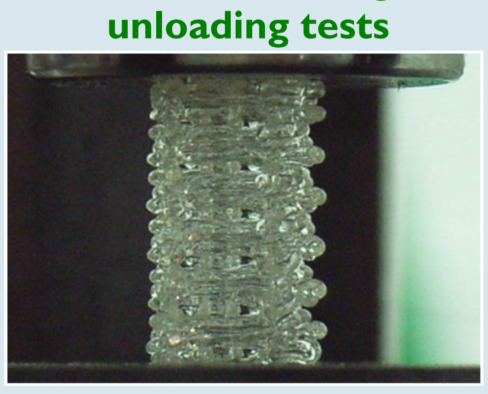
MicroCT imaging



Computation of macroscopic stiffness

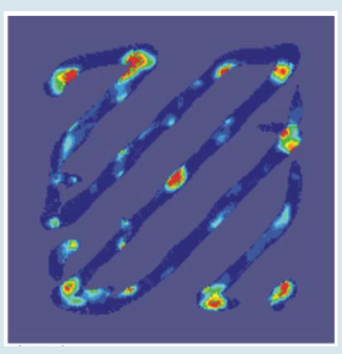


Uniaxial loading-unloading tests

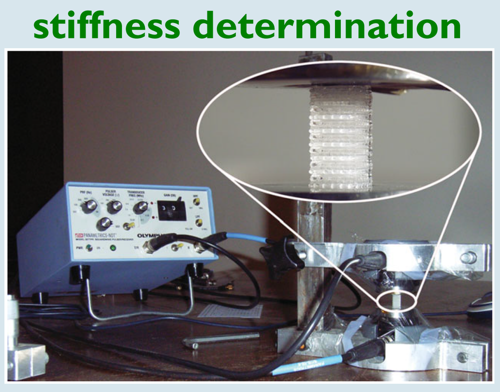


CT-to-elasticity conversion

FE-based utilization assessment



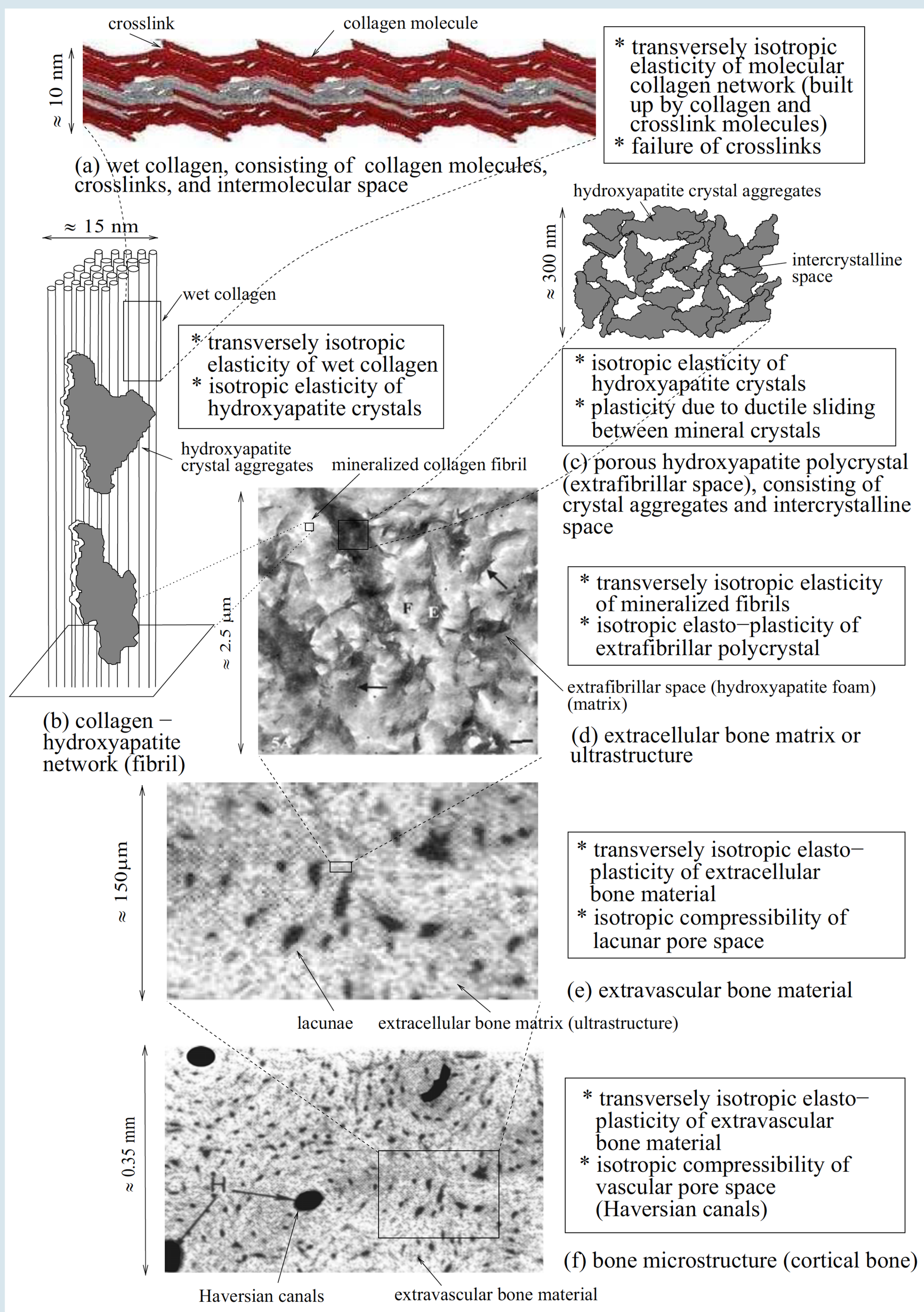
Ultrasonics tests for stiffness determination



Accompanied by **nanoindentation tests** for material characterization on the millimeter scale

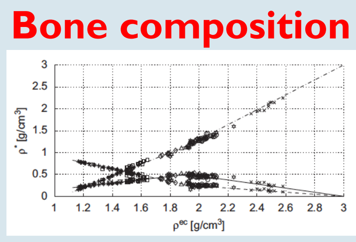
Luczynski et al. (2012), *CMES-Comp Model Eng* 87: 505-528; Luczynski et al. (2013), *J Biomed Mat Res A* 101A: 138-144; Hum et al. (2013), *Strain* 49: 431-439

STRENGTH AND PORO-ELASTICITY HOMOGENIZATION OF BONE TISSUE:

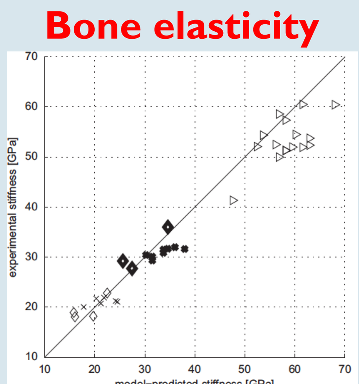


EXPERIMENTAL VALIDATION:

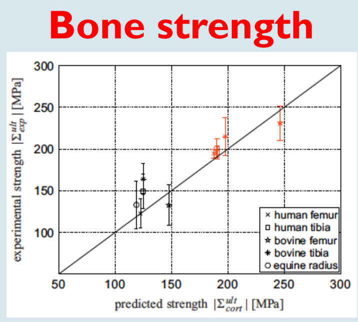
Bone composition



Bone elasticity



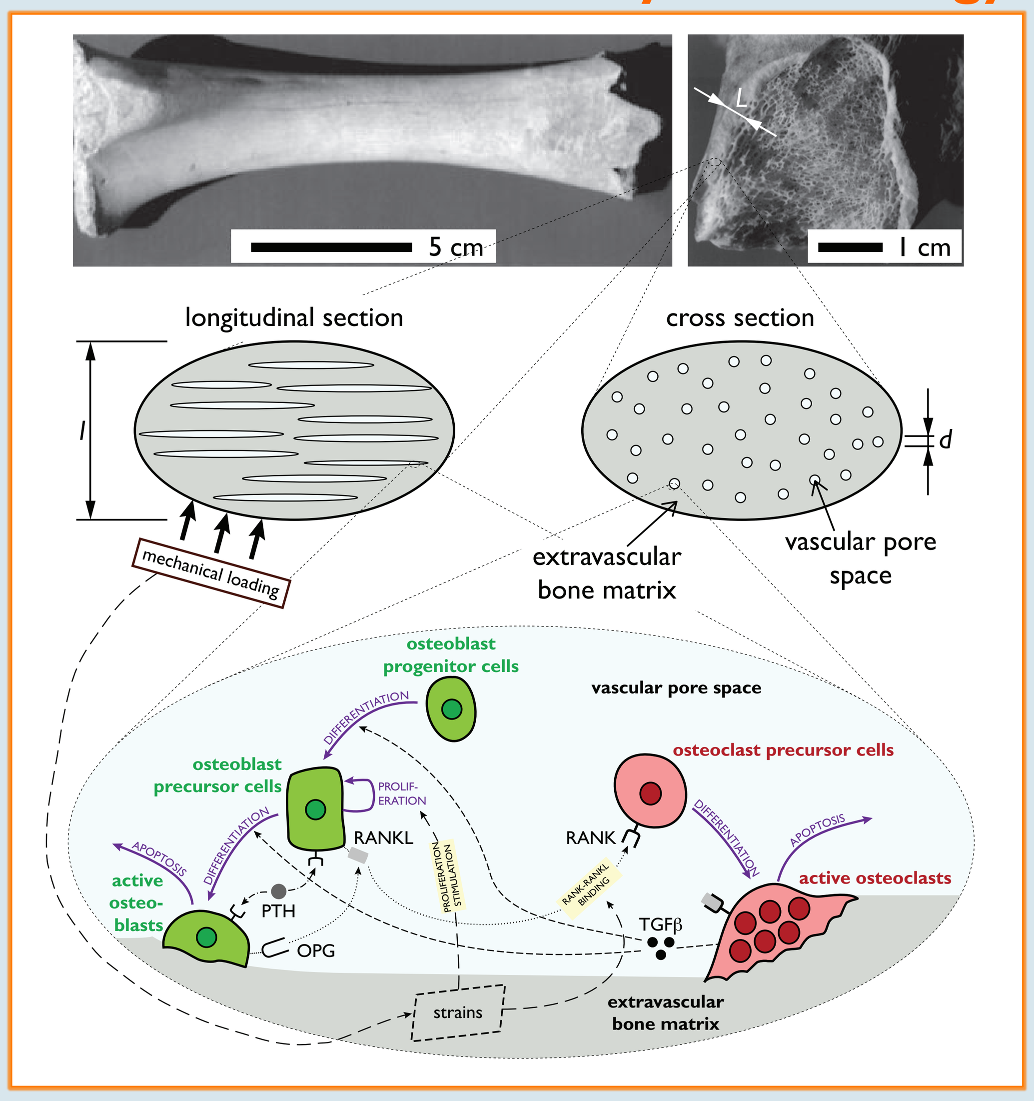
Bone strength



E.g. Fritsch et al. (2009), *J Theor Biol* 260: 230-252; Hellmich et al. (2009), *J Eng Mech* 135: 382-394; Vuong and Hellmich (2011), *J Theor Biol* 287: 115-130

COMPUTATIONAL MODELING OF BONE REMODELING:

Approach: Integration of the concepts of micromechanics and systems biology

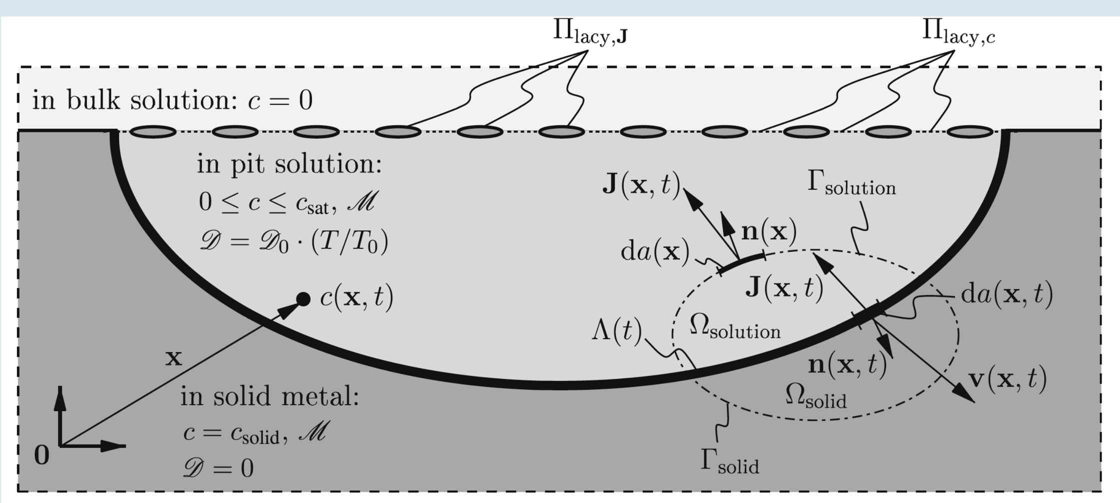


Successful simulation of…

- ✓ Mechanical disuse ("microgravity")
- ✓ Postmenopausal osteoporosis
- ✓ Drug treatment (by means of denosumab)

Scheiner et al. (2013), *Comp Meth Appl Mech* 254: 181-196; Scheiner et al. (2014), *Int J Numer Meth Bio* 30: 1-27

Metallic Materials: Corrosion Models



Modeling through combination of:

- **Mass balance** for continua with progressing fronts;
- Classical **electrochemical** (Butler-Volmer-type) **kinetics** law;
- **Fick's law of diffusion**
- Numerical solution

⇨

Computation of corrosion pit profiles, following from specific electrochemical boundary conditions

Scheiner and Hellmich (2007), *Corr Sci* 37:1947-1967; Scheiner and Hellmich (2009), *Comp Meth Appl Mech Eng* 198: 2898-2910