ACE-X2017

11th International Conference on Advanced Computational Engineering and Experimenting
Vienna (Austria) from 3-6 July, 2017

Layered water in bone as key for its strength, creep, permeability, and mechano-sensitivity

Christian Hellmich[1], Stefan Scheiner, Tamer Abdalrahman, Mehran Shahidi, Bernhard Pichler

[1]TU Wien - Vienna University of Technology, Institute for Mechanics of Materials and Structures, Karlsplatz 13/202, A-1040 Wien (Vienna), Austria

Tel.: +43 1 58801 20220, Fax: +43 1 58801 9 20220, christian.hellmich@tuwien.ac.at

Water is a polarized fluid, forming "ice-like" layers ("liquid crystals") in the neighborhood of electrically charged surfaces. Only recently, our laboratory was successful in elucidating and quantifying their effect beyond the molecular scale, all the way through the hierarchical organization of bone. The talk will highlight corresponding recent discoveries: (i) mineral crystals irreversibly glide along thin water films, leading to elastoplastic behavior at all higher organization levels, such as the polycrystalline extrafibrillar space, the extracellular and extravascular bone matrices, and finally the macroscopic bone tissue [1]; (ii) the interfacial viscosity of these films trigger bone viscoelasticity [2,3]; (iii) layered water viscosity governs the Poisseuille flow in the vascular pores, dictating the permeability properties at the macroscopic scale [4]; and (iv) viscous fluid is trapped in the lacunar pore space, giving rise to hydrostatic pressures optimally stimulating osteocytes [5]. Similar implications go obviously beyond bone, and can be explored in other (geo-)materials hosting layered water, such as clays or hydrating cement [6].

[1] A. Fritsch, Ch. Hellmich, L. Dormieux. Ductile sliding between mineral crystals followed by rupture of collagen crosslinks: Experimentally supported micromechanical explanation of bone strength. Journal of Theoretical Biology 260, 230-252, 2009

[2] L. Eberhardsteiner, Ch. Hellmich, S. Scheiner. Layered water in crystal interfaces as source for bone viscoelasticity: arguments from a multiscale approach. Computer Methods in Biomechanics and Biomedical Engineering 17, 48 – 63, 2014

[3] T. Qu, D. Verma, M. Shahidi, B. Pichler, Ch. Hellmich, V. Tomar. Mechanics of organic-inorganic biointerfaces – implications for strength and creep properties. *MRS Bulletin* 40, 349-358, 2015.

[4] T. Abdalrahman, S. Scheiner, Ch. Hellmich. Is trabecular bone permeability governed by molecular ordering-induced fluid viscosity gain? Arguments from re-evaluation of experimental data in the framework of homogenization theory. Journal of Theoretical Biology 365, 433 – 444, 2015

[5] S. Scheiner, P. Pivonka, Ch. Hellmich. Poromicromechanics reveals that physiological bone strains induce osteocyte-stimulating lacunar pressure. Biomechanics and Modeling in Mechanobiology 15, 9-28, 2016.

[6] Königsberger, Ch. Hellmich, B. Pichler. Densification of C-S-H is mainly driven by available precipitation space, as quantified through an analytical cement hydration model. *Cement and Concrete Research,* 87, 170-183, 2016.