TECHNISCHE UNIVERSITÄT WIEN
Vienna University of Technology

INSTITUTE FOR MECHANICS OF MATERIALS AND STRUCTURES

STIFFNESS IMPROVEMENT OF 45S5 BIOGLASS®-BASED SCAFFOLDS THROUGH PCL AND COLLAGEN COATINGS: AN ULTRASONIC STUDY

Jasmin Hum[1], Krzysztof W. Luczynski[2], Patcharakamon Nooeaid[1], Pippa Newby[3], Olaf Lahayne[2], Christian Hellmich[2], Aldo R. Boccaccini[1]

[1]Institute of Biomaterials, University of Erlangen-Nuremberg, Erlangen, Germany
[2]Institute for Mechanics of Materials and Structures, Vienna University of Technology, Vienna, Austria
[3]Department of Materials, Imperial College London, London, United Kingdom

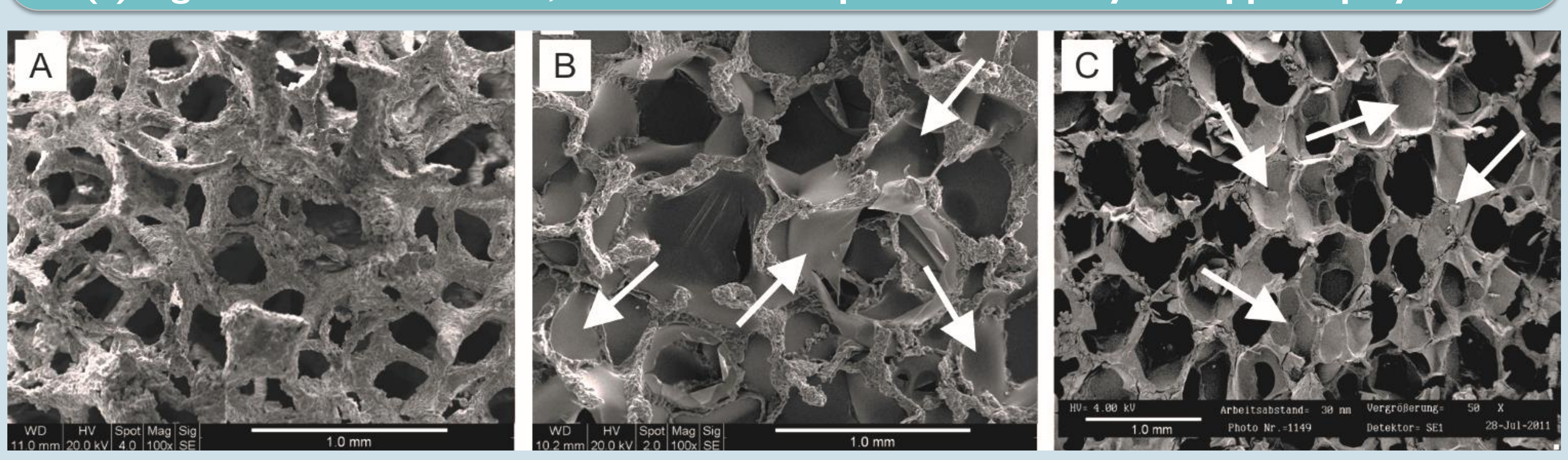
Introduction

Due to its excellent bioactivity, 45S5 Bioglass® is being highly considered in tissue engineering scaffold development. In order to enhance vascularization promoting tissue growth, these scaffolds typically exhibit a highly interconnected porous structure with a porosity between 80 and 90% (see Fig. 1). Often, Bioglass®-based scaffolds of such a high porosity exhibit insufficient stiffness. In order to increase it scaffolds fabricated by the foam replica method, were coated with collagen, gelatin, polycaprolactone (PCL), alginate, and poly(L-lactic acid) (PLLA) [1, 2]. The resulting stiffness gain was quantified by means of ultrasonic measurements [3, 4, 5, 6].

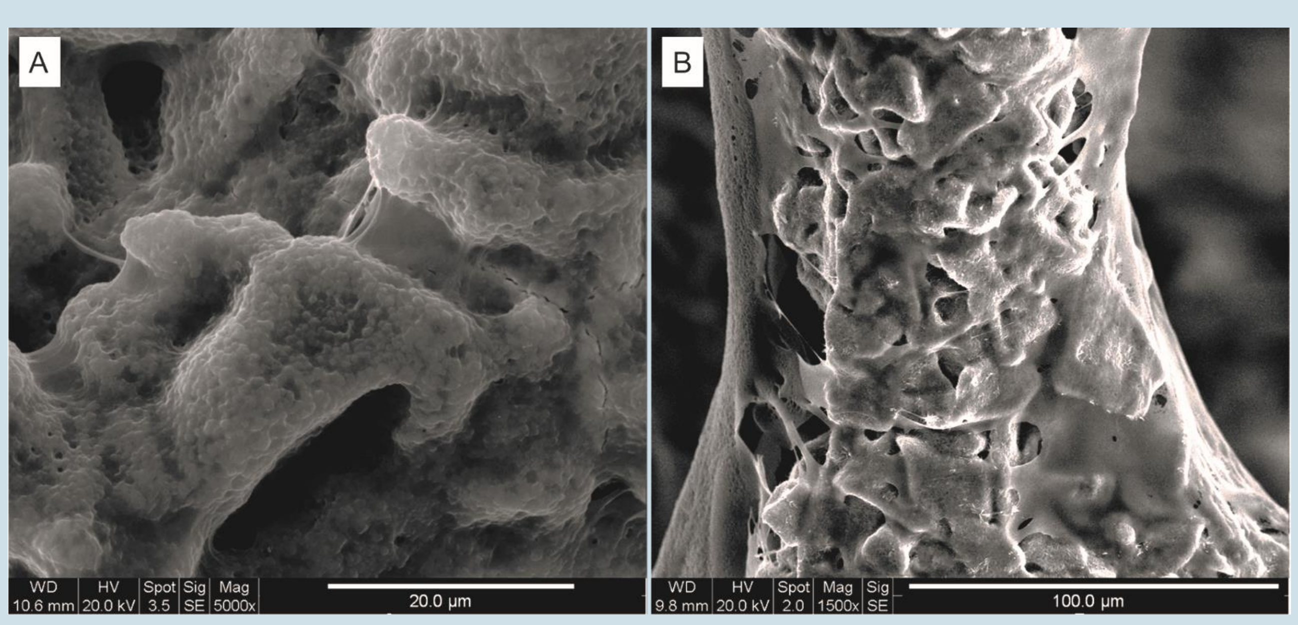
Imaging and ultrasonic measurements

Sanning Electron Micrography

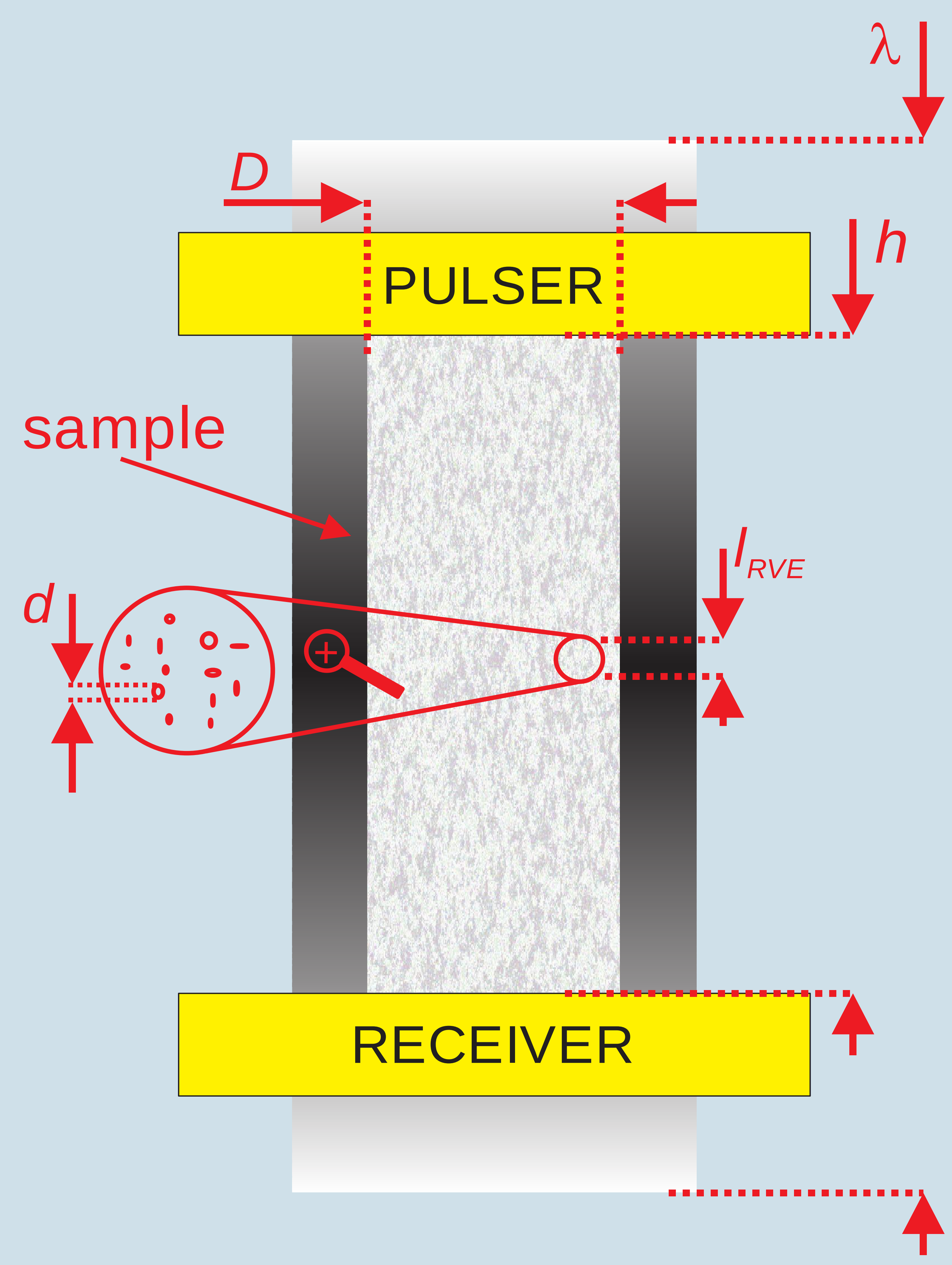
lower resolution Scanning Electron Micrographs (SEM) showing the typical highly interconnected macro-porous structure of the investigated scaffolds: (a) as-fabricated uncoated Bioglass® scaffold, (b) gelatine-coated scaffold, (c) alginate-coated scaffold; arrows indicate pores blocked by the applied polymer



higher resolution Scanning Electron Micrographs (SEM) showing coating micro-textures on Bioglass® struts: (a) collagen coating clogging the micropores (b) PCL coating not clogging the micropores.



ultrasonic measurements



d - characteristic size of microheterogeneities
l_{RVE} – characteristic length of the RVE (representative volume element)
D - sample diameter
h – sample height
λ - wavelength of the transmitted signal

If scale separation condition [9]
$d << l_{RVE} << \lambda$
is fulfilled...

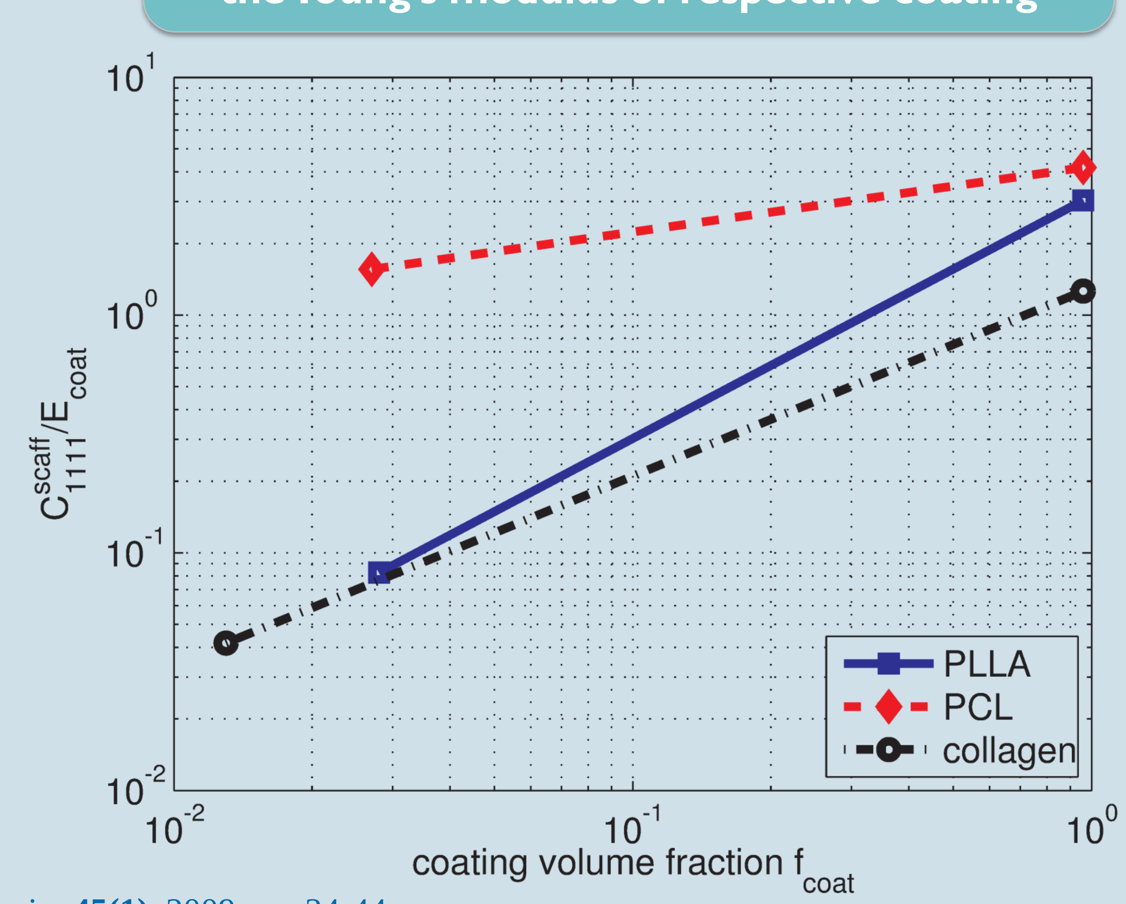
and sample geometry together with the wave length yield transmission of a bulk wave [4]
$\mathcal{F}_1(D/h, h/\lambda) = A\times\log(D/h) + B\times\log(h/\lambda) + 1 \geq 0$
with A=1.426 and B=0.530

then sample stiffness is given as [5]
$C_{1111}^{scaff} = \rho \cdot v^2$
with
ρ - sample mass density
v – velocity of the transmitted acoustic wave

Results

Both PCL and collagen coatings increase the overall scaffold's stiffness (C_{1111}^{scaff}), as comparing to uncoated scaffolds, by 58% and 38%, respectively; while no remarkable stiffness increase was recorded for the other coatings. To reveal the influence of the coatings' stiffnesses (E_{coat}) on the overall scaffolds' stiffnesses (i.e. the micromechanical interactions patterns between Bioglass® and different coatings) a dimensionless relation between coating volume fraction and the ratio of C_{1111}^{scaff}–over-E_{coat} was investigated. Together with ($C_{1111}^{scaff}/E_{coat}$)-values stemming from ultrasonic experiments, theoretical values predicted applying the classical isotropic self-consistent micromechanics scheme [7, 8, 9, 10, 11] were taken into account (see Fig. 2). The fact that the relation between coating volume fraction and the ($C_{1111}^{scaff}/E_{coat}$)-ratio are significantly different among chosen coatings indicates distinct micromechanical interactions patterns. Additionally, scanning electron microscopy (SEM), revealed that PCL (unlike collagen) did not clog the micropores of the as-fabricated scaffolds (which supports the thesis of different micromechanical interactions patterns), which are deemed essential for cell seeding and the resulting in-growth of bone tissue.

relation between the coating's volume fraction and the ratio of coated scaffold stiffness to the Young's modulus of respective coating



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