Effects of curing and organic content on bioactivity and mechanical properties of hybrid sol–gel glass scaffolds made by indirect rapid prototyping

S. Hendrikx¹, D. Kuzmenka¹, R. Köferstein², T. Flath³, H. Uhlig⁴, D. Enke⁵, F.P. Schulze³, M.C. Hacker¹, M. Schulz-Siegmund¹

¹ Pharmaceutical Technology, Institute of Pharmacy, Leipzig University, Eilenburgerstraße 15a, Leipzig, 04317, Germany

² Inorganic Chemistry, Institute for Chemistry, Martin-Luther-University Halle-Wittenberg, Kurt-Mothes-Straße 2, 06120 Halle (Saale), Germany

³ Department of Mechanical and Energy Engineering, Leipzig University of Applied Sciences, Karl-Liebknecht-Straße 134, Leipzig, 04277, Germany

⁴ Institute of Non-Classical Chemistry e. V. at the Leipzig University, Permoserstr. 15, 04318 Leipzig, Germany

Abstract: We employed indirect rapid prototyping templating to fabricate bioactive and macroporous scaffolds for bone regeneration. This templating technique utilizes lost molds made of polycaprolactone by fused deposition modeling, in which the organic/ inorganic hybrid silica sol was filled and cured. Finally, the molds were dissolved and extracted, and the remaining macroporous hybrid glass constructs were recovered. The hybrid glass scaffolds offered a fully interconnected pore structure with 63–72% porosity measured by N₂-pycnometry and Hg-intrusion. In bioactive sol–gel glasses one issue is the insufficient and inhomogeneous incorporation of calcium (II) ions. To address this problem we varied the curing conditions and tested the effect of the organic crosslinker on calcium retention. We strengthened the silica network by covalent crosslinking with trimethylolpropane ethoxylate which was functionalized with 3-(triethoxysilyl)propyl isocyanate. Those scaffolds showed compressive yield strengths of up to 12.7 MPa and compressive moduli between 18 and 288 MPa. Energy dispersive X-ray spectroscopy showed that a crosslinker content of 60% in the hybrids resulted in a homogeneous calcium distribution in the glass, in contrast to 40% where we found a layer of CaCl₂ on the scaffold surface. The materials exhibited bioactivity in simulated body fluid which was monitored by scanning electron microscopy and X-ray powder diffraction.