Acoustic energy focusing and band gap structure of robocast ceramic scaffolds

Martin Koller[†,*], Tomáš Grabec[†], Petr Sedlák[†], Alena Kruisová[†], Benito Román-Manso[‡], Manuel Belmonte[#], Pilar Miranzo[#] and Hanuš Seiner[†]

[†] Institute of Thermomechanics of the Czech Academy of Sciences
Dolejškova 1402/5, 182 00 Praha 8, Czech Republic
*e-mail: koller@it.cas.cz, web page: http://www.it.cas.cz/en/

[‡] School of Engineering and Applied Sciences, Harvard University
52 Oxford Str, 02318 Cambridge MA, USA

[#] Institute of Ceramics and Glass (ICV-CSIC)
Kelsen 5, 28049 Madrid, Spain

ABSTRACT

In this contribution, acoustic phenomena taking place in MHz frequency range in robocast ceramic scaffolds are presented. Robocasting is an additive-manufacturing direct-ink writing method for the fabrication of scaffolds consisting of a layered structure of thin ceramic rods. At first, a ceramic powder is mixed with deionized water and organic additives to form a colloidal suspension with highly shear-thinning behavior. This suspension is subsequently extruded through a thin nozzle following a layer-by-layer 3D printing route to produce a ceramic green body. The organic additives are then burnt out, and the scaffolds are consolidated by spark plasma sintering. Usually, each layer consists of mutually parallel thin rods and the neighboring layers are oriented at a different angle. As the rods in the neighboring layers partially intersect and the scaffolds are typically made of tens of layers, the scaffolds have a periodic structure with phononic-crystal behavior [1].

The acoustic properties of several scaffold geometries were studied both experimentally and numerically. The elastic responses were calculated by finite element method (FEM) where a computational unit cells were designed to represent the periodic geometry of the sintered scaffolds [2]. It is shown that tetragonal scaffolds, where the rods in the neighboring layers are perpendicular, focuses acoustic energy along the principal directions of the ceramic rods. In these scaffolds, the energy focusing is more pronounced in the less dense structure having the higher in-plane spacing of the rods. On the other hands, hexagonal structures, which have the periodicity of 3 layers with the orientation angle of 60° between the neighboring rods, are in-plane isotropic in the low-frequency limit. Nevertheless, the FEM study also showed that the acoustic energy becomes focused along the ceramic rods even in these hexagonal structures when the wavelengths are comparable to the principal dimensions of the scaffolds. The FEM study was also performed up to higher frequencies and it was found there are several frequency band gaps for the longitudinal waves. The transmission of longitudinal waves was also studied experimentally, measuring the transmission amplitude ratios. It was found that the calculated band gaps well correspond to the frequencies at which the amplitudes of the transmitted longitudinal waves were decreased by several orders of magnitudes compared to the input signal amplitude.

REFERENCES

[1] Kruisová, A. et al. Ultrasonic bandgaps in 3D-printed periodic ceramic microlattices. *Ultrasonics* (2018) **82**:91–100.

[2] Koller, M. et al. Anisotropic Elasticity of Ceramic Micro-Scaffolds Fabricated by Robocasting. *Acta Phys. Pol. A* (2018) **134**:799–803.