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APPLICATION OF ADDITIVE TECHNOLOGY TO CREATE UNIVERSAL CARRIERS OF CELLULAR STRUCTURES

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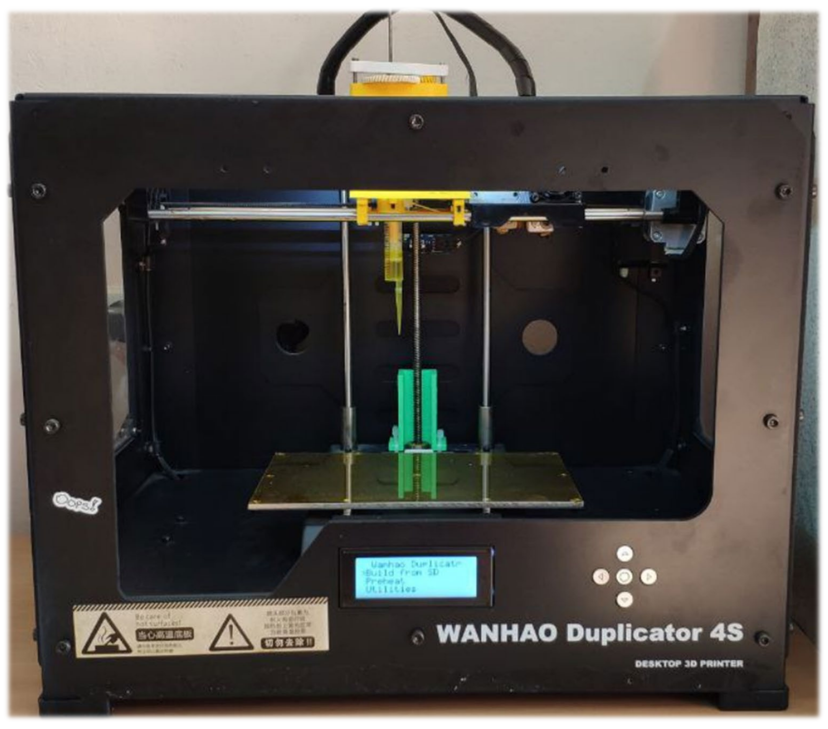
Abstract

The work is devoted to obtaining biocompatible carriers with mechanical properties similar to living tissues by extrusion 3D-printing. Printing of models was carried out with biocompatible hydrogels of sodium alginate and chitosan in order to determine the optimal concentrations of components and process parameters.

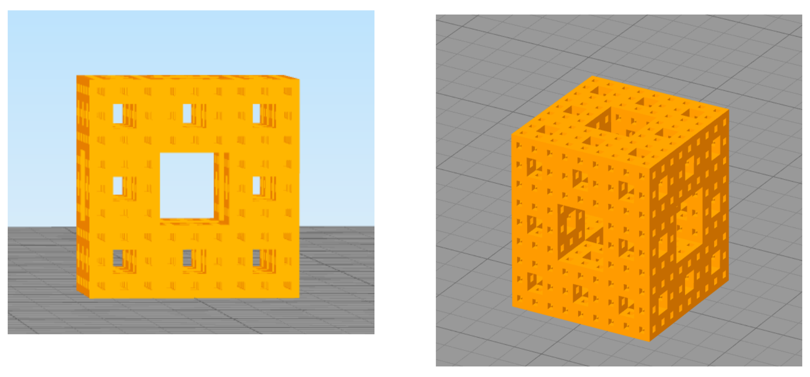
Methods

For printing, an upgraded 3D-printer was used, created on the basis of the Wanhao Duplicator 4S (PRC) by installing a special extrusion head - a syringe extruder.

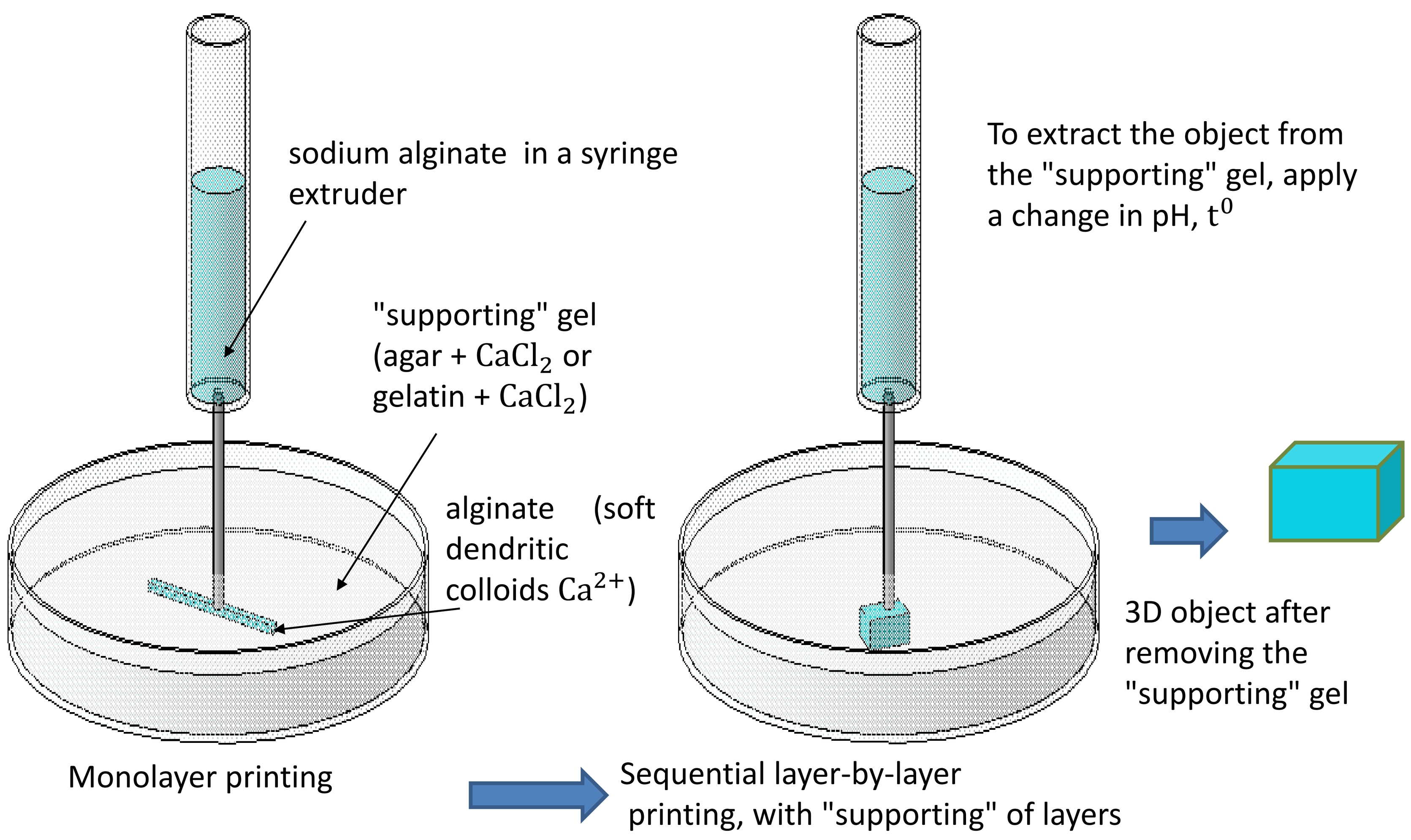
The original models were built in the form of a Menger sponge (a fractal cube with an edge length of 1.6 cm and hole sizes of 0.1 × 0.1; 0.3 × 0.3 and 0.5 × 0.5 mm^2) using the program KOMPAS-3D. Solutions of sodium alginate in distilled water and solutions of chitosan in acetic acid were used as the extruded material. The printing process from sodium alginate or chitosan was carried out in a volume of "supporting" gels from agar or gelatin with the addition of $CaCl_2$ for sodium alginate and $(NH_4)_2HPO_4$ for chitosan.



Upgraded 3D-printer was, created on the basis of the Wanhao Duplicator 4S (China)



Computer simulation of three-dimensional porous samples in the form of a Menger sponge



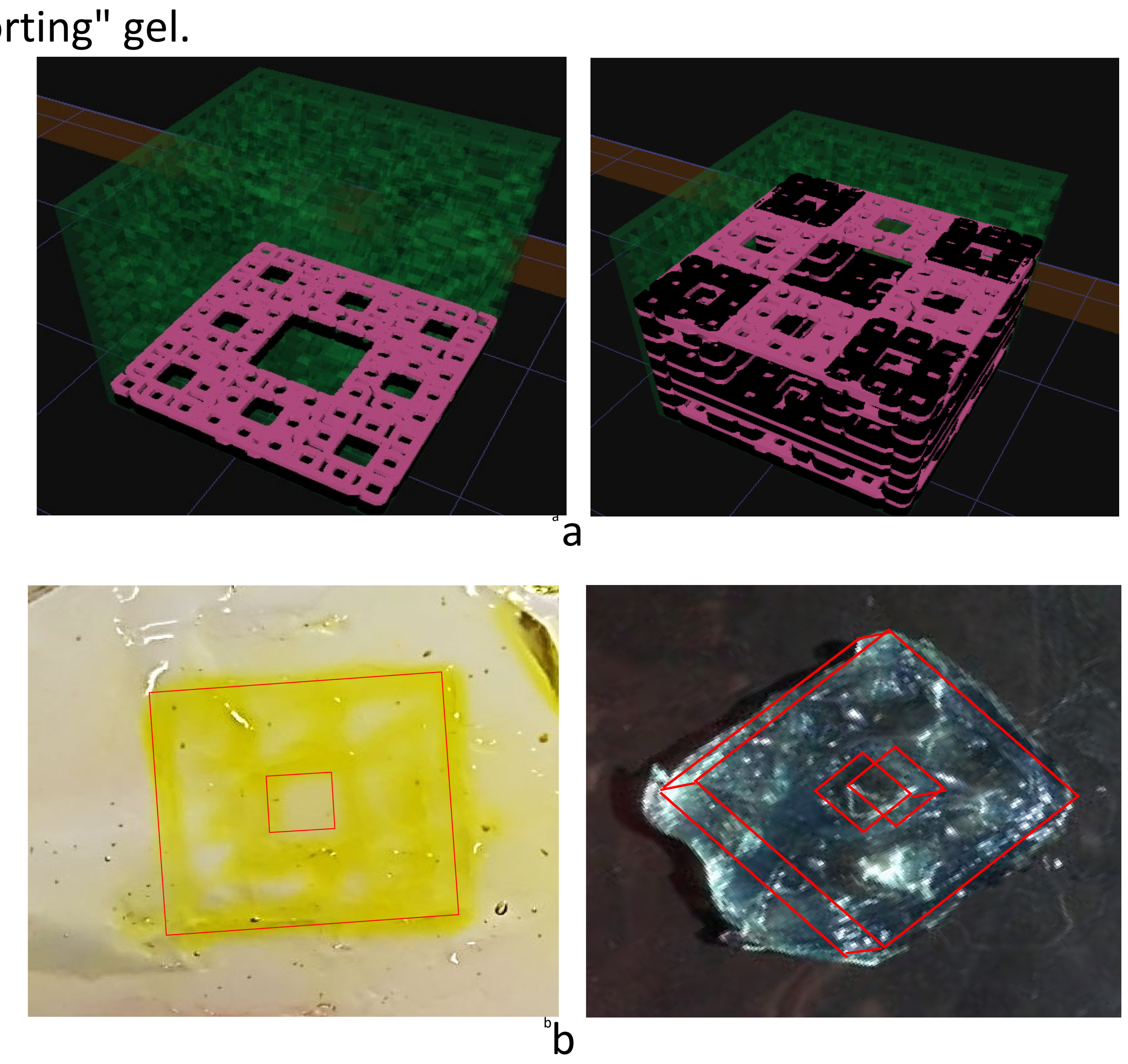
The process of obtaining objects from a hydrogel by 3D-printing

3D-printing was performed for the following compositions: sodium alginate (1-2 wt% in an aqueous solution), agar (0.3-0.4 wt% in 0.15 wt% in a $CaCl_2$ solution), gelatin (1, 0-2.0 wt% in $CaCl_2$ solution), $CaCl_2$ (0.15 wt%); chitosan (1.5-3 wt.% in 0.5% acetic acid solution) in a "supporting" gel $(NH_4)_2HPO_4$ (20 g / l).

Results

Print quality is determined by the stability and fidelity of the printed model. The accuracy of the model and the form of the structure of the print object is greatly influenced by the speed of extrusion of the material and the movement of the extruder-syringe.

Using the KISSlicer software for the modified 3D-printer, various speeds of the extruder-syringe were adjusted: when printing the outer perimeter of the model, when printing its inner filling and feeding material. The determination of the operating speeds of the 3D-printer was carried out by applying a monolayer of the model with a hydrogel in the volume of a "supporting" gel.



Computer modeling (a) and 3D printing (b) of three-dimensional porous samples using sodium alginate in a "supporting" agar gel

Table.- Optimal printing modes for hydrogels

Extrusive hydrogel composition	Maintenance gel composition	Print speed internal filing of the model, mm/s	Print speed of the outer perimeter of the model, mm/s	Hydrogel extrusion rate, ml/sec
sodium alginate	agar+ $CaCl_2$	9-11	9-11	1,3
sodium alginate	gelatin+$CaCl_2$	2	2	1,3
chitosan	$(NH_4)_2HPO_4$	6-8	6-8	1,3

Conclusions

The possibility of using a water-based sodium alginate hydrogel and chitosan in an aqueous solution of acetic acid for 3D-printing is presented. Three-dimensional models in the form of Menger cubes were printed from the listed pairs of substances.

Optimal speeds of movement of the extruder-syringe based on Wanhao Duplicator 4S have been determined for 3D-printing with sodium alginate hydrogel in agar "supporting" gel – 9–11 mm/s, for sodium alginate in gelatinous "supporting" gel – 2 mm/s, for chitosan in "supporting" gel with the addition of $(NH_4)_2HPO_4$ – 6–8 mm/s

The presented technological approaches can be used for 3D-printing of volumetric objects for biomedical applications.