SEM and CT techniques in the analysis of scaffolds made by AM

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INTRODUCTION

Additive manufacturing (AM) allows producing objects with functional internal structures, one of its applications is the production of medical scaffolds and implants which may substitute bone tissue[1]. Micro-CT is a non-destructive method that enable to characterize 3D geometry of objects[2]. Its application in analysis of bone scaffolds allows for obtaining full geometric characterization of manufactured structures as 3D models and evaluation of the conformance of scaffolds to their CAD designs.

MATERIALS AND METHODS

Scaffolds geometry manufactured by SLM from Ti-6Al-7Nb alloy are shown in Figure 1b. The struts in the elementary cell has a diameter of 150µm, the distance between the slats is 600µm. The sample has a cubic shape built from 8x8 cells corresponding to dimensions 4,95x4,95mm. Micro-CT characterization of samples was prepared with voxel size of 19,95µm. During the measurement the X-ray tube voltage was set on 120kV and current on 100µA. Registered 1000 projection with a single projection integration time of 1s. Obtained 3D volumetric data was processed and visualized with advanced 3D voxel analysis and visualization software package. Struts diameters measured by micro-CT were compared with those obtained with a scanning electron microscope (SEM).

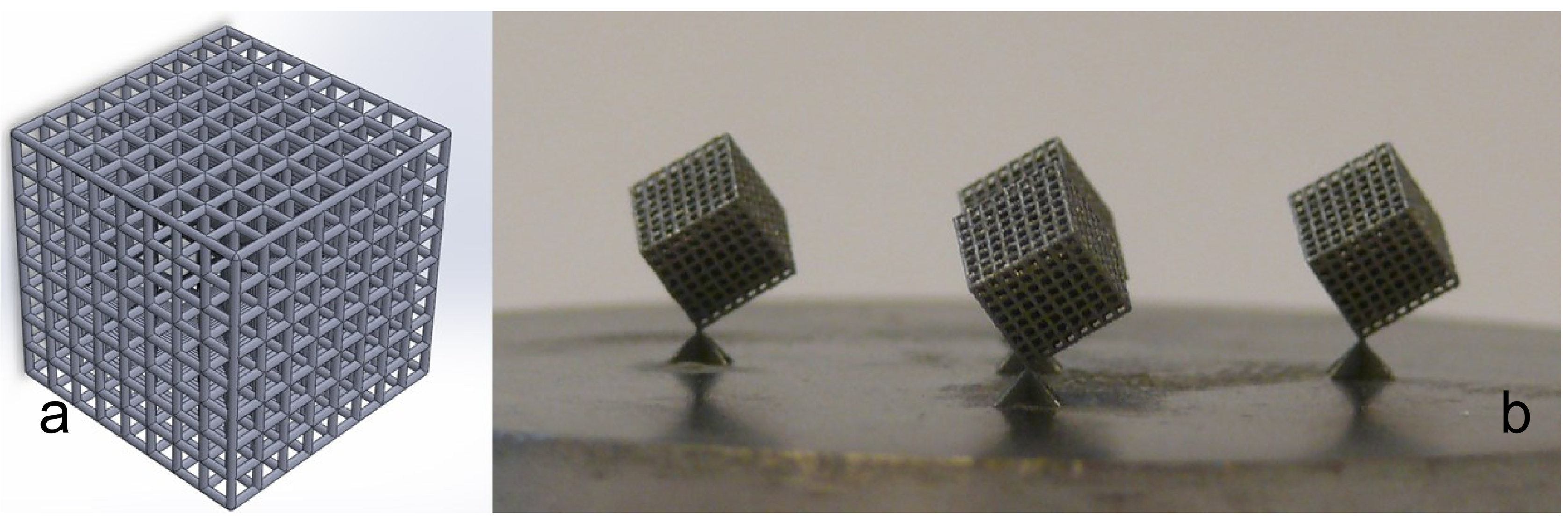


Figure 1. (a) CAD model; (b) manufactured samples

RESULTS AND DISCUSSION

The comparison result as a deviations geometry color map beetween volumetric and CAD model is shown in Fig. 2. Figure 2 also shows the direction of samples building. In all tested samples the deviations of the geometry were higher in the downward facing surfaces and amounted to 120µm. The presence of the overhanging surface is caused by many factors like inclined angle, scanning speed and laser power[3].

Porosity registered with micro-CT was lower than designed for 7-8 mm³, while surface area increased by 180-240mm². The porosity and surface area of scaffolds are factors that influence in bone cell adhesion[4]. Information about the actual values of these quantities is very important for the proper design of such structures .

Accuracy of the micro-CT method was verified by scanning electron microscope. The diameters of the struts in the directions X and Y were measured in the same plane. The differences in the dimensions obtained by microtomography and SEM did not exceed 10µm.

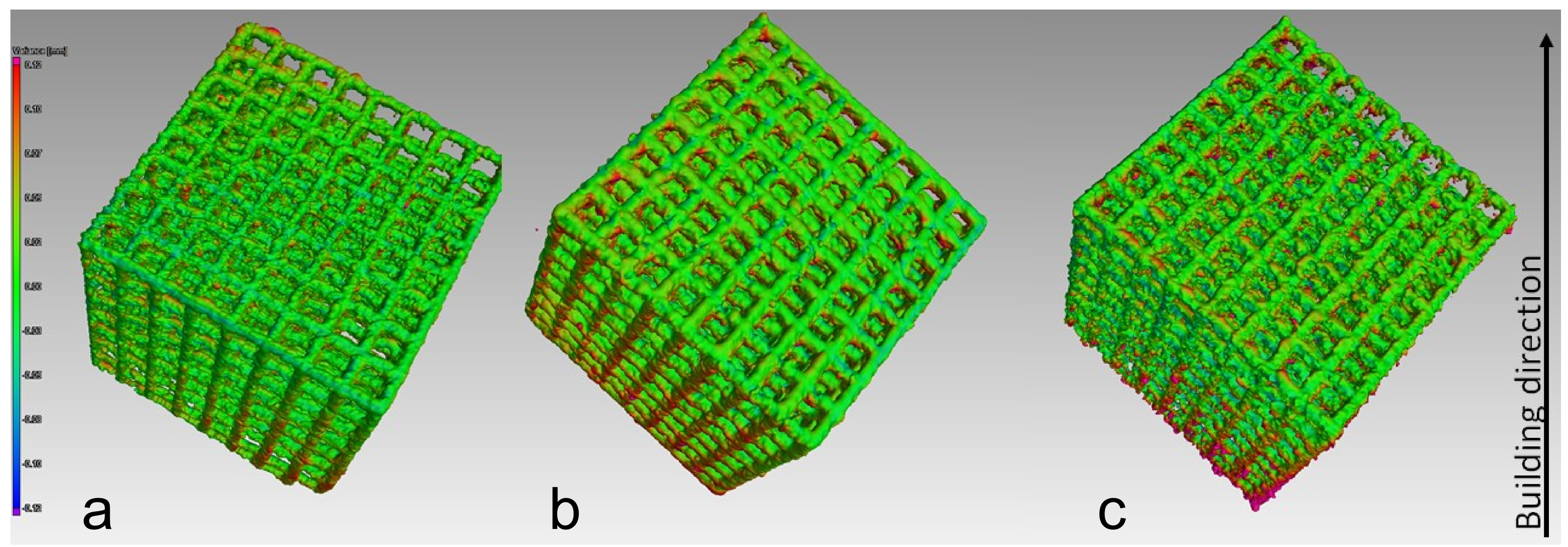
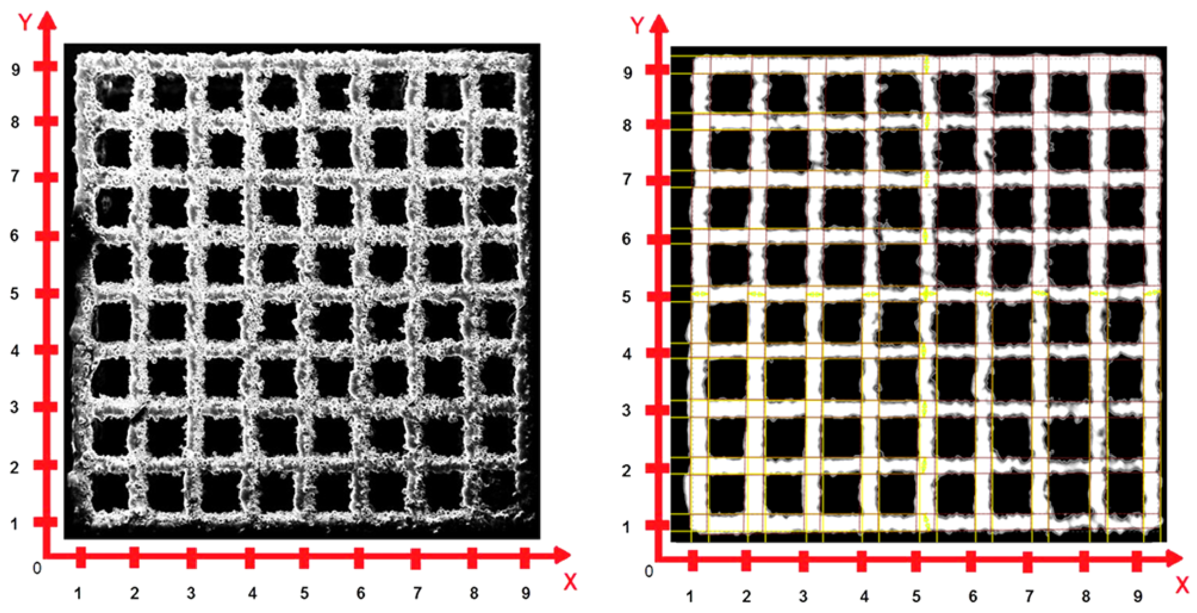


Figure 2. Actual/nominal comparision with CT data and CAD model. The results of comparisions are presented as a color map (a) Scaffold 1 ,(b) Scaffold 2, (c) Scaffold 3

Table 1. Porosity and surface area designed and measured by µCT

Scaffold	Porosity[%]		Surface area [mm²]	
	CAD	µCT	CAD	µCT
1	85,37	78,71	434,690	614,262
2		76,63		631,237
3		77,14		672,382



Diameter[µm]	
CAD	
Direction X	Direction Y
150	150
SEM	
177,9±4,9	172,2±6,5
µCT	
180,5±4,6	171±8,8

Figure 3 Comparing diameters in the directions X and Y on the same plane determined by SEM and CT

CONCLUSIONS

1. Computed microtomography allows to determine the quality and geometric characterictic of scaffolds with high accuracy.
2. Using micro-CT method allows to indentify overhangings created during scaffold manufacturing.
3. Micro-CT method allows to design bone scaffolds with exact porosity and surface area which might be used to prepare right bone implants.
4. Although SEM method is accurate, the examined sample is destroyed. Micro-CT allows to determine 3D geometry of the sample in non-destructive way with comparable to SEM method accuracy.

LITERATURE

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