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Abstract

Nanostructures of metallic alloy implants (Ti6Al4V and CoCrW) were studied using SWAXS (Small and Wide Angle X-ray Scattering) Method. Implants were prepared in the Medical Design and Production Center of Gülhane Military Medical Academy (GATA-METUM) using selective laser melting (SLM) techniques. With the collaboration of Hacettepe University and GATA-METUM, these metallic implants will be improved to higher standards such as biocompatibility and mechanical strength by understanding nanostructures of them [1]-[3]. First investigations showed that by changing the parameters such as product position on the table, annealing temperature or cool down period, nanostructures of products can be manipulated.

1. Introduction

Titanium alloy implant production is needed to be controlled in many ways in order to obtain biocompatible and mechanically resistant samples. In this study we will be examining Selective Laser Melting as production method and focus on final angle of product on the production table (production angle) and annealing parameters such as peak temperature, application time and cooling method.

2.1 SLM

Selective Laser Melting can be called as a 3D printing process. In the figure below it can be seen that system is composed of a powder supplying mechanism and a proper laser which has enough power to melt that powder.

Layer by layer mapped data of the product is fed into the system and laser melts each point in the matrix one at a time.

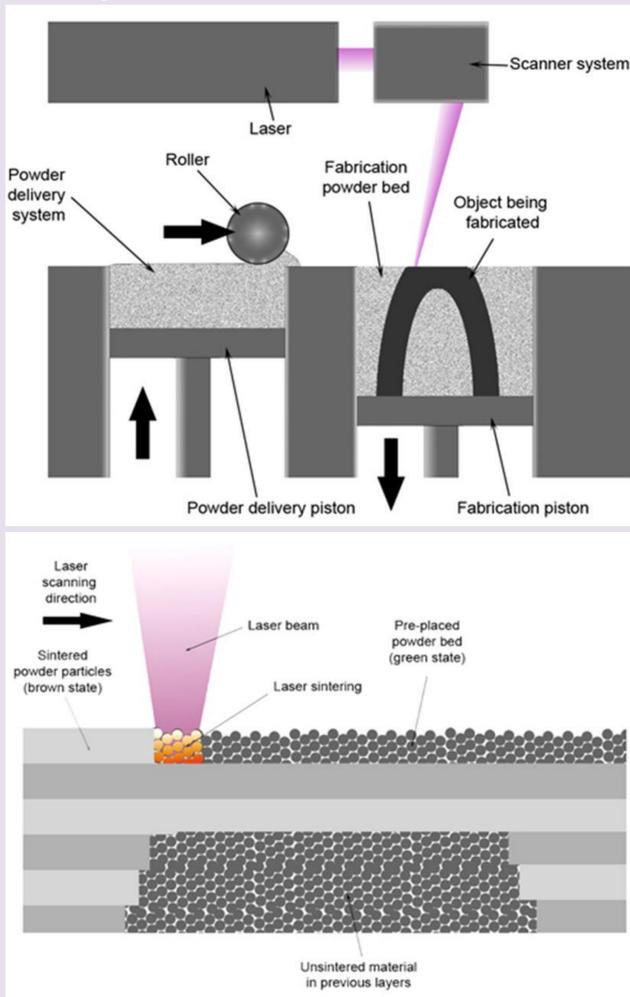


Figure 1. Schematic diagram of SLM [6]

Selective laser melting comprises the following physical phenomena: absorption and scattering of laser radiation, heat transfer, phase transformation, fluid flow within the molten pool caused by surface-tension gradient, evaporation and emission of material, and chemical reactions. The SLM process is also defined by a large number of parameters including the processing parameters such as laser power, scanning speed, scan line spacing (hatch distance), thickness of layer, scanning strategy, working atmosphere, temperature of powder bed, and material-based input parameters. All of them have an effect on the process of the tracks formation. Unfortunately, their mutual interaction is not always clear. That is why very important scientific understanding of modification of processing parameters, i.e. how the modification each of these parameters influences on the other and the SLM process as a whole [4].

2.2 GATA-METUM

GATA-METUM stands for 'Gülhane Askeri Tıp Akademisi- Medikal Tasarım ve Üretim Merkezi' means Medical Design and Production Center within Gülhane Military Medical Academy. GATA-METUM started up in 2004 with the collaboration of Gülhane Military Medical Academy and Middle East Technical University in order to provide necessary medical implants, prosthesis and orthosis for Turkish veterans and citizens. The center began to production in 2011 by approval of Lieutenant General Orhan AKBAŞ, Commander of GATA.

Since 2011 GATA-METUM successfully handles modeling and production of implants using various materials such as plastic, silicon or metallic alloy. The Center uses Concept Laser M2 Cusing Machine as SLM technology (Figure 2).

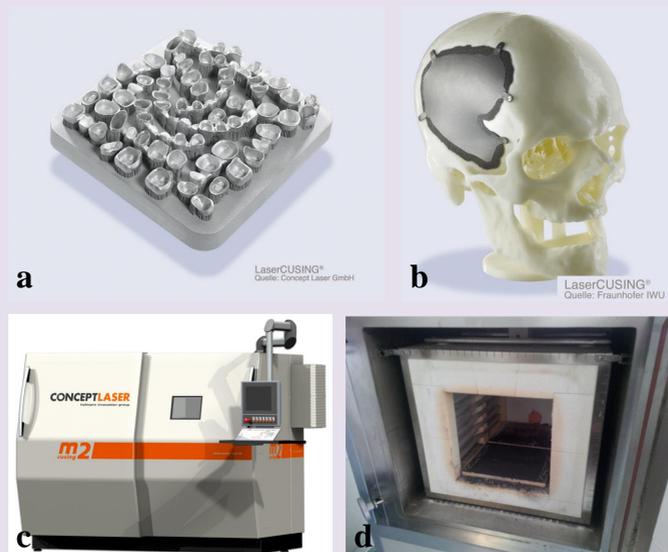


Figure 2. a) Dental implants on production plate. b) Skull plate implant. c) Concept Laser M2 Cusing SLM machine [5] d) GATA-METUM annealing oven

Implants are modeled specifically to the person and the part of the body. And then model is given to the SLM system.

The center has its own solution for the annealing problem. They are using the oven in the Figure 2-d, which has been designed specifically for GATA-METUM

2.3 SWAXS Method

Small and wide angle x-ray scattering (SWAXS) experiments were performed with a Kratky compact Hecus (Hecus X-ray systems, Graz, Austria) system equipped with a linear collimation system and X-ray tube Cu target ($\lambda = 1.54 \text{ \AA}$). The generator was operated at a power of 2 kW (50 kV and 40 mA). Simultaneous measurements of SAXS and WAXS range are possible in the system with two separate linear-position-sensitive detectors used with 1024 channel resolution for each one.

Distances between channels and the sample to detector are $54 \mu\text{m}$ and 31.5 cm , respectively. Scattering curves (SAXS) were monitored and calibrated in q ranges as seen in the Figure 4-a. All samples were measured for 10 minutes at 23°C by using sample holder of the system.



Figure 3. Hecus SWAXS system on our laboratory [7]

2.4 Experiments

First experiments are conducted with 12 different samples which are grouped by the production angle, annealing temperature and final shape.

- Group-1- is composed of cylindrical samples as final shape, annealing temperature 840° and production angle of 0° , 45° and 90° for sample no 1, 2 and 3 respectively.
- Group-2- is composed of cylindrical samples as final shape and annealing temperatures 0° , 840° and 940° for sample no 4, 5 and 6 respectively.
- Group-3- is composed of samples 7, 8 and 9. All parameters are same as Group-1- except final shape is rectangular prism.
- Group-4- is composed of samples 10, 11 and 12. All parameters are same as Group-2- except final shape is rectangular prism.

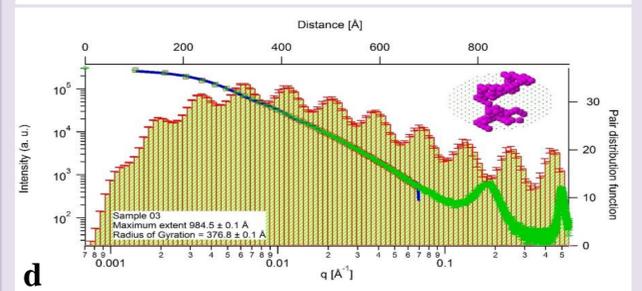
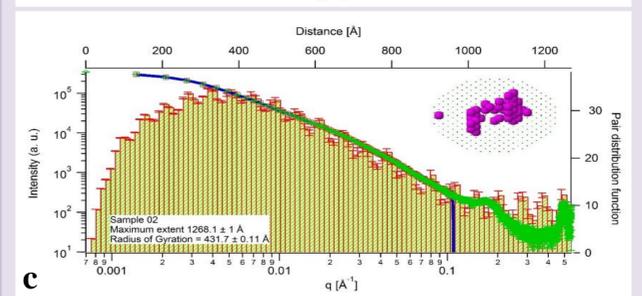
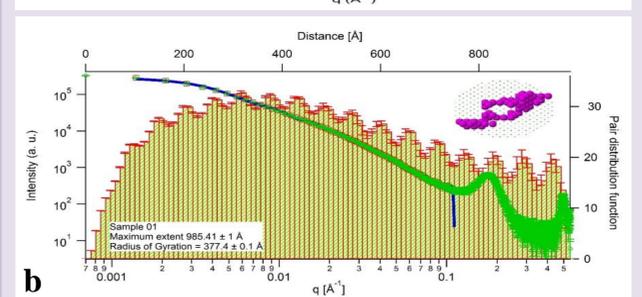
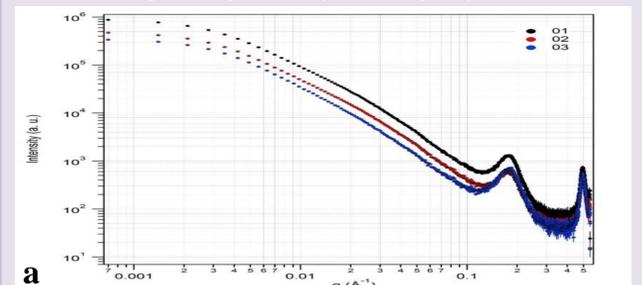


Figure 4. a) SAXS patterns of Group-1-. b) PDDF of the Sample 01 (0°) and DAMMIN output. c) PDDF of Sample 02 (45°) and the DAMMIN output. d) PDDF of Sample 03 (90°) and DAMMIN output.

3. Conclusion

Examining SAXS results we see that changing the production angle effects the nano structure of implants. Although the samples which have the cylindrical form as final shape give better results than prismatic ones This might be because much more layers are exposed to x-rays. So we can say that final shape is irrelevant when considering nano structure. SLM technique studies suggest that final shape is important as surface roughness [8] but we can not clearly see that from SAXS results. Finally annealing seems to change the nanostructure but we need to study the phase transitions of samples. Studies about the phase transitions of Ti-6Al-4V samples suggest that 1040° is critical about α transition [9]. For next generation of samples, production angles such as $0^\circ, 20^\circ, 45^\circ, 70^\circ, 90^\circ$ and annealing temperatures such as $0^\circ\text{C}, 840^\circ\text{C}$ and 1040°C must be further examined. It would be better if mechanical properties are measured and XRD experiments are conducted.

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- [5] Pictures on Figure 2-a,b,c are from <http://www.concept-laser.de/>.
- [6] Schematic diagram on Figure 1 is from http://en.wikipedia.org/wiki/Selective_laser_sintering.
- [7] Picture on Figure 3 is from <http://www.hecus.at/>.
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