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Surface Structuring by Electron Beam Technique in Titanium Alloys for Biomedical Applications

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ABSTRACT

Titanium-based materials are used successfully as orthopedic devices due to their mechanical properties and biocompatibility. Mechanical properties of implants are strongly related to the microstructure obtained by thermo-mechanical processes and their biocompatibility depends on the chemical composition and the quality of the surface. The osteoconduction and osseointegration of implants are related to the surface topography and roughness of implant materials. For that, several techniques can be used to improve the functionalization of biomaterials, altering the surface from the nanometer to millimeter level for a specific application. This work investigates the structuring of titanium alloys by electron beam technique and the cell morphology as a function of the surface condition. Structured figures are designed following different criteria in order to develop a specific topography and roughness on the surface. The final geometry depends also on the beam parameters and the physical properties of the material, obtaining a range of roughness in the micrometer scale. This range is due to the change of the microstructure near the surface which brings an additional modification on the surface.
Mouse MC3T3-E1 osteoblasts are used to evaluate in vitro attachment interactions as a function of the surface condition.

EXPERIMENTAL METHOD AND RESULTS

MATERIALS

- Commercial pure titanium, grade 2 (Ti Gr2)
- Alpha beta titanium alloy Ti-6Al-4V

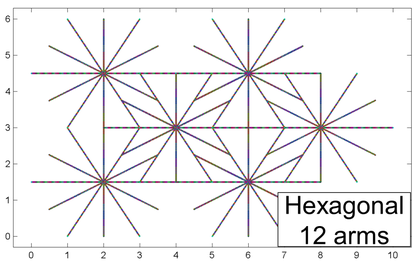
Samples of 15x15x2mm are polished up to P4000 silicon carbide paper before structuring.

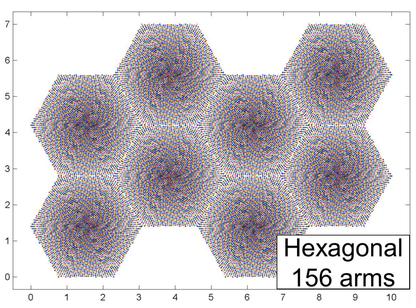
SURFACE STRUCTURING DESIGN

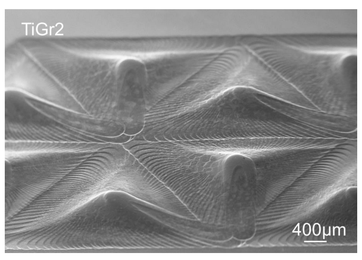
The mechanism of structuring with electron beam (EB) technique is described by J. Tändl et al. [1]. The structures are designed by MATLAB and exported as a coordinate file to operate the beam deflection [2].

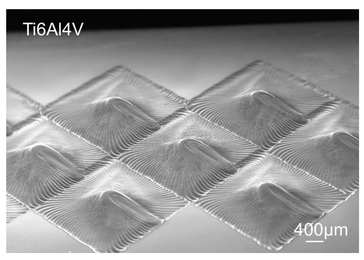
Machine parameters for structuring:
- Voltage [kV]
- Beam Current [mA]
- Welding Time [s]
- Read Frequency [Hz]

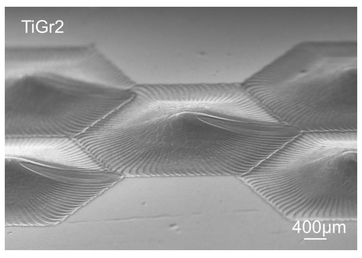
Criteria to design the structure:
- Type of polygon
- Number of arms
- Arm overlap
- Spiral arms
- Point spacing
- Beam Travel direction
- Array arrangement

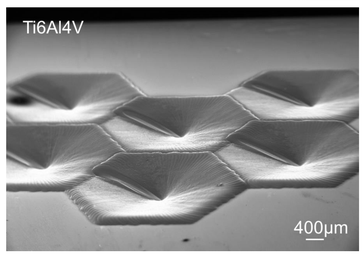






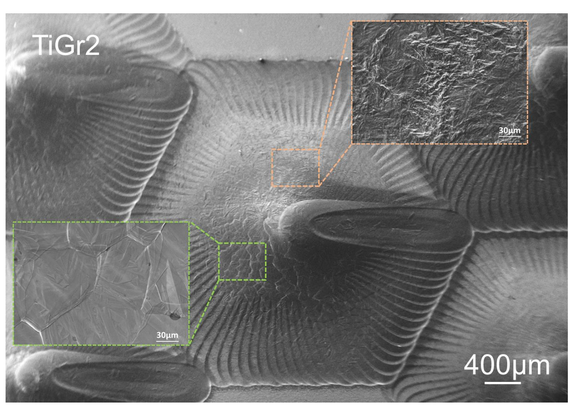


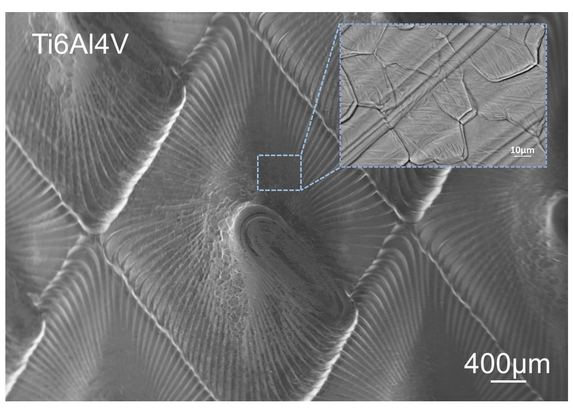




SURFACE MODIFICATION

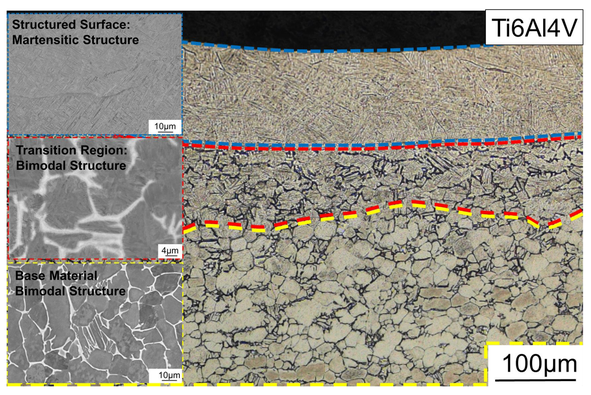
The surface roughness is observed as a function of the surface structuring (beam deflection design) and the change of the microstructure morphology near to the surface.

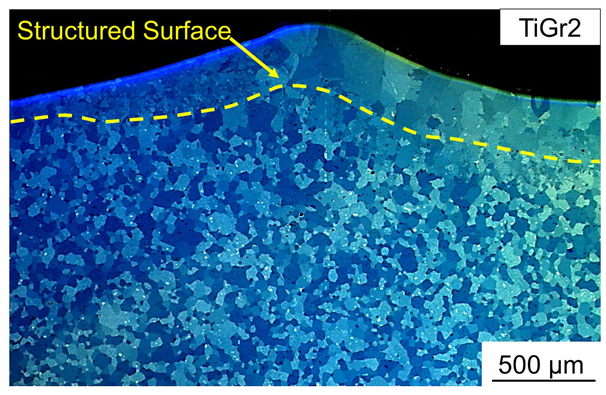




EFFECT OF THE STRUCTURE ON THE MICROSTRUCTURE

The heat input of the electron beam process changes the microstructure of the titanium alloys. A change in the morphology of the phases is observed in Ti6Al4V , while the grains size is modified in TiGr2.

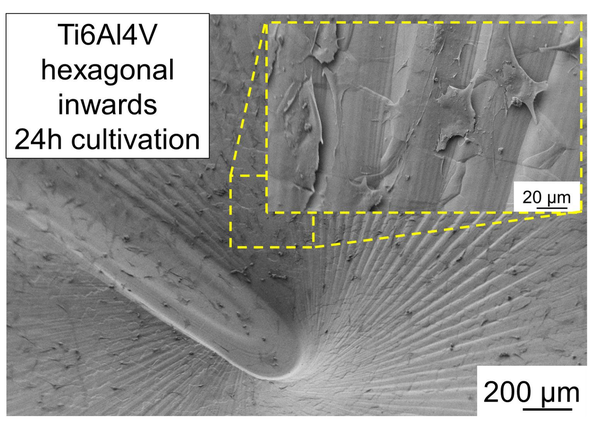


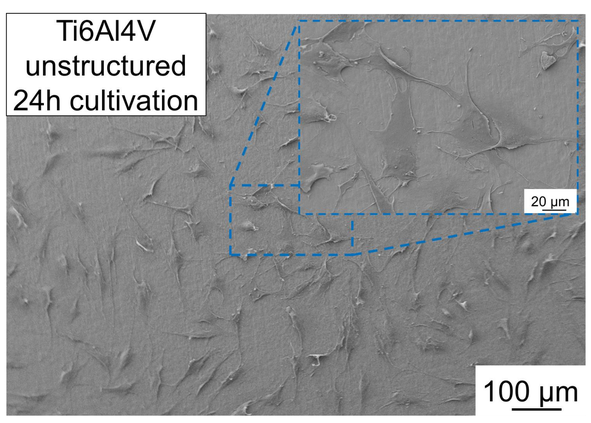


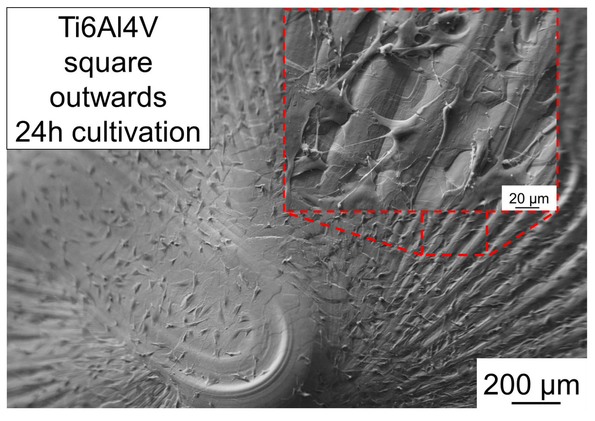
CELL MORPHOLOGY

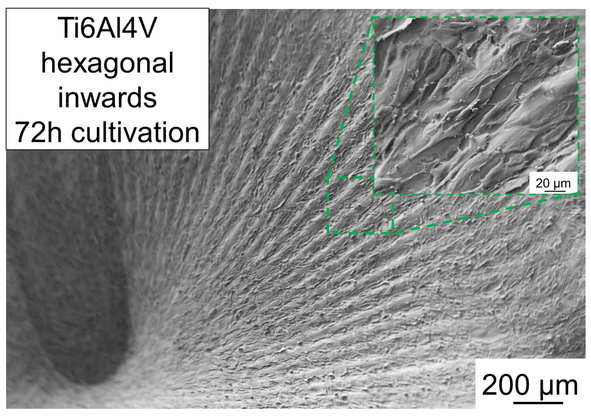
In vitro tests are carried out with MC 3T3-E1 osteoblastic cells on unstructured and structured samples during 24h and 72h. The cells are seeded with a density of 10000 cells/cm^2.

- The cells spread uniformly with polygonal morphology on the material.
- The cells on the square outward sample build connections through elongated filopodia.
- Increasing cultivation time, led to proliferation of the cells and the cells look more elongated.









CONCLUSIONS

The electron beam technique can be used to design different structures on titanium alloys. The structure of each titanium alloy denote an influence of the physical properties of the material and the process parameters. The beam current is higher for Ti6Al4V than for TiGr2. The increment of the number of arms in the figure reduce the roughness. The heat input during the structure process produces changes in the microstructure and grain size of the alloys. The osteoblastic cells are with polygonal morphology on every structure compare to the unstructured control. The cells on the square outward sample even show connections through elongated filopodia. With increasing cultivation time the cells led to proliferation.

ACKNOWLEDGMENT

This investigation is sponsored by the government of Styria, within the project “Oberflächenveränderung von Titanlegierungen zur Verbesserung der Biokompatibilität von Implantaten” in the framework of the HTI_Tech for Med.
The Electron Beam Machine is sponsored by the European Fond of Regional Development (EFRE), government of Styria and the TU Graz.

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