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Biocompatibility of pure refractory metals and their combination as high entropy alloys

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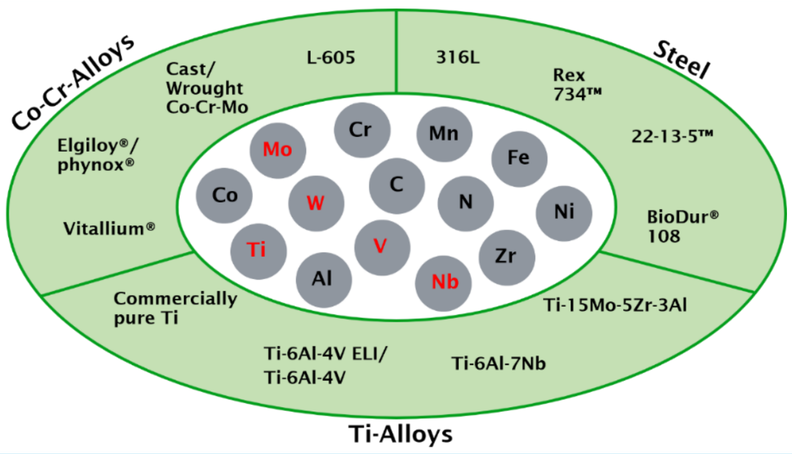
Motivation:

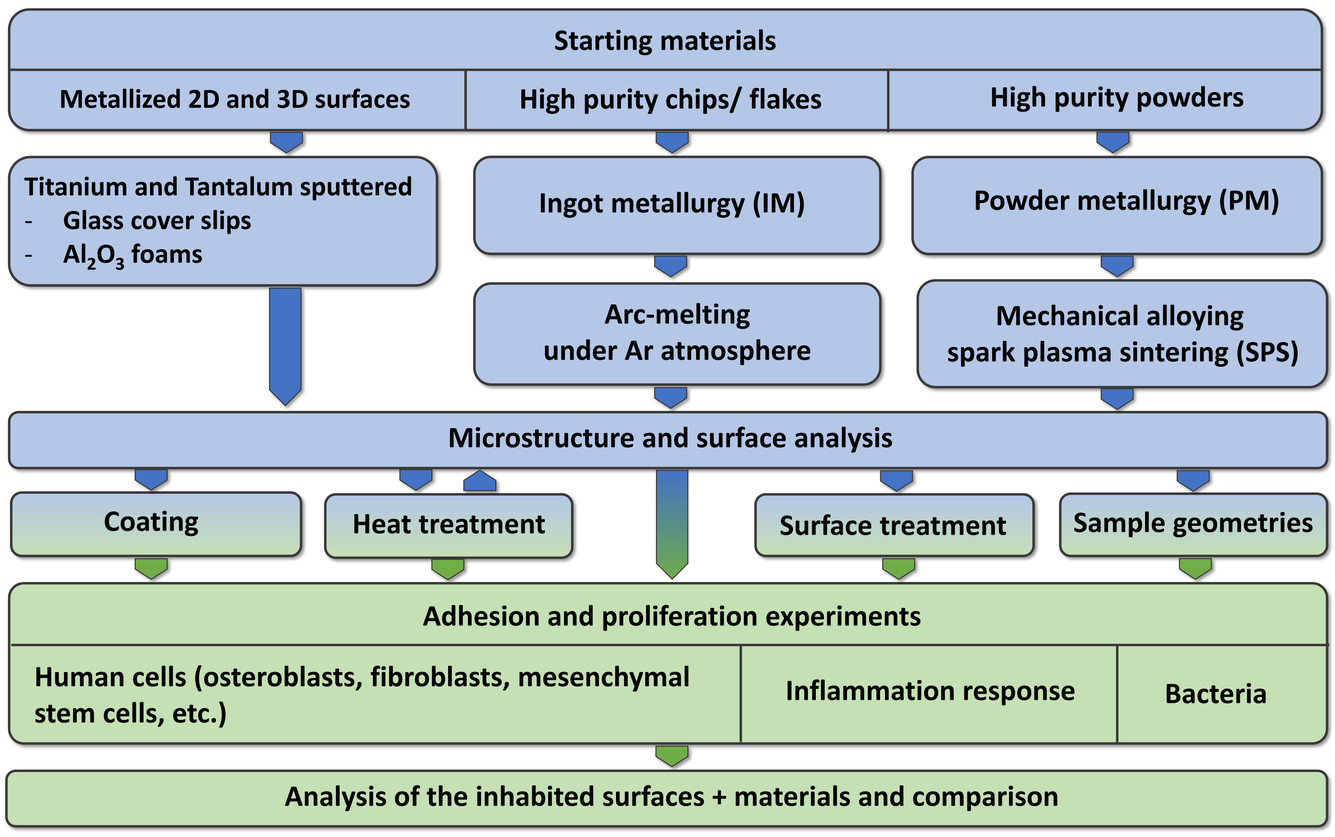


The innovative class of materials based on refractory metals represent a unique alloy design strategy for the development of potential new biomedical materials.

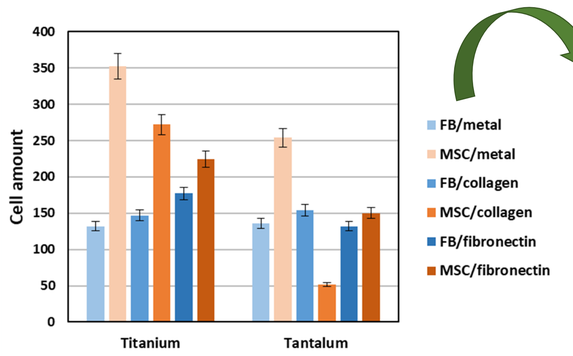
- Broad variety of established materials for biomedical applications exists
- Most alloys are based on Titanium, Cobalt or Iron (medical steels)
- Recent investigations indicated that refractory alloying systems may also be of interest because they often contain one or more potentially biocompatible element

Development of refractory metal-based multi component systems that combine biocompatibility and outstanding mechanical properties (abrasion, mechanical strength, hardness, etc.)

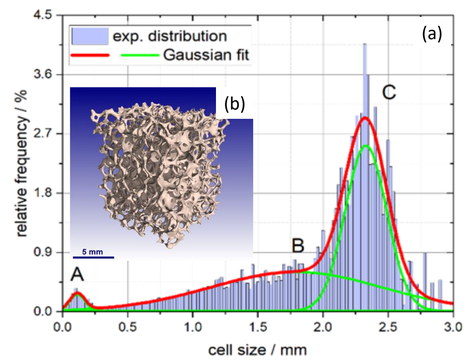
Flow chart for material design and bicompatibility asessment:



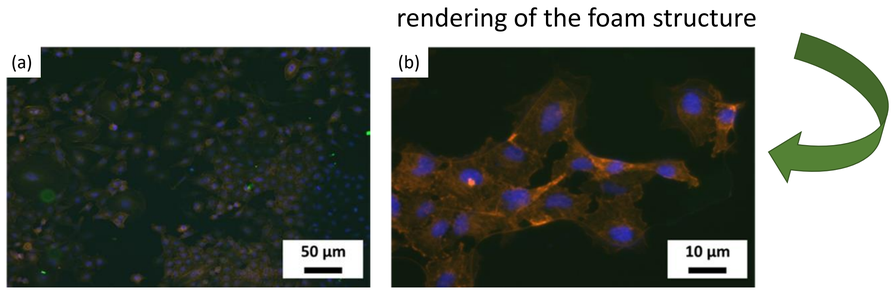
Proliferation of fibroblasts (FB) and mesenchymal stem cells (MSC) on metallized glass cover slips



Comparison of cellular behavior on collagen or fibronectin un-modified or modified coated glass-metal surfaces.



(a) µ-CT data of Al_2O_3 foams; hollow strut cavities (A), the cell windows (B; ~1.8 mm) and actual foam cells (C; ~2.3 mm); (b) 3D rendering of the foam structure



Stem cells culture on metal modified ceramic foams. (a) blue stained (Dapi) nuclei on formalin fixed samples. (b) enlargement of the formalin fixed cells on the surface - clearly to see are the blue nuclei and the red stained cytoskeleton.

First investigations on multicomponent Ta-Nb-Ti system and cell attachment:

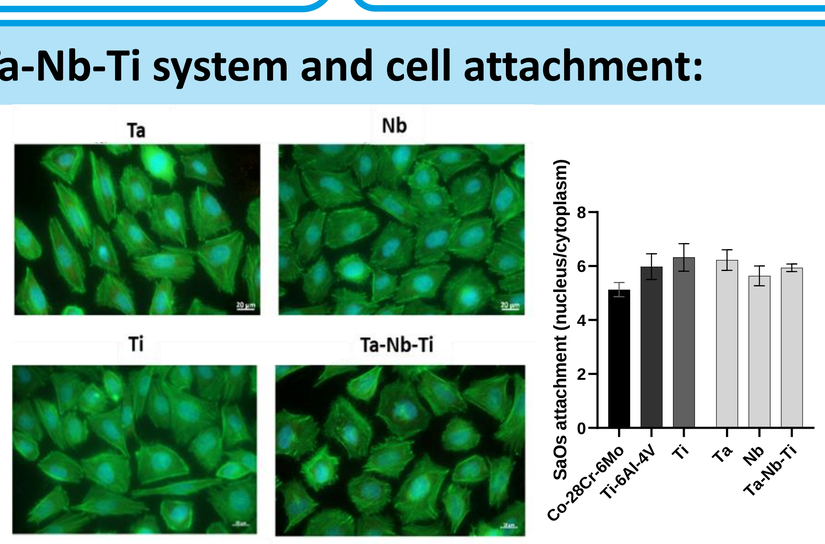
- Dendritic Ta-Nb-Ti alloy with two modifications of bcc crystal structure:

bcc I	3.288 Å
bcc II	3.291 Å

- EDS element mapping:
  - Higher fraction of Ta in dendritic crystals
  - Lower melting Ti enriched in interdendritic regions

- Comparison of the samples' surfaces and obtained hardness values

- Exemplified: Images of several samples, obtained via confocal microscopy



- SaOs-2 (human osteoblasts) attachment to the materials after 24 h (cytoskeleton: green, nucleus: blue) and calculation of nucleus to cytoplasm ratio for the tested alloys.

Analysis of the fluorescently labelled osteoblasts indicated no difference between novel alloy Ta-Nb-Ti and the other samples, considering the amount of cells, as well as the ratio between nucleus and cytoplasm (cell attachment).

Summary and Conclusion

- The cultivation process on planar substrates was transferred to open cellular Ti- and Ta-metallized Al_2O_3 foams
- This results in an almost equally proliferation rate of MSCs and FBs on the metallized Al_2O_3 foams

- First investigations regarding an equiatomic Ta-Nb-Ti system were carried out (Microstructure-, XRD-, Surface- and microhardness analysis)
- Biocompatibility assessment indicated good attachment and growth of human osteoblasts on the samples' surface

Promising starting point for further development of biocompatible HEAs

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