Boron and Hafnium as coating materials on 316L SS and Ti6Al4V alloy

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General Abstract

verall aim of this research was to produce hard coatings for moral heads of hip implants with reduced wear rates and lity, yielding a reduction in hip implant failures. Initially m (Hf) and Boron (B) were investigated as potential terials.

Technical Abstract

m of this project was to investigate the suitability of Boron afnium coatings on 316L stainless steel and Ti6Al4V as a of producing harder and less wearing surfaces and ved biocompatibility.

Introduction

ing Hf and B as coatings was based on the following vations. Hf is a hard and highly corrosion resistant refractory with excellent bulk biocompatibility[1]. Boron forms very hard netallic bonds with iron from the matrix[2] and was used in applications showing good biocompatibility[3]. In vivo Hf and B may release ions. It is these ions that were investigated. We opted for $HfCl_2$ and BPO_4 solutions for improved biocompatibility studies, since in solution they form Hf^{4+} and B^{4+} ions.

Materials & Methods

The pack cementation method was employed as a coating technique, using Hafnium Chloride and Boron Carbide under protective conditions for 5 hours at 950°C.

Cytocompatibilty of both Hf^{4+} and B^{4+} was assessed with respect to SaOs2 osteoblast like cells (NCBES). Inert alumina (Al_2O_3) was used as the control in this experiment. Positive (Cr^{3+} and $Ni^{2/3+}$) and negative (NaCl and Na_2/K_2PO_4) controls were used for comparison. Cell activity was assessed after 24 hours, using Alamar Blue Assay (Figure 1) and cell count by calculating total DNA.

Alamar blue is substituted for molecular oxygen in the electron transfer chain. This effect is reduced by cell activity and this reduction is read as a fluorescent product by microfluorometry.

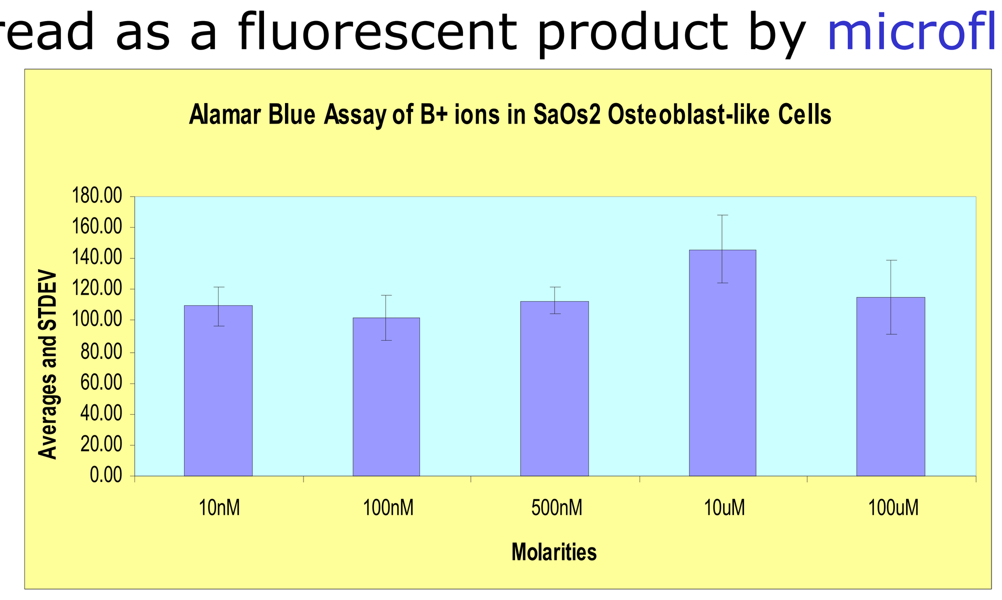

Figure 1 Cell Activity of BPO_4 using Alamar Blue Assay

The quality of the achieved coatings was high and the coating-substrate interface was found to have a tooth-shaped morphology.

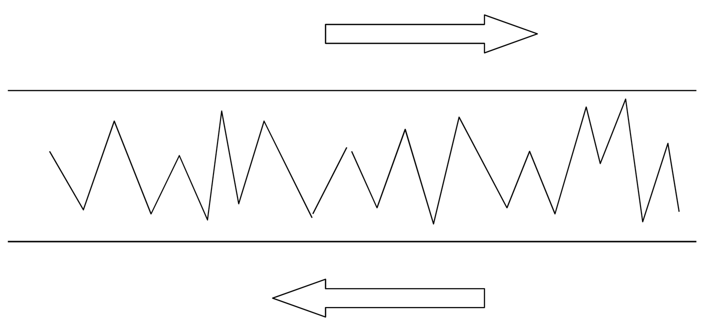

Figure 2 Tooth-shaped morphology at the coating-substrate interface

Results

The fabricated interface is particularly desirable, as it strengthens the adherence of the coatings on the substrate and ultimately reduces wear debris generation. This feature was not observed in the case of the coated Ti6Al4V, because of the presence of large amounts of oxides (Figure 2b). Oxides formed due to an insufficient vacuum available for the coating of the Ti6Al4V (10^{-2} mbar). Ongoing work in our group will address this issue by using a higher vacuum of 10^{-5} mbar. This shortcoming is indicated by the high oxygen content as recorded by the EDX spectrum of the SEM system (Figure 3).

(a) (b)

Figure 2 (a) Optical microscope image of coating on 316L sample. (b) Optical microscope image of coating on Ti6Al4V sample

Figure 2 (a) shows a more desirable interface on a 316L sample. A substantial thickness (40-50µm) was attained for both samples.

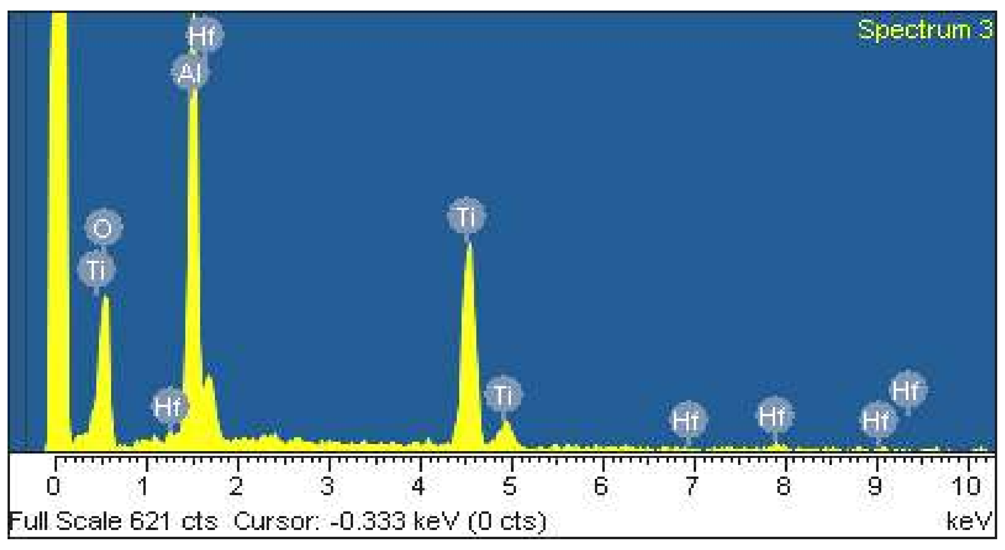

Figure 3 EDX graph of a Hf coated Ti6Al4V sample

The EDX graph shows that Hf has also been laid down on the surface of the Ti6Al4V samples, despite the oxides present and confirms that the employed method has the potential to be used for this type of coatings.

First results obtained from the cytocompatibility studies of SaOs2 cells exposed to Hf^{4+} and B^{4+} predict excellent cytocompatibility properties.

Conclusions

It has been shown that Hf^{4+} and B^{4+} pose limited threat to SaOs2 cells and are a suitable coating material Ti6Al4V and 316L substrates. It has also been shown that coatings are easily achievable on 316L substrates, but more work is needed to improve the coating quality on Ti6Al4V substrates.

Acknowledgements

Marie Curie fellowship for financing my attendance to the Knowledge Based Materials Summer School.

References

1 Matsuno et al, Biomaterials 22; 1253 – 1262 (2001).
2 Ueda et al., Surf Coat Technol, 126:1; 25-39 (2000).
3 Pelletier et al., Surf Coat Technol, 158/9; 309-17 (2002).

Glossary

Femoral Head – The large ball like section of the hip implant, representing the femur or thigh bone connection point

Biocompatibility – The property of being biologically compatible by not producing a toxic, injurious or immunological response in living tissue

Pack Cementation Method – Technique whereby sample to be coated is embedded in a powder mix which, utilises the chemical vapour deposition principal to form the final coating

Cytocompatibility – The property of being biologically compatible by not producing a toxic, injurious or immunological response in cells in suspension

Hip Implant

SaOs2 osteoblast like cells – Cell line from isolated bone osteosarcoma

Alamar Blue Assay – Alamar Blue is substituted for molecular oxygen in electron transfer chain

Microfluorometry– The study of certain organic compounds within cells, in situ, by measuring the light intensities of the selectively stained areas of cytoplasm. The compounds studied and their locations in the cells are made to fluoresce and are observed under a microscope.

Tooth Shaped Morphology – View sketch above for jagged interface

SEM – Scanning Electron Microscopy

EDX – Energy Dispersive X-Ray Spectroscopy