

Bioactive Ceramics Based on Nb₂O₅ and Ta₂O₅

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Abstract. Bioactive ceramics have the ability to chemically bond to bone. This class of biomaterials can be used as coatings on metallic implants, alloplastic bone defect fillers and as scaffold for tissue engineering. The most widely used bioactive ceramics are hydroxyapatite, Ca₁₀(PO₄)₆(OH)₂ and tricalcium phosphate, Ca₃(PO₄)₂.

This study presents new bioactive ceramics based on Nb₂O₅ and Ta₂O₅. These materials were produced from bioinert ceramics chemically activated by an alkali hydrothermal treatment. Scanning electron microscopy, energy dispersion X-ray spectroscopy and X-ray diffraction analyses on samples incubated in simulated body fluid showed the presence of bone-like apatite, confirming that the modified ceramics surface became bioactive.

Introduction

Porous bioactive ceramics are used as scaffolds for bone healing. These materials have tissue response controlled by chemical and morphological properties. Surface chemistry accounts for bioactivity, the ability of chemically bonding to bone. Bioactive glasses and hydroxyapatite exchange ions with human plasma and spontaneous bone-like apatite is precipitated on the surface. These surfaces undergo a sequence of events encompassing ions exchange, biomolecules and cells adhesion and newly-formed bone is bound to the bioactive surface [1].

The main morphological requisites for allowing bone ingrowth are the existence of open and interconnected pores and nano-scaled roughness. Pore diameters larger than 100 µm allows proper vascularisation, while nano-scaled topography yields fluid exchange [2,3]. Several ceramic processing routes are used to mimic bone architecture in bone substitutes in order to design scaffolds for bone engineering.

Inert ceramics and metals cannot establish chemical bonding to bone. However, alkali treatments were developed with the aim of structurally modifying former bioinert surface, which become bioactive [4]. Titanium, niobium and tantalum can be bioactivated by alkali treatments. These treatments structurally modify titanium and niobium oxides, creating a bioactive surface [4]. The present study proposes alkali treatments on bulky tantalum and niobium ceramics. These are inert ceramics which become bioactive and are proposed to be used as bioactive ceramics with potential use for bone repair.

Methods

Optical grade Nb₂O₅ and Ta₂O₅ powders were supplied by Companhia Brasileira de Metalurgia e Mineração, CBMM, and Mamoré Mineração e Metalurgia Ltda., respectively. Dense Nb₂O₅ and Ta₂O₅ disks were produced by uniaxially pressing at 100 MPa and sintering at 1350°C. Porous bodies were produced by wax spheres addition to the ceramic powders, uniaxially pressing and sintering, according to the method described by Prado da Silva et al. [2].

After sintering, the ceramic bodies were hydrothermally treated in NaOH solution ranging from 0.1M to 10M, at 60°C during 24 hours. The specimens were washed in deionized water and dried at 60°C overnight [5].

The disks were incubated in SBF during 7, 14 and 21 days, in order to assess bioactivity. The samples were analysed by scanning electron microscopy (SEM) and energy dispersive X-ray spectroscopy.

Results and Discussion

Scanning electron microscopy (SEM) observation of specimens incubated in simulated body fluid showed the presence of precipitates on the treated surfaces. However, bone-like apatite-like precipitates were widely observed on the specimens treated with 0.5M NaOH solution at 60°C during 24 h. Energy dispersive X-ray analyses showed the presence of Ca and P peaks.

Figure 1 shows, by SEM, the presence of precipitates on the surface of bioactivated tantalum oxide specimen (a), with corresponding EDS spectrum (b). EDS analyses identified the presence of calcium and phosphorous peaks.

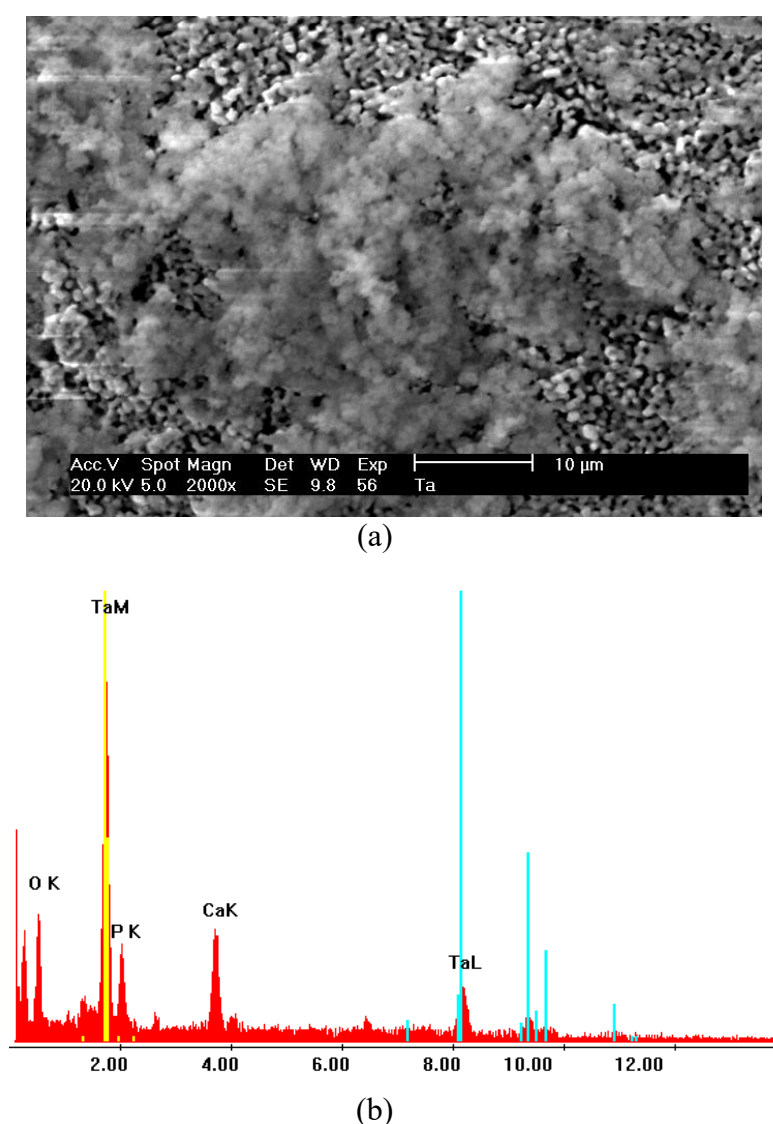
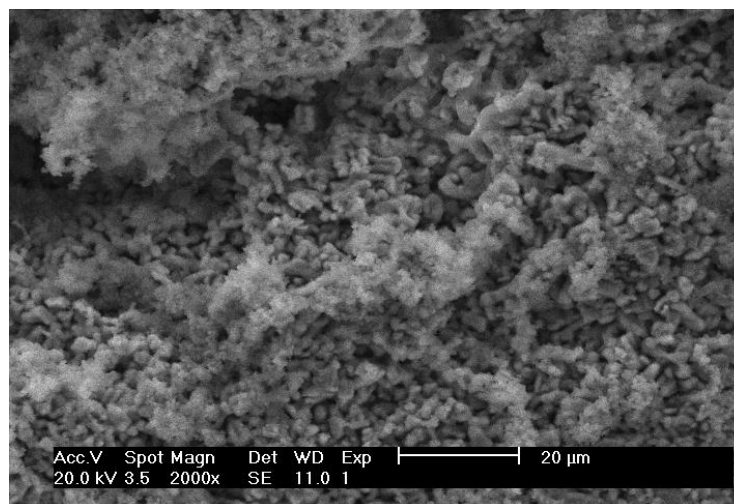


Figure 1 – SEM analysis on Ta_2O_5 sample treated with 0.5M NaOH during 24 hours incubated in SBF during 30 days(a) and corresponding EDS spectrum (b).

Figure 2 shows similar results for niobium samples bioactivated by the alkali treatment with 0.5M NaOH. Figure 2a shows the presence bone-like apatite precipitates (a), with corresponding EDS spectrum (2b). Calcium, phosphorous and sodium peaks are observed.



(a)

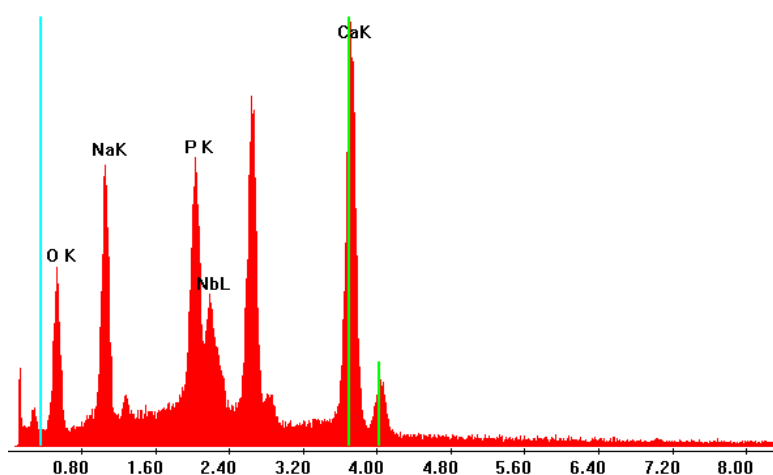


Figure 2 – SEM analysis on Nb_2O_5 sample treated with 0.5M NaOH during 24 hours incubated in SBF during 30 days(a) and corresponding EDS sepctrum (b).

These results confirm that the treatments were effective in producing bioactive ceramics from former bioinert materials. This study presents products that are bioactive but non-resorbable ceramics. This class of materials is an intermediate between implant and grafts and are proposed to be used to repair bone defects. Figure 3 shows porous Nb_2O_5 sample, with macropores and nano-scaled porosity.

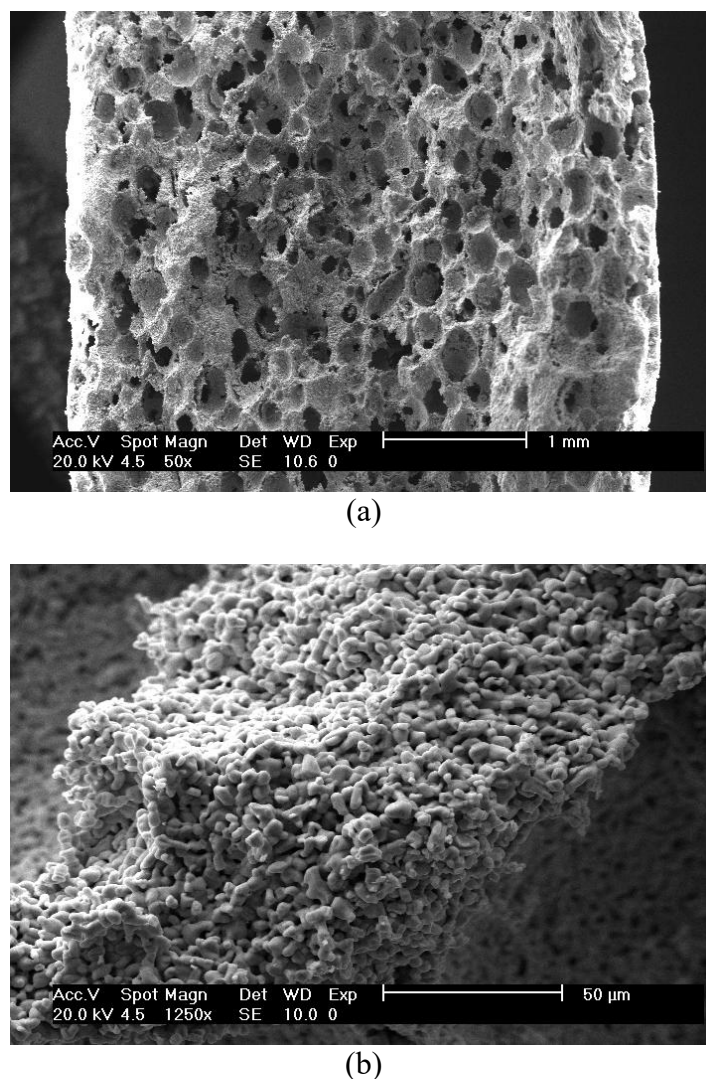


Figure 3 – Porous Nb₂O₅ sample showing macroporous structure (a) and nanometric features on the interconnections walls.

Conclusions

The alkali treatments were effective in inducing bioactivity on the former inert ceramics. This result indicates a potential for use as non-resorbable bone fillers.

References

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