

COMPOSITE MATERIAL ON Al_2O_3 BASIS COATED WITH VITREOUS CARBON FOR MEDICAL NEEDS

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Abstract

The composite on Al_2O_3 basis is bio-inert, non-toxic, non-allergic and non-carcinogenic material and for that reason it is frequently used for orthopedic and dental implants. Unfortunately it is chemically inert in the human body and cannot form the biological bond with the bone tissues. To overcome the problem we applied biocompatible vitreous carbon coating. We studied the influence of the addition of CaTiO_3 on XRD data and on the physico-mechanical properties of the Al_2O_3 ceramics, which will be used as substrate for the biocompatible polymer matrix material. The obtained results show that the chemical composition and the technological parameters favor the formation of sufficiently strong ceramic composite material.

Keywords: ceramics, vitreous carbon, coating

INTRODUCTION

Ceramics are defined as the art and science of making and using solid articles which have as essential component inorganic non-metallic materials and are composed largely of them [1]. The inherent brittleness of the traditional ceramics has limited their ability to compete with ductile metals and polymers for technical applications. However in recent years innovative techniques in the fabrication of ceramics have led to their use as high-tech materials [2, 3].

The Al_2O_3 ceramics are chemically inert in the human body, unlike surface reactive (bioglass) or resorbable (tricalcium phosphate) materials. On the other hand, carbon in its different varieties displays excellent biocompatibility. A composite material comprising Al_2O_3 ceramic as a substrate material and vitreous carbon coating will unite the advantages of both materials.

RESULTS AND DISCUSSION

The alumina ceramic have a fine grain polycrystalline structure consisting mainly of $\alpha\text{-Al}_2\text{O}_3$ (corundum). The microstructure is essential for the mechanical properties of the ceramic components. Increase in the grain size decreases the strength of the material. Sintering aids are used to improve sintering and to control grain size. The possibilities to use CaTiO_3 as sintering aid are investigated.

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CaTiO_3 is added to Al_2O_3 micron powder in quantity 3, 6 and 9 wt.%. Samples are fabricated by pressing and sintering at different temperatures. The obtained phases are determined by Roentgen diffraction analysis. Samples with 3 and 6 wt.% calcium titanate have $\alpha\text{-Al}_2\text{O}_3$ (corundum) as primary phase, CaTiO_3 (perovskite) as secondary phase and most unexpectedly $\beta\text{-Al}_2\text{O}_3 - \text{CaO}\cdot 6\text{Al}_2\text{O}_3$ (hibonite) in quantity comparable to the quantity of perovskite in both samples (Fig.1). The difference between the two is in the quantity of the secondary phases – perovskite and hibonite. These two phases are approximately two times more in sample with 6% CaTiO_3 compared to the sample with 3% CaTiO_3 .

There is a considerable difference in the XRD powder patterns of sample 3 compared to the two previous samples. The $\alpha\text{-Al}_2\text{O}_3$ (corundum) is still the predominant phase but CaTiO_3 (perovskite) and $\text{CaO}\cdot 6\text{Al}_2\text{O}_3$ (hibonite) have increased their quantity several times.

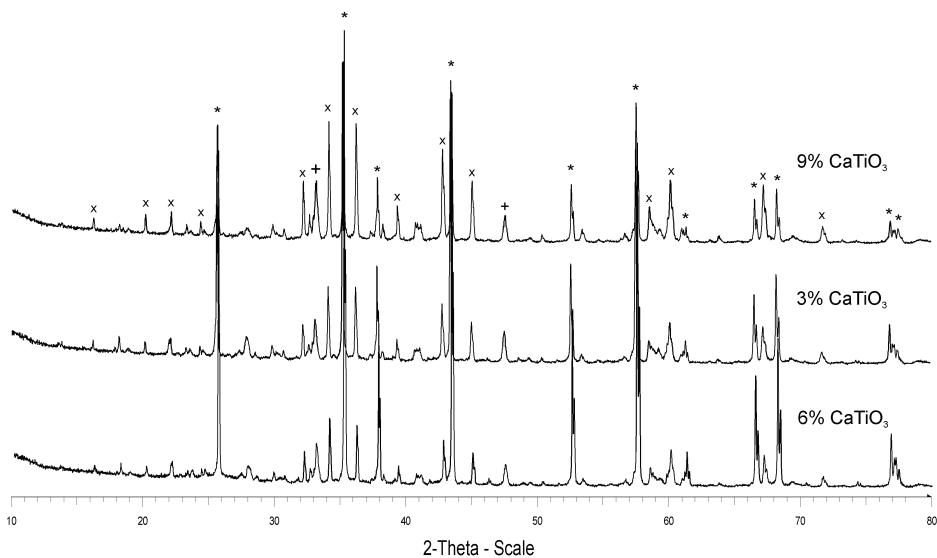


Fig.1. XRD powder patterns of samples with 3, 6 and 9 wt.% CaTiO_3 addition and sintering temperature 1580°C . Symbols representing different phases are as follows: (*) $\alpha\text{-Al}_2\text{O}_3$ – Corundum, (x) $\text{CaO}\cdot 6\text{Al}_2\text{O}_3$ – Hibonite, (+) CaTiO_3 – Perovskite.

An increase in the sintering temperature from 1580 to 1680°C increases the quantity of the hibonite - $\text{CaO}\cdot 6\text{Al}_2\text{O}_3$ and respectively the CaTiO_3 content is decreased (Fig.2).

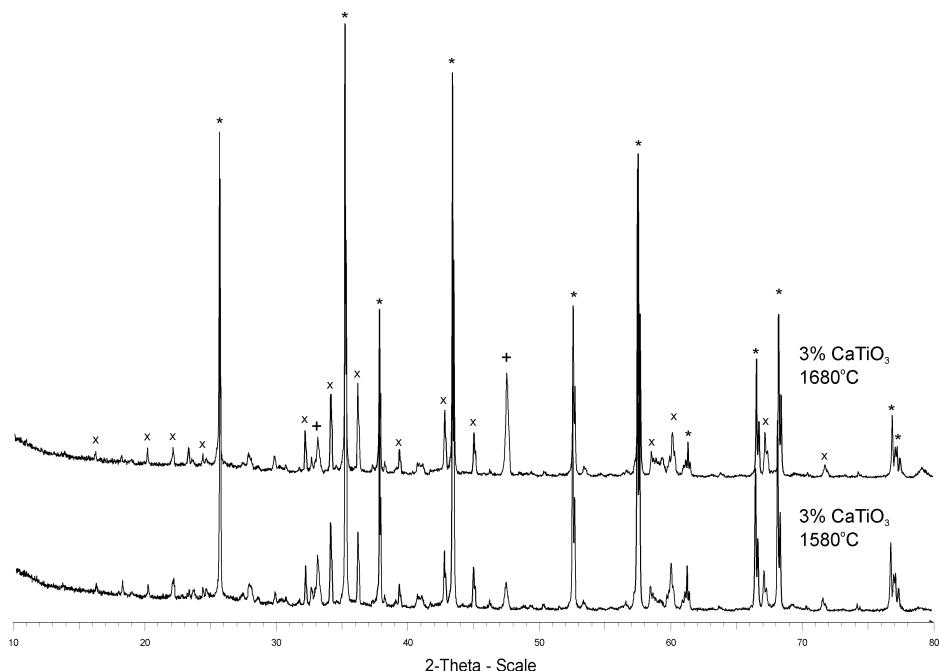


Fig.2. XRD powder patterns of samples with 3 wt.% CaTiO_3 addition and sintering temperatures 1580°C and 1680°C . Symbols representing different phases are as follows: (*) Al_2O_3 – Corundum, (x) $\text{CaO}(\text{Al}_2\text{O}_3)_6$ – Hibonite, (+) CaTiO_3 – Perovskite.

The mechanical properties versus sintering temperature and the quantity of the sintering aid are studied. The compressive strength was determined as in [4]. The average values of the compressive strength depending on the CaTiO_3 content and the temperature of the heat treatment are given in Table 1.

Tab.1. Compressive strength of samples in relation with CaTiO_3 content.

Sample	CaTiO_3 content [wt.%]	Temperature [°C]	Compressive strength [MPa]
1	3	1580	174.3
2	6	1580	118.6
3	9	1580	48.3
4	3	1680	132.0
5	6	1680	99.3

An increase of the CaTiO_3 content is detrimental for the mechanical characteristics of the composite material on Al_2O_3 basis (Fig.3).

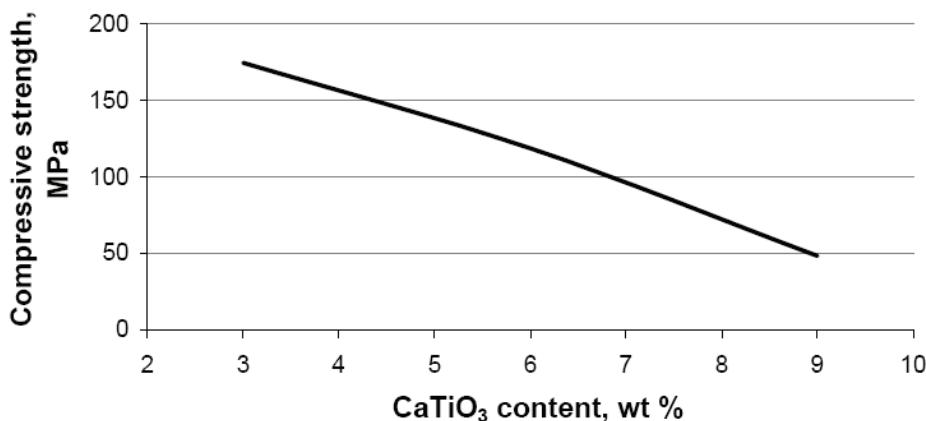


Fig.3. The compressive strength in relation to CaTiO₃ content.

Part of the calcium titanate reacts with the alumina and is converted into CaO·6Al₂O₃ – β-alumina. According to Buchvarov [5] the presence of β-alumina is not favourable for the mechanical characteristics of ceramic on Al₂O₃ basis.

The same phenomenon is observed with an increase of the sintering temperature (Table 1). The higher the temperature, more β-alumina is generated and the compressive strength is going down.

CONCLUSIONS

Calcium titanate can be used as sintering aid for ceramic on Al₂O₃ basis.

During the temperature treatment part of the CaTiO₃ reacts with the alumina and is converted into CaO·6Al₂O₃ – β-alumina. The presence of β-alumina is not favourable for the mechanical characteristics of ceramic on Al₂O₃ basis.

The content of CaTiO₃ must not exceed 3 wt.% in alumina based ceramic.

The sintering temperature of ceramic on Al₂O₃ basis containing CaTiO₃ should not be higher than 1600°C.

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