

Microcasting of Ti-Alloy Using Phosphate Bonded Investment Moulds for Dental Applications

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Abstract: In this paper, microcasting has been addressed as a metal forming process based on the of investment casting. The investigation carried on characterization of Ti- 6Al-7Nb alloy cast by vacuum pressure casting process in phosphate bonded investment moulds. The thermal behavior of phosphate bonded investment moulds was described. Macrostructure and micro-hardness of cast microparts are also presented.

Keywords: Ti-6Al-7Nb alloy, phosphate bonded investment moulds, vacuum pressure casting.

1. INTRODUCTION

Microcasting is a metal forming process based on the well-known investment casting. The construction of high quality crown and bridge restorations depends on the various materials involved in the dental casting process. The working temperature of the investment powder and liquid are critical factors in determining the setting time, expansion, surface roughness and consequently the final fit of the castings [1]. An increase in temperature of slurry and/or powder decreases the working time and accelerates setting. The correct positioning of the wax/resin patterns is important in order to ensure sufficient thickness of investment material around the objects to withstand the casting forces and provide sufficient expansion. It is always advisable to cover the pattern resin with a layer of wax to allow for its expansion during the burnout process. A surface tension reducing agent is designed to allow the investment to flow uniformly and smoothly over all areas of the pattern helping to eliminate casting bubbles. All of the phosphate bonded investment materials. For the crown and bridgework technique, the powder/ binder ratio is of 100 g to 22 ml. Insufficient mixing produces result rougher casting surfaces.

Titanium has been used for dental prosthesis frameworks because of its excellent biocompatibility, high corrosion resistance, low density, adequate mechanical properties and low cost. Silica-based phosphate-bonded investments exhibit a thermal expansion compatible with titanium casting shrinkage, but the silica is highly reactive at high temperatures [2-3]. Other thermally more stable refractory oxide materials (calcium oxide, magnesium oxide and aluminum oxide) have been developed, but they have shown thermal expansion unable to compensate for the casting shrinkage of molten titanium. The porosity of phosphate bonded investment (PBI) is also an important factor to be studied to ensure that gas porosity defect in casting can be minimized.

The purpose of this investigation was characterization of Ti- 6Al-7Nb alloy cast by vacuum pressure casting process in phosphate bonded investment moulds.

2. MATERIALS METHODS

Phosphate bonded investments were initially used for dental alloys with a high melting temperature at casting temperatures between 1200^o and 1500^o C. They consist of magnesium oxide and ammonium hydrogen-phosphate as binder and the two different SiO₂ modifications quartz and cristobalite as filler. The powdery binder and filler components are mixed with a liquid which mainly consists of aqueous silica sol (Table 1). In contrast to the wax patterns used in investment casting process, microcasting process mostly works with injection molded plastic patterns which have much higher mechanical strength. The improved mechanical properties permit easier handling and assembling of the pattern during the manufacturing process. The shaping of the microcavities in the mold insert, used for injection molding, can be achieved by several methods. In the present work, microelectro discharge machining was employed to get microcavities.

The microcasting process requires a lost plastic pattern to be mounted on a gate and feeding system made of wax. The pattern assembly was completely embedded in ceramic slurry. This process differs from the technical investment casting process where normally an investment shell mould was built-up by repeatedly dipping the pattern in ceramic slurry followed by stuccoing [4-28]. After drying, the ceramic was sintered, resulting in an investment shell mold with high mechanical strength. Simultaneously, the plastic melt during the burning process and was pyrolyzed.

The liquid metal was poured into investment mould under vacuum pressure. The investment mold is evacuated, then the melt is poured into the mold, filling the cavity only due to gravitational forces. After that, pressure is applied to the melt. For cost-effective microcasting, the assembly of single patterns is built up into tree-form as shown in figure 1. In microcasting, single polymer patterns are normally fixed with wax. Patterns for microcasting should be constructed according to the well-known design rules for casting. In order to produce faultless patterns, different wall thicknesses and sharp edges should be avoided. The cross-sectional thickness of the sprue system should increase in the direction of the sprue bottom, because solidification must begin in the microparts and end in the bottom of the tree.

Table 1: Investment slurry preparation.

Temperature powder and liquid	25°C
Mixing ratio	100g: 22 ml
Stirring time under vacuum	60 sec
Steering speed	360 rpm
Processing time	6 min.

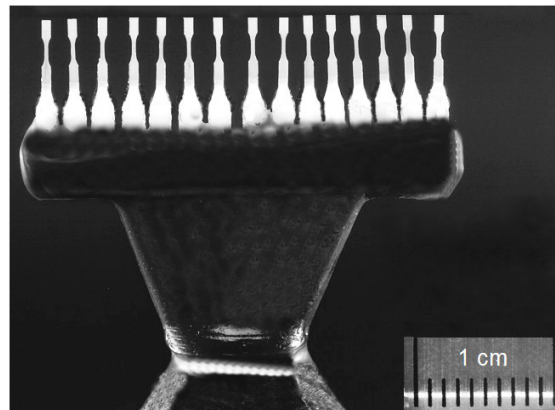


Figure 1: Pattern assembly.

Owing to the much higher surface to volume ratio in microchannels compared with macrostructures and the distinct influence of surface roughness, the occurrence of turbulent flow needs to be taken into account. Another aspect is the extremely high cooling rate and therefore extremely fast solidification in the small structures, which hinders form filling much more than in macrostructures. For vacuum pressure casting of microparts, dental casting machines are used. Figure 2 shows a scheme of the process. The Ti-alloy was melted in the crucible. On top of the crucible the open mold is fixed upside down. After evacuation, the machine turns itself upside down. As a result, the melt flows into the mold by gravity. Complete form filling even of small cavities is achieved by subsequent application of pressure to the melt.

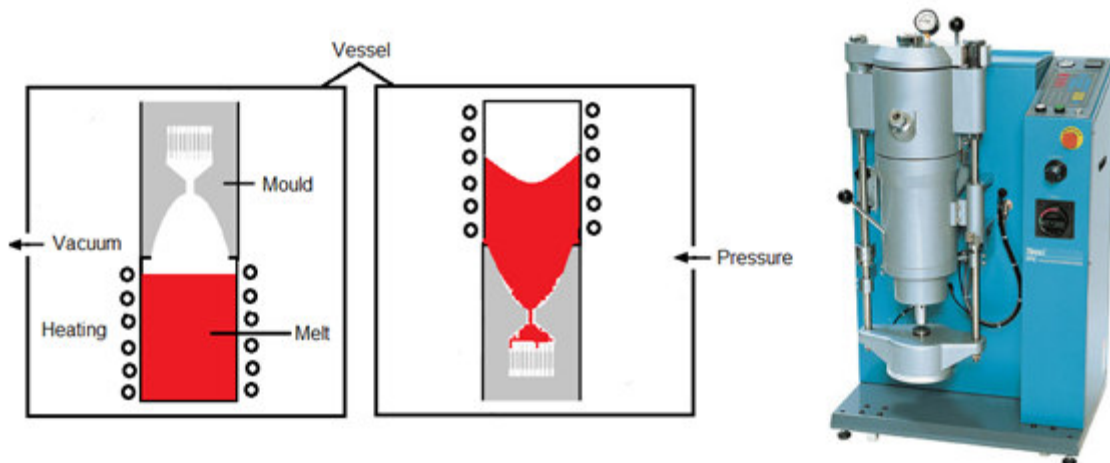
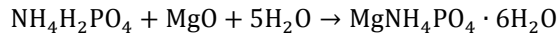


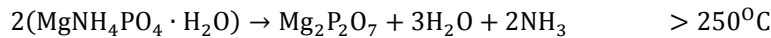
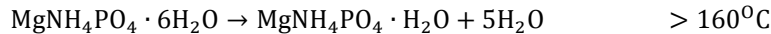
Figure 2: Vacuum pressure casting process.

3. RESULTS AND DISCUSSION

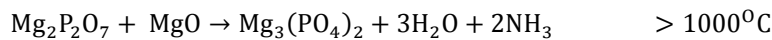
The investment material consist of magnesium oxide and ammonium hydrogenphosphate as binder and the two different SiO₂ modifications quartz and cristobalite as filler. The powdery binder and filler components are mixed with a liquid which mainly consists of aqueous silica sol. The water content in the liquid is necessary to facilitate a chemical reaction



In the burning process, ammonium phosphate is converted into magnesium pyrophosphate, releasing water and ammonia.



Above 1000°C the investment decomposes by continuous reaction of excrescent magnesium oxide with the phosphate of the binder and the silicate of the filler.



The thermal and chemical expansion of the binder is controlled by the silica sol concentration of the liquid and generally increases with increasing concentration of the liquid as shown in figure 3. Ti- 6Al-7Nb alloy was cast by vacuum pressure casting process. The microstructure shows hexagonal α phase and white regular body-centered β phase irregular shape platelets forming variously oriented colonies (figure 4). Variations in microvickers hardness with depth from the surfaces of castings are demonstrated in figure 5. As can be seen from the graph the hardened layer thickness appears to be roughly 100–150 mm. In addition, the bulk microvickers hardness of Ti is much lower. The hardened layer, that is almost unavoidable in investment-cast Ti and Ti-alloys, forms through the decomposition of the investment oxides and diffusion of the resulting elements into the casting.

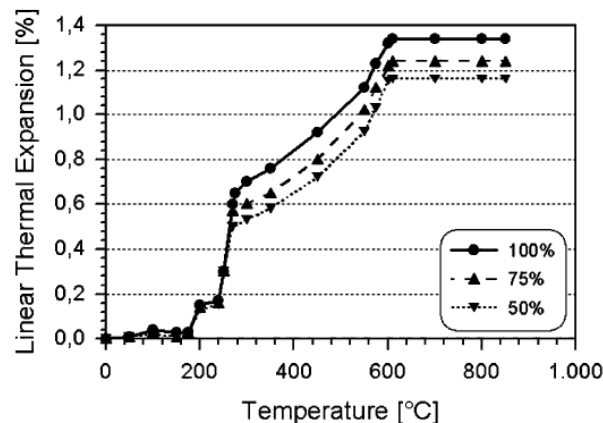


Figure 3: Thermal expansion of phosphate bonded investment.

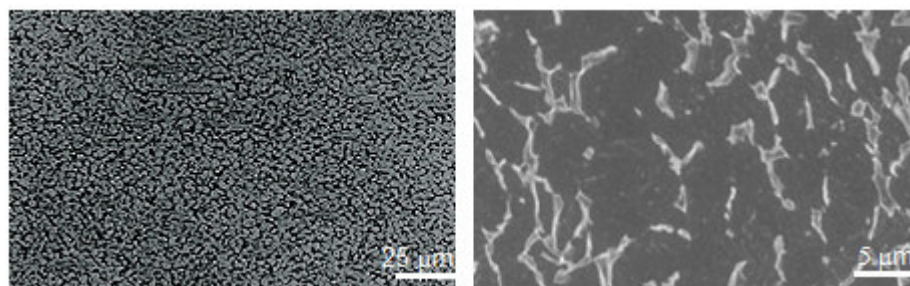


Figure 5: Microstructure of Ti-6Al- 7Nb alloy.

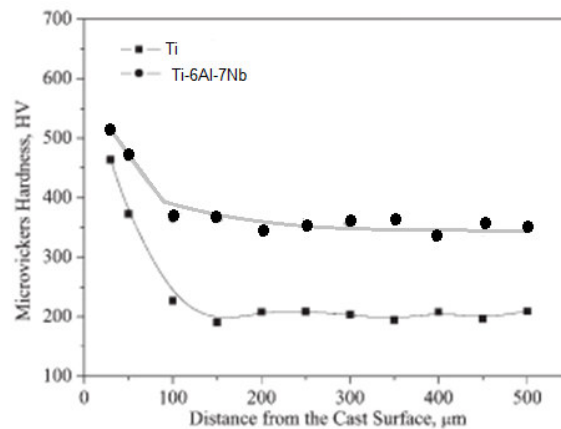


Figure 5: Cross-sectional microvickers hardness of Ti-6Al-7Nb alloy.

Ti-6Al-7Nb alloy has a high biocompatibility. The oxides from Ti-6Al-7Nb is saturated in the body and are not transported in vivo or are a bio burden. The alloy will not create adverse tissue tolerance reactions and creates fewer giant cell nuclei. Ti-6Al-7Nb also shows a high compatibility to be ingrowth to the human body.

4. CONCLUSIONS

This paper proves that the microcasting is an ideal fabrication method for metal parts in microdimensions. Investment casting is a suitable technique for the manufacture of metallic microparts. The thermal and chemical expansion of the binder is controlled by the silica sol concentration of the liquid. The hardened layer thickness appears to be roughly 100–150 mm for Ti-6Al-7Nb alloy. Ti-6Al-7Nb alloy has a high biocompatibility.

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