Trans Indian Inst Met (2014) 67(3):407–410
DOI 10.1007/s12666-013-0371-6

TECHNICAL PAPER

TP 2771

Production of Co–Cr–Ti Composite and Investigation of Mechanical Properties

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Received: 15 June 2013 / Accepted: 4 October 2013 / Published online: 11 January 2014

Abstract Intermetallic materials such as Co_2Ti, Cr_2Ti are among advanced technology materials that have outstanding mechanical and physical properties for high temperature applications. Especially creep resistance, low density and high hardness properties stand out in such intermetallics. The microstructure, mechanical properties of %64Co–%32Cr and %4Ti powders were investigated using specimens produced by tube furnace sintering at 800–1200 °C temperature. A composite consisting of ternary additions, a metallic phase, Ti, Cr and Co have been prepared under Ar shroud and then sintered in tube furnace. XRD, scanning electron microscope, were used to characterize the properties of the specimens. Experimental results carried out for composition %64Co–%32Cr–%4Ti at 1200 °C suggest that the best properties as 182.09 HV and 5,584 g/cm^3 density were obtained at 1200 °C.

Keywords Sintering · İntermetallic · High temperature · Composite

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1 Introduction

In the past 20 years, the number of dental implant procedures has increased steadily worldwide, reaching about one million dental implantations per year. The clinical success of oral implants is related to their early osseointegration [1, 2]. Geometry and surface topography are crucial for the short- and long-term success of dental implants. These parameters are associated with delicate surgical techniques, a prerequisite for a successful early clinical outcome. Cobalt–chromium base alloys can be generally described as non-magnetic, wear, corrosion and heat resistant. Among them, Co–Cr alloys, stainless steel, and Ti-based alloys are most widely used for hard tissue replacements, such as total hip replacements, total knee replacements or dental implants [3]. Many properties of the alloys originate from the crystallographic nature of cobalt, the solid solution strengthening effect of chromium and alloying elements, the formation of extremely hard carbides and the corrosion resistance imparted by chromium [4–6]. The defects of dental cast alloys include mainly shrinkage porosity, inclusion, micro-crack and dendritic structure. Only few reported works were available on the influence of casting procedures on the corrosion resistance of dental alloys [7–10]. Few studies on coupling cobalt with different alloys have been undertaken. These studies concluded that when Co was coupled with a low corrosion resistance alloy, this alloy might be subject to galvanic corrosion. When Co was coupled with high corrosion-resistant alloys, a stable and passive combination was produced. Therefore, it was suggested that it is beter to avoid Co contact with metal that has low passivity [11–14].

The purpose of this article is to present the results of an experimental study of the effect of titanium addition on the microstructure and some properties of Co–Cr alloys.

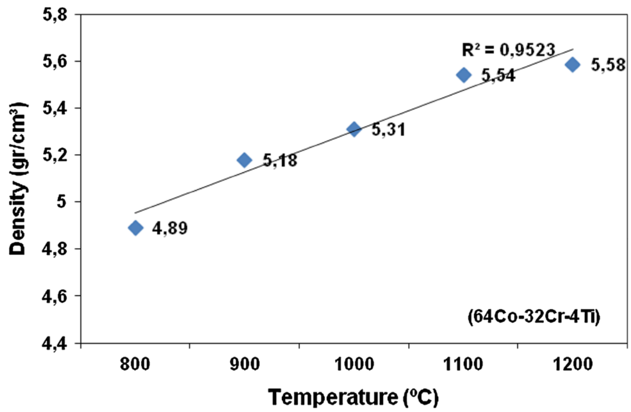


Fig. 1 The density change with respect to sintering temperature

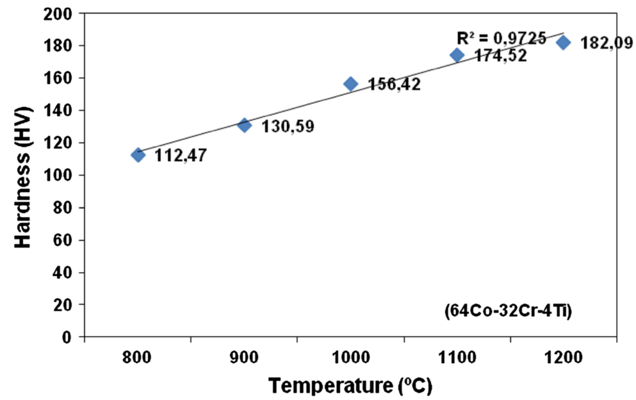


Fig. 2 The micro hardness tests results from sintered specimens treated at different temperatures

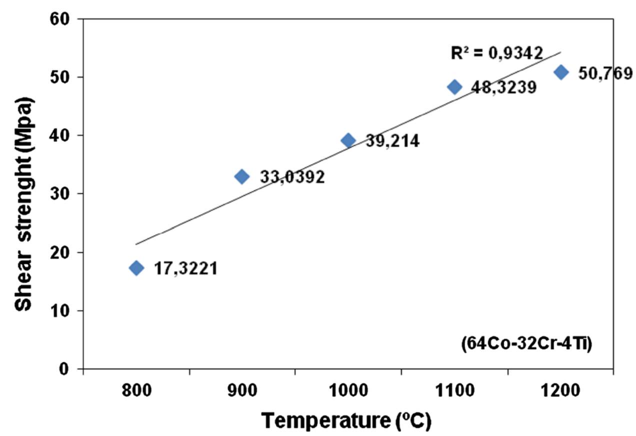


Fig. 3 Shear strength results from specimens sintered at different temperatures

Hardness and corrosion behaviour of the as-cast Co–Cr–Ti alloys would be evaluated with a hope of developing an alloy suitable for biomedical application.

2 Material-Method and Preparation of Sample

Starting powders employed in this study were as follows: the purity of 99.8 % for Ti powders with a particle size lower than 40 µm, the purity of 99.95 % for Cr powders a particle size lower than 75 µm and the purity of 99.9 % for Co powders with a particle size lower than 150 µm. The composition of %64Co–%32Cr–%4Ti specimens was prepared in 10 g rectangular compressed pre-form. They were mixed homogenously for 24 h in a mixer following the weighing. The mixture was shaped by single axis cold hydraulic pressing using high strength steel die. A pressure of 300 bar was used for compacting all the powder mixtures. The cold pressed samples underwent sintering at 800, 900, 1000, 1100 and 1200 °C for 2 h in a traditional tube furnace using Argon gas atmosphere. The specimens were cooled in the furnace after sintering and their micro hardness and shear strengths measurements were carried out using METTEST-HT (Vickers) micro hardness tester and Shimadzu Autograph AG-IS 100KN universal tensile testing machine, respectively.

Shimadzu XRD-6000 X-ray diffraction analyzer was operated with Cu K alpha radiation at the scanning rate of 2° per minute. LEO 1430 VP model scanning electron microscope fitted with Oxford EDX analyzer was used for microstructural and EDX compositional analysis.

The volumetric changes of %64Co–%32Cr–%4Ti composite material after sintering were calculated by using ($d = m/V$) formula (Fig. 1). The volume of post-sintered samples was measured with Archimedes principle. All the percentages and ratios are given in weight percent unless stated otherwise.

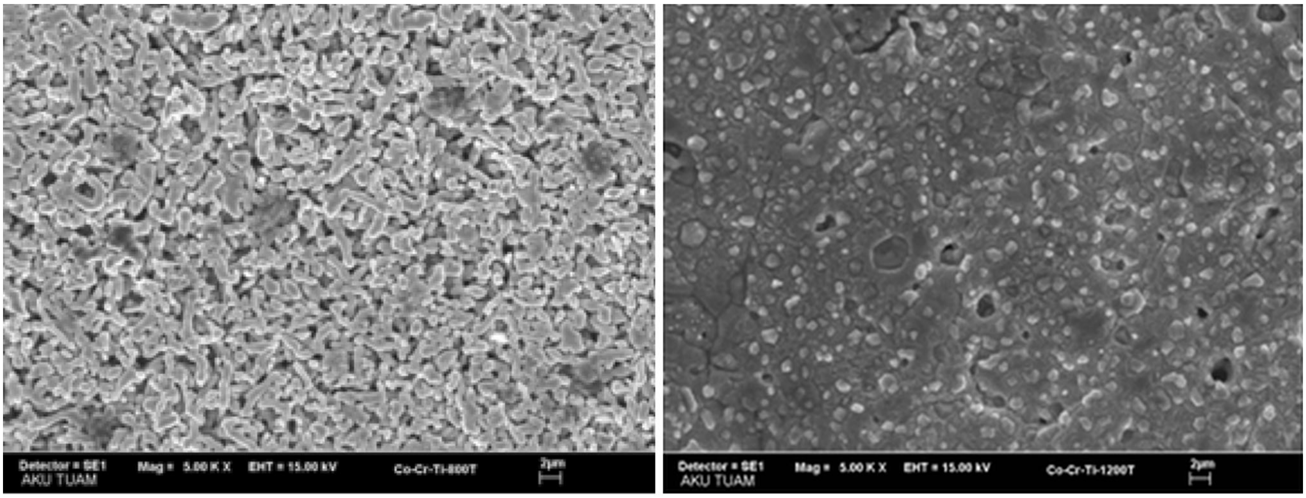
3 Experimental Results and Discussion

3.1 Characterization of Specimens

In the study, the samples prepared and shaped were sintered at temperatures ranging from 800 to 1200 °C in conventional furnace and made ready for physical, mechanical and metallographic analyses. Density-temperature change curve is shown in Fig. 1. The highest sintered density was achieved at 1200 °C as 5,58 g/cm^3.

The micro hardness-temperature change diagram is shown in Fig. 2. The micro hardness values of the composite samples were produced using conventional sintering technique within the temperature range 800–1200 °C. According to this, the highest micro hardness value in the composite samples produced using powder metallurgy method was observed to be 182.09 HV at 1200 °C.

Shear strength and hardness of the metal-matrix composite specimens were also determined. The relation between the sintering temperatures and shear strength values is shown in Fig. 3. The shear strength value in the



(a) 800°C **(b)** 1200°C

Fig. 4 SEM view of Co–Cr–Ti composite

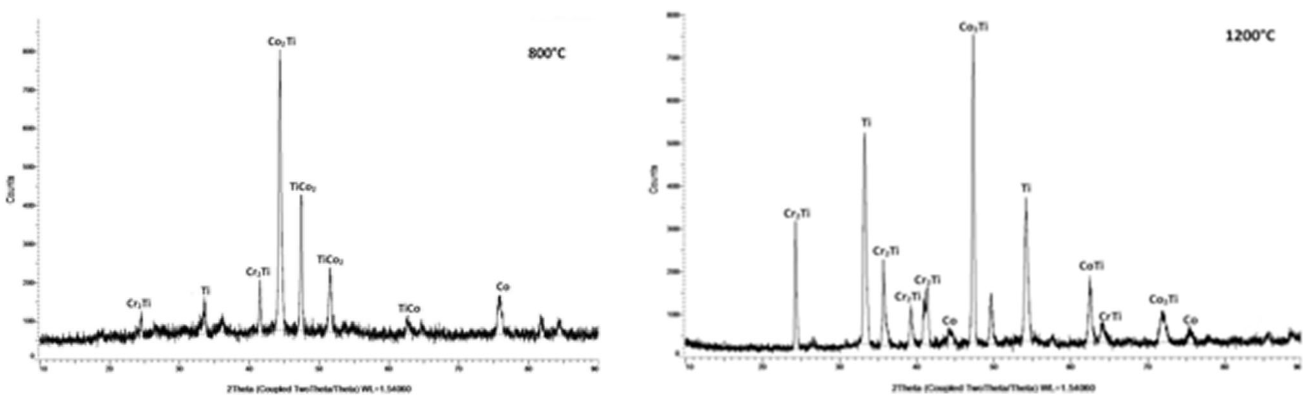


Fig. 5 The XRD analysis Co–Cr–Ti composite Sintered in tube furnace at 1200 °C

composite samples was observed to be 50.769 MPa at 1200 °C.

3.2 Metallographic Analysis

The SEM analysis result of the metal matrix composite specimen obtained from Co–Cr–Ti powders sintered at 800 °C is shown in Fig. 4a, grain growth is observed and a homogeneous structure. In Fig. 4b, at 1200 °C grain boundaries can be seen and the pores smaller and circular in shape. Sintering is better understood at this temperature. This density, hardness and shear strength values are confirmed.

3.3 XRD Analysis

In Fig. 5, CoTi, Cr_2Ti, Co_2Ti, Co, and Ti peaks can be seen in the XRD analysis from Co–Cr–Ti composite sintered in tube furnace at 1200 °C.

Co–Cr–Ti powders were mixed and then sintered in a conventional furnace. After sintering, a considerable drop in the mechanical properties of specimens sintered at 800 and 1200 °C were observed. It was concluded that Co–Cr–Ti particles were formed by CoTi, Cr_2Ti, and Co_2Ti intermetallic phases when sintered at 1200 °C and hardness test results suggest that Co–Cr–Ti composite sintered at 1200 °C shows Vickers micro hardness values respectively.

4 Conclusion

The following results were concluded from the experimental findings.

- The highest density in composite made from Co–Cr–Ti powders sintered at different temperatures was obtained as 1200 °C The highest density sample was found as 5, 58 g/cm^3 at 1200 °C.

- The highest microhardness in Co–Cr–Ti composite samples fabricated using powder metallurgy method was found as 182.09 HV at 1200 °C.
- The highest Shear strength sample was obtained as 50,769 MPa at 1200 °C.
- A composition %64Co–%32Cr–%4Ti at 1200 °C suggest that the best properties.

Acknowledgments This study was supported by the Afyon Kocatepe University (BAPK) project No. 13.MYO.02. We would like to thank the Scientific Research Coordination Unit.

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