Cobalt-Chromium -HAP Composite

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Introduction

The success of orthopedic biomaterials is perhaps best exemplified by its market size, dwarfing biomaterial-catergory sales at $14billion (2002), and is expected to grow at rate of 7% to 9% annually. Global sale of fracture management products totaled $15 billion (2000), of which $12 billon was spent on joint replacements. Knee implant products valued at $2.5 billion (2002), represent approximately 700,000 knee replacement surgeries, which include first-time joint replacement procedures and revision procedures for replacement, repair, or enhancement of an implant product or component from a previous procedure. Revision procedures are growing at an accelerated rate of approximately 60% in the United State. The clinical success of total joint replacement procedures for knees and hips has spurred demands for total joint replacement of other joints, such as shoulders and elbows.

The medical and dental industry has used various materials, known as biomaterials, purposefully to replace or repair a body feature, tissue, organ or function. The performance of biomaterials in direct contact with living tissue is controlled by biofunctionality and biocompatibility. Metals and alloys are major constituents of biomaterials, where biocompatibility issues of corrosion resistance and influence of corrosion products on the surrounding tissue are paramount to their consideration. Corrosion resistance of commonly used materials such as austenitic stainless steels, cobalt–chromium, titanium and its implant alloys, is due to a thin surface layer of oxide.

Various in-vitro and in-vivo tests have shown that the alloys are biocompatible and suitable for use as surgical implants. The most biocompatible and widely used metallic implant is titanium alloy due to its lightweight, bio-corrosion resistance and mechanical properties. However, the release of A1 and 4V ions from the alloy might induce some longterm health problems. Furthermore, the low wear resistance of titanium alloys could accelerate the release of such harmful ions.

Fabrication of implant alloys has been established by casting. However, the melting temperature of implant alloys is very high, especially for cobalt, molybdenum and titanium alloys. Besides, the casting also produced dendritic structures that weakened the strength of the implant. Therefore, an alternative route is needed to avoid the high cost of melting and casting, as well as to improve the strength of the implant. Powder metallurgy is a promising alternative and an investigation of cobalt composites is described and discussed.

Preparation of composites

Cobalt implant composite (CIC) is fabricated by powder metallurgy technique, where Cobalt, Chromium and Hydroxyapatite (HAP) powder are mixed in planetary ball mill at 600rpm for 30minutes. The composites consist of 5, 10, 15 and 20 weight percent of HAP, added to ensure the implant is compatible with bones. The raw materials are first blended then pressed or compacted before being sintered. Uni-axial compacting is achieved with a Universal Testing Machine (UTM) with 500MPa of pressure. Sintering is achieved with a Carbolite tube furnace with an argon gas flow of $6ft^3/h$ and a gas pressure of 1 bar. The heating rate for the sintering temperature was 20°C/min until it reaches 1000°C, where it is held for 120 minutes. The cool off rate is 20°C/min to return to room temperature.

Battery of Tests

A Gas Pycnometer is used to determine the density of the cobalt implant composites. Particle size is an important parameter and a particle size analyzer is used to analyze particle size distribution of the cobalt, chromium and HAP powders. A Vickers micro hardness tester helps determine hardness of samples. The force is set at 30N for a 5s dwell time. Compression test to determine the strength of the composite, when a material's behaviour under large and permanent (i.e; plastic) strains is desired, as in manufacturing applications, or when the material is brittle in tension, is executed on a 5x5x10 mm sample. This test force is compressive and the specimen contracts along the direction of the stress.

Results and Discussion

Particle Size

Particle size is an important parameter since the stability, chemical reactivity, flow ability and strength of composites are affected by the size and characteristics of the constituent particles. The technique follows a dry method where a laser differentiates the size of each particle. Cobat and Chromium powders show good monomodal distribution whilst HAP displays multimodal distribution. The mean particle sizes of the powders are 4, 180, 9 µm for Cobalt, Chromium and HAP powder respectively, as seen from Fig. 1.

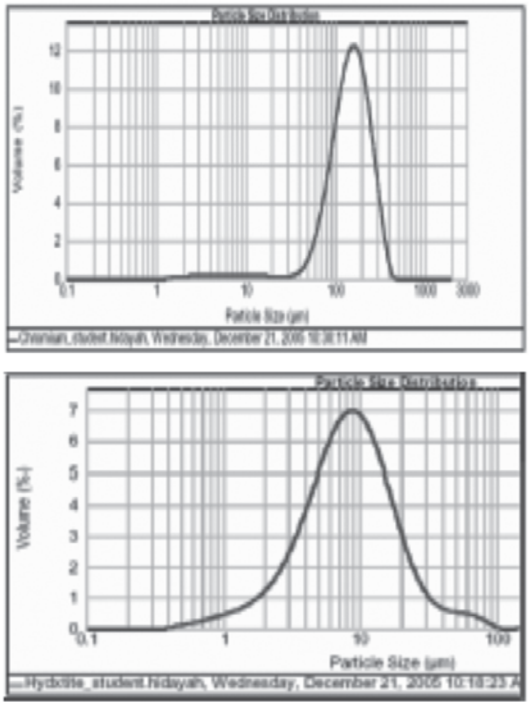
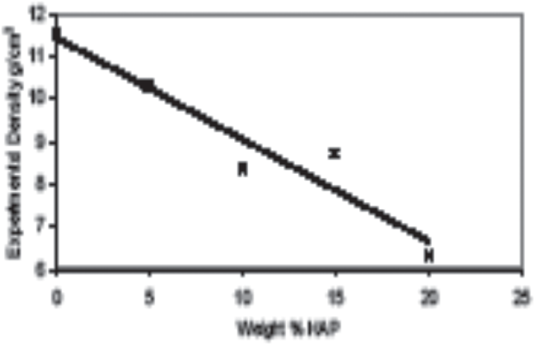


Fig. 1. : Particle size distribution for Cobalt, Chromium and HAP powders, respectively.

Density test

Fig. 2 shows the theoretical graph of correlation between density and weight percentage of HAP which is having a straight line and leisurely decreased. In general, both experiment and theory exhibit similar patterns, with a gradual decrease when HAP percentage increases. The difference between added HAP percentage for both densities is slightly different. This is due to the theoretical assumption that the filler and matrix are homogenously mixed prior to sintering. However, the experimental conditions might void the assumption.



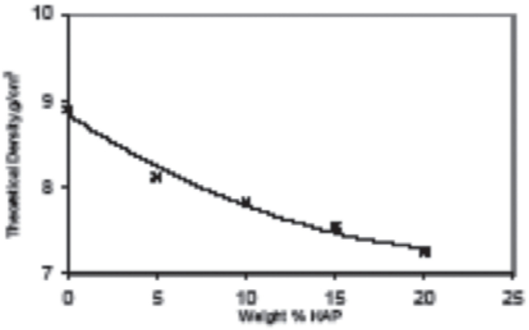


Fig. 2. : Experimental and theoretical density curves as a function of HAP wt-%.

Vickers Micro Hardness Test

The hardness test is conducted on composites with the different weight percentage of HAP, from 0 to 20 percent. Hardness decreases slightly with increasing weight percentage of HAP. This is due to the amount of hydroxyapatite powder added to the composite. Compared to zero percent HAP, all other percentage mixes show a reduced hardness. It is clear that the hardness of the composite is reduced when cobalt is replaced by HAP.

Compression Test

The compression test, investigating the behaviour of the composites under large and permanent deformation, is conducted to validate the results of calculation. The experimental data, plotted Fig. 3, identifying the relation between compressive strength and weight percentage of HAP, proves that compressive strength decreases slowly.

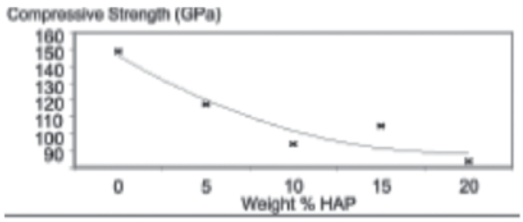


Fig. 3. : Relationship between weight percent of HAP and compressive strength of Cobalt composite.

Conclusion

Cobalt composite implants have been successfully fabricated via powder metallurgy. All powders show good monomodal distribution whilst HAP indicates a multimodal distribution. The mean particle sizes of the powders are 4, 180, 9 µm for Cobalt, Chromium and HAP powder, respectively. Experimental and theoretical density show similar patterns, with density gradually decreasing with increasing percentage of HAP. The hardness and compressive strength of the composites also decrease with increasing weight percent of HAP. Since HAP functions to make the implants more compatible with human bones, a HAP range between 0 to 5 percent is recommended for the composites.

Acknowledgements

The authors are grateful to Universiti Malaysia Perlis for the financial support under Short Term Research Grant.

This article is a modified version of the original which was published in International Journal of Material Science, Volume 3, Number 1 (2008), pp. 25–31.