CHAPTER 5

Conclusion and Suggestions

Synthetic HA bodies were synthesized by very low cost solid state sintering reaction with different Ca/P molar ratios, isothermal sintering and soaking times. The increase of Ca/P molar ratios and isothermal sintering had clearly much influence on, their density, porosity, and strength, HA phase content and their optimized condition which was the highest quantity of HA phase, so this study was succeeded follow by the objective of this thesis, while soaking times had not clearly trend for these condition.

For the sample with Ca/P ratio of 1.69 sintered at temperature from 1100 to 1300 °C for 2 hours. These conditions were the optimized condition which was the highest quantity of HA phase. The phase content of HA increased from 85.91 % to 91.44 %. This result was in agreement with the finding of Yang et al. [46] who indicated that the formation of β-TCP was faster than of HA, but HA is more thermodynamically stable than β-TCP. Besides, it was in good agreement with the finding of Guo et al. [17] who reported that thermal decomposition of synthetic HA processed between 1160 to 1300 °C led to HA dehydration into oxyHA and then oxyapatite transforms into β-TCP and CaO. The apparent density increased from 2.877 ± 0.054 to 3.141 ± 0.078 g/cm^3. The bulk density increased from 1.287 ± 0.033 to 2.375 ± 0.074 g/cm^3. The true density increased from 2.887 ± 0.004 to 3.145 ± 0.004 g/cm^3. An apparent porosity decreased from 55.27 ± 0.85 % to 24.37 ± 1.15 %. Hardness increased from 7.48 ± 2.10 to 39.80 ± 9.56 HV. The bending strength increased from 2.60 ± 0.59 to 13.60 ± 1.55 MPa. Therefore, Ca/P molar ratio of 1.69 had more effect on synthesis, the physical properties and strength than the other Ca/P molar ratios.

The optimized isothermal sintering at 1300 °C for 2 hours of the samples with Ca/P ratio of 1.69 was found to the maximum value of HA phase were 91.44 % and impurities phases were 5.18 % of β-TCP and 3.38 % of CaO. The samples with Ca/P ratio of 1.69 was close to theoretical value of HA at 91.44 %; an average value of

apparent density of these samples was 3.141 ± 0.078 g/cm^3, the bulk density was 2.375 ± 0.074 g/cm^3 and the true density was 3.145 ± 0.004 g/cm^3 and were found to be lower than theoretical value of 3.167 g/cm^3 of stoichiometric HA, but the bulk density was higher natural cortical bone density (1.8 - 2.0 g/cm^3) and natural cancellous bone density (0.1 - 1.0 g/cm^3). An average value of maximum hardness of these samples was 39.80 ± 9.56 HV and lower than theoretical value of 600 HV of stoichiometric HA, but its values closed to natural cortical bone (40.4 HV) and higher than natural cancellous bone (35.2 HV). An average value of the bending strength of these samples was 13.60 ± 1.55 MPa and lower than theoretical values of 115 - 200 MPa of stoichiometric HA, but its values in ranged of natural cancellous bone (10 - 20 MPa), while its values not in range of natural cortical bone (50 - 150 MPa).

The sample with Ca/P ratio of 1.69 was nontoxic to and biocompatible with soft tissues. The samples with Ca/P ratio of 1.69 had the inflammatory cells lower than the samples with ratio of 1.65, were more stable than the samples with ratio of 1.65 at the same temperature and time, and had a potential for using as bone graft. However, the samples with Ca/P molar ratio of 1.69 had pore sizes lower than theoretical size of 100 - 500 μm and low percentage of apparent porosity.

In order to improve the solid state reaction for synthesize HA consist of;

1. The production of submicron to nanometer mixture powders by reducing the size of larger particles by mechanical forces. The mechanical method is involved milling powder at high speed of equipment.

2. Pressure sintering is important factor in the sintering behavior for synthesize HA. Densification of green body is usually by compaction. Uniaxial pressing is the most normal method of success forming by increase pressure for higher compaction and decrease porosity.

3. To improve the crystallinity of mixture powders via calcinations process.

4. Firing of compact powders can be use for production of synthetic HA obtain from controlling stage of heating schedule at annealing stage before to cool down of samples for precipitation of second phases.