CHAPTER V

CONCLUSIONS

From the results and discussion in the previous chapters it can be concluded that the effect of additives (SiO_2 and glass frit) on mechanical properties and bioactivity properties of porous HA is as follows:

The effects of SiO_2 and glass frit additive on the mechanical properties of HA ceramics fabricated by uniaxial pressing and polymeric sponge method were investigated. The presence of additives altered the phase transformation to β or α- TCP and the ceramics became biphasic consisting of HA and TCP at high sintering temperature and additive content. Sintering studies showed that these additives could improve the density and mechanical properties of HA. In the case of HA with SiO_2 additive, the compressive strength of HA increased with increasing SiO_2 content to 0.5wt% and after that they decreased with increasing SiO_2 content. It followed a trend to increase with increasing silica content to 5.0wt%. At 10wt%SiO_2, compressive strength drastically decreased due to appearance of cracks on the surface of HA and increasing amounts of pores. In the case of HA with varied amount of glass frit additive, the compressive strength of HA increased with increasing the glass frit content due to the grain size of HA decreasing below that of HA alone. The maximum average microhardness and compressive strength obtained was 520 HV and 68 MPa, respectively, for HA samples having 20.0 wt% glass frit additive sintered at 1300 $^{\circ}$C for 4 h. Thus, we have improved the mechanical properties of HA by addition of a glass frit.

The influence of SiO_2 and glass frit additive on the bioactivity of HA ceramics was observed. HA with additions, SiO_2 or the glass, (lower than 5.0wt%) demonstrated good *in vitro* bioactivity since it could rapidly induce the formation of precipitation of new Ca-P layers on HA surface after immersion in SBF, even for a short soaking time (less than 1 day), resulting in the high degree of bioactivity of the sample. HA samples added with a higher additive content, > 10wt%, were more resistant to corrosion due to the high mechanical strength and slow formation of new Ca-P on the surface. These results were the fundamental to the following study, the fabrication of porous HA by the polymeric sponge method.

Porous HA could be produced by coating the 700 μm pore size polyurethane foams with HA slurry, followed by sintering at 1200 to 1400 °C. Porous HA, after sintering at 1300 °C for 4 h showed excellent densification, strong enough for sample handling such as cutting and grinding, which were required for shaping. Additionally, porous HA sample with the glass higher than 20wt% melted at 1400 °C. At sintering temperatures lower than 1200 °C, porous HA samples did not completely sinter and were weak and did not handle well. Therefore, a sintering temperature at 1300 °C is suitable for porous HA processing. Porous HA sintered at 1300 °C had low compressive strengths of ~1.15 MPa due to high porosity. Porous HA with varied amount of glass additive from 0.5 to 20.0wt% gave more dense and slightly decreased porosity. The porosity slightly decreased from 85 to 78%, when the additive increased from 0.5 to 20.0 wt% and the compressive strength varied between 0.67 to 11 MPa.

It is suggested that porous HA samples with glass frit additive may be used as bone replacement materials in medical applications due to the higher density of HA with glass frit additive which leads to high mechanical strength that does not require the repeated coating. The biphasic calcium phosphates (BCP), consisting of mixtures of HA/β-TCP or β-TCP/ α-TCP are commonly used as bone substitutes. Biphasic material gave an efficient bone substitute that can degrade by dissolution and therefore replaced by natural bones. Additionally it remained highly porous, with interconnected pores, and having a suitable pore size, 100-420 μm, sufficient for bone ingrown, leading to the enhanced compressive strength of porous implants. Moreover, the polymeric sponge method is a suitable technique for fabricating porous HA in a commercial manufacturing organization because of its simplicity and low cost.