Supplementary Information

Self-propagating Intermediate-temperature Synthesis (SIS) Method

Self-propagating Intermediate-temperature Synthesis (SIS) is a selected temperature range of the well-known Self-propagating High-temperature Synthesis (SHS) with lower temperature synthesis. Generally, the SHS combustion reaction requires high temperatures, usually above 1000 °C. Aluminum which is used in this work has an intermediate melting temperature (below 1000 °C), thus it cannot be processed by using SHS. Hence the SIS is required. However, since SIS is operated at lower temperature, it needs a support constraint to facilitate the combustion reaction well. In this case, the heat pressure is used. The exothermic reaction has also been established by the ANSYS simulation results that in the SIS there is an exothermic reaction. It can encourage the diffusion between the HAp matrix and Al reinforcement, with Mg as wetting agent.

In this study, the composite is made by using hydroxyapatite, aluminum and magnesium. The exothermic reaction in the SIS method will produce a phase product in the form of spinel ($MgAl_2O_4$) in the composite according to following reactions:

$$2Al + 3/2\ O_2(g) \rightarrow Al_2O_3 \quad (1)$$

$$Mg + 1/2\ O_2(g) \rightarrow MgO \quad (2)$$

$$Al_2O_3 + MgO \rightarrow MgAl_2O_4 \quad (3)$$

Figure S1 shows the particle size distribution of the synthesized HAp powders and commercial Mg powder, obtained after sieving using sieve with the mesh size from 100, 170, 250, 325, 450, to 650. The majority of the particle size is at the range of 90 – 150 microns for HAp powder, and > 150 μm for the Mg powder.

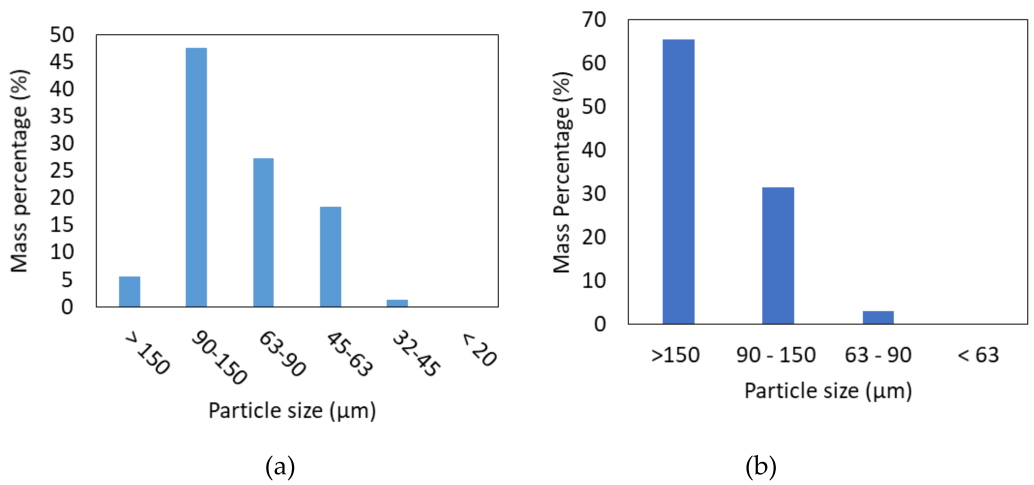

Figure S1. Particle size distribution of (a) the synthesized HAp, and (b) Mg powder.

In this study the distribution of temperature and heat flux is also analysed. The lower the heat flux value produces lower porosity. This due to the lower the heat flux, the better the heat distribution. And the better the heat distribution, the lower the porosity level of the SHS product. The distribution of process temperature and heat flux is presented in Figure S2.

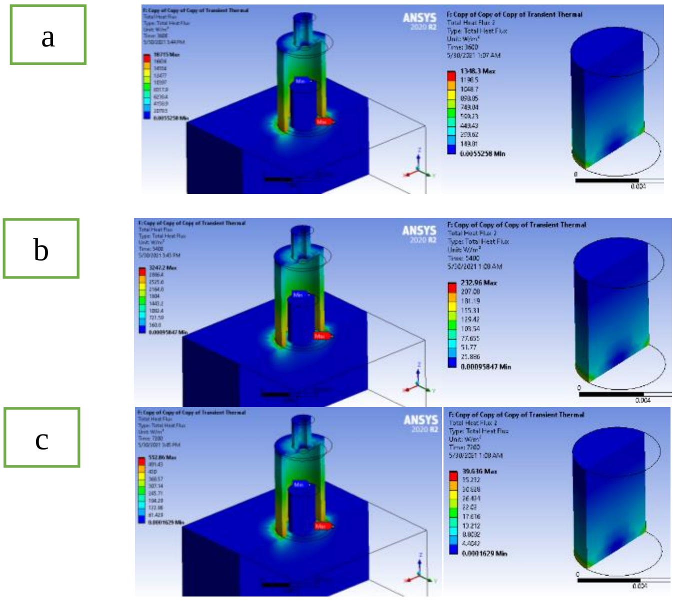

Figure S2. Transient thermal distribution of heat flux by SIS heating.

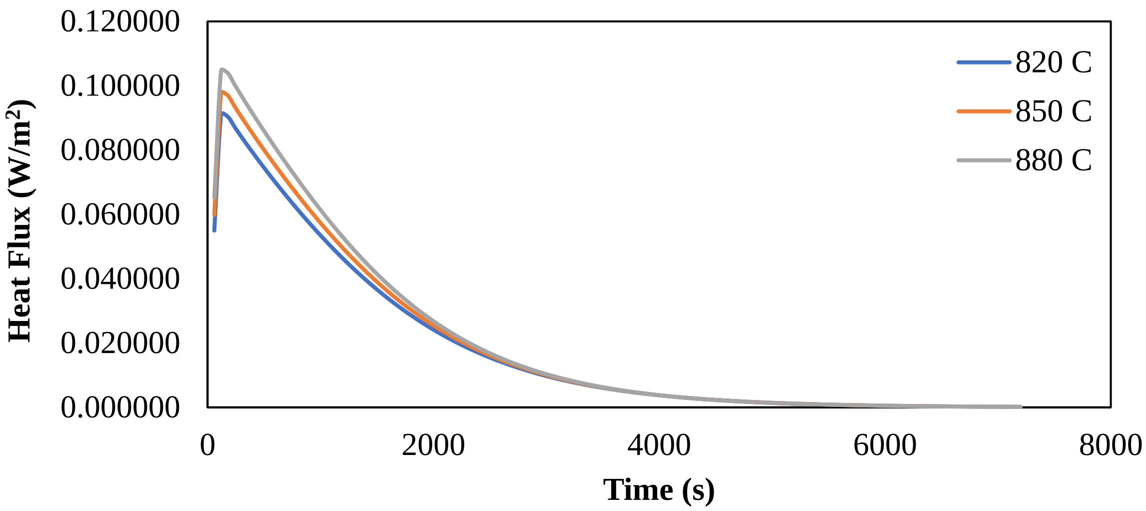

Figure S3. The heat flux plots of SIS heating.

Figure S3 shows the distribution of heat flux when a moderate temperature between 750-900 ^{o}C is applied, with heating time unit in second. It can be seen that after 7000 seconds the heat flux is near to zero. This implies that the change in heat flux after heating for 7000 seconds will not have a significant effect on the optimization process.

Table S1. Difference between the minimum and maximum temperature of the sample during SIS heating.

Time (s)	Heating Temperature (°C)		
	820 °C	850 °C	880 °C
3600	0.15	0.15	0.14
5400	0.03	0.03	0.02
7200	0.01	0.01	0

The temperature at the top of the sample cover is the highest temperature, which indicates that in the SIS method, heat propagation occurs from the top of the sample cover to the bottom. Then the part of the sample that has the highest temperature at the bottom indicates that the bottom of the sample is more temperature resistant. Table 1 listed the temperature difference in the samples. At 7200 seconds, it has reached a very low temperature difference, which is close to zero and even reaches zero for the temperature at 880

°C. Figure S4 shows the optimization plot results using the Taguchi method with the factors of temperature and heating time with three levels factor analysis (820, 850, and 880 °C for temperature; and 3600, 5400, and 7200 seconds for heating time). The result of the Taguchi method suggested that most optimum condition is using a heating temperature of 880 °C and a heating time of 7200 seconds.

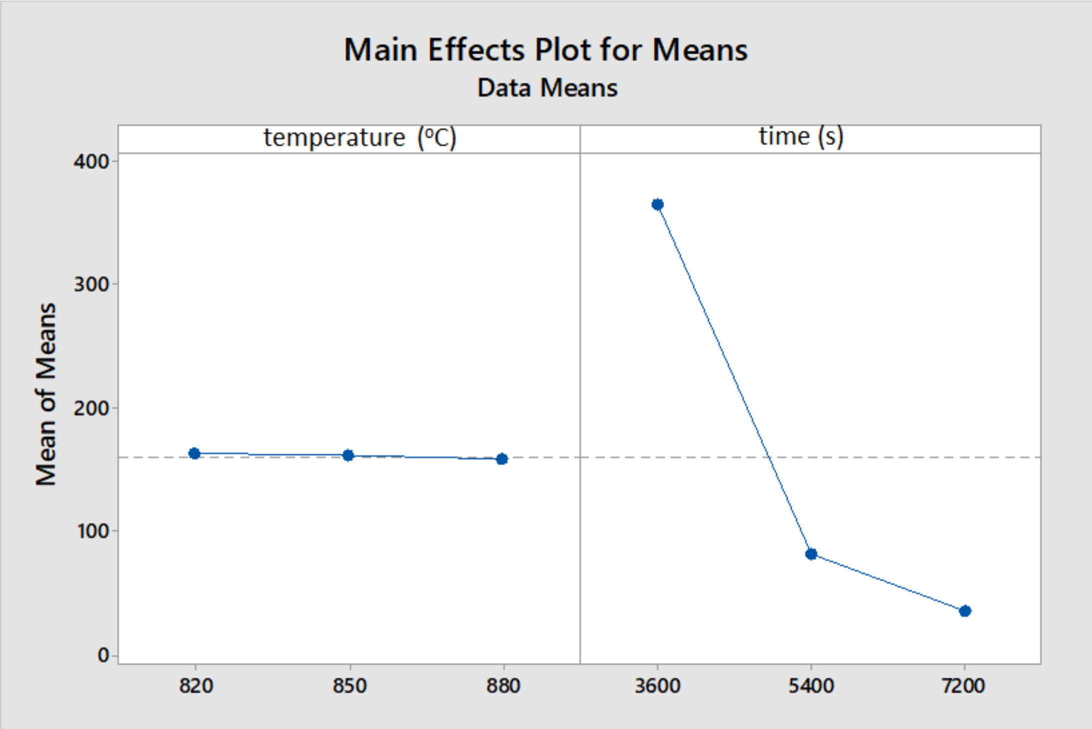

Figure S4. Results of Taguchi method optimization evaluated by Minitab.

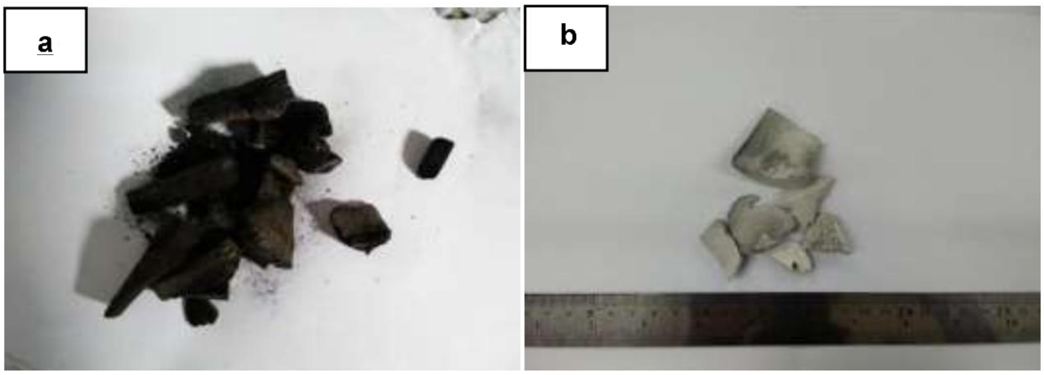

Figure S5. Photograph of bovine bones after calcination in (a) inert nitrogen gas, and (b) air atmosphere.

Figure S6. Photograph of the HAp powder from different batches.