Microwave Processing of Amorphous Magnesium-Calcium Phosphate

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Statement of Purpose: In this presentation, we report microwave sintering of magnesium-calcium phosphates with predominantly amorphous phases and calcium phosphate and magnesium phosphate. Different Mg:Ca ratios on densification, microstructure evolution and mechanical properties were studied. The sintered amorphous materials of calcium-magnesium phosphate was solid solutions of β-tricalcium phosphate doped with magnesium with a chemical formula of \( \text{Ca}_{(3-x)}\text{Mg}_x\text{(PO}_4\text{)}_2 \).

Methods: The amorphous magnesium-calcium phosphate (aMCP), MgP and aHA powders were prepared according to a precipitation method from ethanol medium which previously published by our group. Table 1 represents the composition of the powders. Powders were pressed to form compacted pellets prior to heat treatment via microwave. 1 g of each powder sample was put into a 1 cm diameter cylindrical steel die and pressed using a uniaxial hydraulic press at 10 ksi for 3 min. The compacted pellets were sintered in a semi-industrial grade microwave sintering samples were heated at 1150 °C for about 20 minutes, after which they were allowed to cool to room temperature [1-2].

<table>
<thead>
<tr>
<th>#</th>
<th>Mg Mmole</th>
<th>Ca Mmole</th>
<th>P Mmole</th>
<th>Mg:Ca</th>
<th>(Mg+Ca):P</th>
</tr>
</thead>
<tbody>
<tr>
<td>H6</td>
<td>22.5</td>
<td>22.5</td>
<td>22.5</td>
<td>1</td>
<td>2</td>
</tr>
<tr>
<td>H7</td>
<td>15</td>
<td>30</td>
<td>22.5</td>
<td>0.5</td>
<td>2</td>
</tr>
<tr>
<td>H8</td>
<td>30</td>
<td>15</td>
<td>22.5</td>
<td>2</td>
<td>2</td>
</tr>
<tr>
<td>H9</td>
<td>45</td>
<td>-</td>
<td>28</td>
<td>-</td>
<td>1.63</td>
</tr>
<tr>
<td>H10</td>
<td>45</td>
<td>-</td>
<td>28</td>
<td>-</td>
<td>1.63</td>
</tr>
</tbody>
</table>

Table 1 composition of powders

Results:

![Fig 1](image1)

Fig 1 (a-c) X-ray pattern of \( \beta\)-T(Ca, Mg) P. Peaks w represent Whitlockite, peaks S represent Standfieldit. (d) X-ray pattern of sintered MgP, peaks S represents Struvite, peaks with N represent Newberryite, peaks F with represent Trinagnesium Bis(phosphate(v)), Peaks with X represents (e) X-ray pattern of HA/β-TCP, Peaks H represent HA and peaks T represent β-TCP, (f) Shift of peak positions of the \( \beta\)-T ((Ca, Mg) P) due to the substitution of \( \text{Mg}^{2+} \).

![Fig 2](image2)

Fig 2 Microstructural evolution of \( \beta\)-T(Ca, Mg) P(H6, H7, H8), HA/β-T(Ca, P) (H10) with an average size of 2.7 µm and MgP sintered (H9) with average particle size of 8.5µm when sintered at 1150°C.

![Fig 3](image3)

Fig 3 (left) Density variation of \( \beta\)-T(Ca, Mg) P with different Mg content (H6, H7, H8), HA/TCP (H10) and MgP (H9) when sintered at 1150°C, (right) Average Vicker hardness variation of \( \beta\)-T(Ca, Mg) P with different Mg content (H6, H7, H8), HA/TCP (H10) and MgP (H9)

Conclusion: The amorphous magnesium-calcium phosphate transferred into nano crystalline \( \beta\)-TCP upon microwave sintering method. The results indicate that initial Mg:Ca ratio control the magnesium substitution amount in \( \beta\)-TCP structure. Increasing magnesium substitution up to a certain amount into the TCP lattice improved mechanical properties and the densification process while accelerating the sintering kinetics for all Mg ratios.

References