FABRICATION AND CHARACTERIZATION OF POLYMER-HYDROXYAPATITE NANOCOMPOSITES FOR BONE TISSUE ENGINEERING

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FABRICATION AND CHARACTERIZATION OF POLYMER-HYDROXYAPATITE NANOCOMPOSITES FOR BONE TISSUE ENGINEERING
骨組織工程聚合物-羟基磷灰石納米複合材料的制備與表征

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ABSTRACT

Hydroxyapatite (HA) with a chemical structure of Ca$_{10}$(PO$_4$)$_6$(OH)$_2$ is a major component and an essential ingredient of normal bone and teeth. Synthetic HA is commonly used as a filler material for conventional polymer composites due to its excellent biocompatibility and bioactivity. Polyethylene-HA composite (HAPEX$^{\text{TM}}$) filled with 40vol% HA microparticles has been used for orbital floor prosthesis, middle ear implant and maxillofacial surgery. HAPEX$^{\text{TM}}$ is restricted to such orthopedic applications due to its low mechanical strength. Accordingly, much effort has been devoted to the development of polymer composites with good biocompatibility and mechanical strength close to that of human cortical bones.

Recent advances in nanotechnology offer unique opportunities to develop nanostructured materials for biomedical applications. Bone tissue is a natural composite consisting of HA nanocrystals embedded in the collagen fibrils. The incorporation of HA nanofillers into the polymer matrix can mimic closely the structure of human bones. In this study, HA nanomaterials (nano-HA) of different morphologies were synthesized using polymer assisted sol-gel and micelle-hydrothermal techniques. The structure and properties of synthesized products were characterized by means of X-ray diffraction (XRD), Fourier transform infrared
spectroscopy (FTIR), field emission scanning electron microscopy (FE-SEM), transmission electron microscopy (TEM) and energy-dispersive X-ray analysis (EDX). XRD and FTIR results indicated that the synthesized products exhibit typical diffraction peaks and characteristic vibration bands of HA. Nano-HA synthesized from the sol-gel method displayed spherical morphology with diameters ranging from 50-70 nm. And nano-HA prepared via micelle template synthesis had a rod-like feature. Furthermore, simulated body fluid (SBF) immersion test revealed that both nano-HA materials exhibit good bioactivity due to the ease of apatite layer formation on their surfaces.

Commercially available HA nanorods (nHA) with an average aspect ratio of 6 were selected as nanofillers for high density polyethylene (HDPE), polypropylene (PP), polyamide-6 (PA6) and polyetheretherketone (PEEK). The main objectives of this study were to investigate the structure, thermal and mechanical properties as well as bioactivity of polymer/nHA nanocomposites. Nanocomposites with polymer matrices based on HDPE, PP and PA6 were prepared by melt-compounding while the PEEK/nHA nanocomposites were fabricated using thermal sintering process. Tensile tests showed that the additions of low filler content improve the tensile modulus and yield strength at the expense of tensile ductility and impact strength. However, the tensile strength and stiffness of HDPE/nHA and PP/nHA nanocomposites are much
lower than those of cortical bones. This is due to the low tensile strength of polyolefins. On the other hand, PA6 and PEEK based nanocomposites exhibit tensile strength close to that of cortical bones. The high tensile strength of PA/nHA nanocomposites derives from strong interfacial interactions between the polymer matrix and nHA. The main disadvantage of PA/nHA nanocomposites for orthopedic applications is the high moisture absorption of PA6. Thus only PEEK/nHA nanocomposites with high mechanical strength are promising load bearing materials to replace defective bones.

*In vitro* SBF immersion and osteoblast cell culture tests were used to assess the bioactivity of polymer/nHA nanocomposites. In general, apatite mineral crystals and mouse osteoblasts can be deposited, attached and proliferated on these nanocomposites, particularly for those with higher nanofiller content. These results imply excellent bioactivity of the polymer/nHA nanocomposites.
# TABLE OF CONTENTS

<table>
<thead>
<tr>
<th>Section</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>ABSTRACT</td>
<td>I</td>
</tr>
<tr>
<td>ACKNOWLEDGEMENTS</td>
<td>IV</td>
</tr>
<tr>
<td>TABLE OF CONTENTS</td>
<td>V</td>
</tr>
<tr>
<td>LIST OF FIGURES</td>
<td>VIII</td>
</tr>
<tr>
<td>LIST OF TABLES</td>
<td>XIV</td>
</tr>
<tr>
<td>CHAPTER 1 INTRODUCTION</td>
<td>1</td>
</tr>
<tr>
<td>1.1 Bone implant materials</td>
<td>2</td>
</tr>
<tr>
<td>1.2 Nature of Bones</td>
<td>7</td>
</tr>
<tr>
<td>1.3 Nano-hydroxyapatite</td>
<td>12</td>
</tr>
<tr>
<td>1.3.1 Structure of nano-HA</td>
<td>13</td>
</tr>
<tr>
<td>1.3.2 Synthesis of nano-HA</td>
<td>14</td>
</tr>
<tr>
<td>1.3.3 Properties of nano-HA</td>
<td>20</td>
</tr>
<tr>
<td>1.4 Polymer/HA nanocomposites</td>
<td>23</td>
</tr>
<tr>
<td>1.4.1 Polymer matrix</td>
<td>24</td>
</tr>
<tr>
<td>1.4.2 Interfacial state</td>
<td>28</td>
</tr>
<tr>
<td>1.4.3 HA morphology</td>
<td>29</td>
</tr>
<tr>
<td>1.5 Preparation of Polymer/HA nanocomposites</td>
<td>31</td>
</tr>
<tr>
<td>1.6 Biomimic properties of polymer/HA nanocomposites</td>
<td>36</td>
</tr>
<tr>
<td>1.6.1 Biomechanical properties</td>
<td>36</td>
</tr>
<tr>
<td>1.6.2 In vitro Bioactivity</td>
<td>38</td>
</tr>
<tr>
<td>1.6.3 Cellular response</td>
<td>40</td>
</tr>
<tr>
<td>1.7 Objective of this study</td>
<td>42</td>
</tr>
<tr>
<td>1.8 References</td>
<td>45</td>
</tr>
<tr>
<td>CHAPTER 2 HYDROTHERMAL SYNTHESIS AND BIOACTIVITY OF HYDROXYAPATITE NANORODS</td>
<td>56</td>
</tr>
<tr>
<td>2.1 Introduction</td>
<td>56</td>
</tr>
<tr>
<td>2.2 Experimental</td>
<td>58</td>
</tr>
<tr>
<td>2.2.1 Materials</td>
<td>58</td>
</tr>
<tr>
<td>2.2.2 Synthesis of HA nanorod</td>
<td>59</td>
</tr>
<tr>
<td>2.2.3 Materials characterization</td>
<td>60</td>
</tr>
<tr>
<td>2.2.4 In vitro test</td>
<td>60</td>
</tr>
<tr>
<td>2.3 Results and Discussion</td>
<td>62</td>
</tr>
<tr>
<td>2.3.1 Structure analysis</td>
<td>62</td>
</tr>
<tr>
<td>2.3.2 Thermal stability</td>
<td>65</td>
</tr>
<tr>
<td>2.3.3 Morphology characterization</td>
<td>67</td>
</tr>
<tr>
<td>2.3.4 In vitro test</td>
<td>71</td>
</tr>
<tr>
<td>2.4 Summary</td>
<td>75</td>
</tr>
</tbody>
</table>
2.5 References........................................................................................................ 76

CHAPTER 3 SYNTHESES OF HYDROXYAPATITE NANOSPHERES THROUGH A FACILE SOL-GEL METHOD ............................................................... 78

3.1 Introduction.................................................................................................. 78
3.2 Experimental ................................................................................................ 79
  3.2.1 Synthesis of HA nanospheres............................................................ 79
  3.2.2 Powder Characterization................................................................... 80
3.3 Results and Discussion ................................................................................ 81
3.4 Summary ...................................................................................................... 87
3.5 References.................................................................................................... 87

CHAPTER 4 PREPARATION AND CHARACTERIZATION OF POLYOLEFIN/HYDROXYAPATITE NANOCOMPOSITES .................................................. 89

4.1 Introduction.................................................................................................. 89
4.2 Experimental .............................................................................................. 92
  4.2.1 Materials ........................................................................................... 92
  4.2.2 Fabrication of nanocomposites ......................................................... 93
  4.2.3 Materials Characterizations .............................................................. 94
  4.2.4 Tribological test ................................................................................ 96
  4.2.5 In vitro tests....................................................................................... 97
4.3 Results and discussion ................................................................................. 99
  4.3.1 Characteristics of HDPE/nHA nanocomposites................................ 99
  4.3.2 Tribological properties of HDPE/nHA nanocomposites................. 105
  4.3.3 Properties of PP/nHA nanocomposites ........................................... 113
    4.3.3.1 Structure ............................................................................... 113
    4.3.3.2 Thermal properties ............................................................... 117
    4.3.3.3 Mechanical properties.......................................................... 120
  4.3.4 In vitro bioactivity of PP/nHA nanocomposites............................ 122
4.4 Summary .................................................................................................... 126
4.5 References.................................................................................................. 128

CHAPTER 5 MECHANICAL, THERMAL AND BIOACTIVE BEHAVIORS OF POLYAMIDE 6/HYDROXYAPATITE NANOCOMPOSITES ..................................................... 130

5.1 Introduction................................................................................................ 130
5.2 Experimental.............................................................................................. 133
  5.2.1 Preparation of nanocomposites....................................................... 133
  5.2.2 Mechanical tests............................................................................. 134
  5.2.3 Thermal properties.......................................................................... 134
  5.2.4 In vitro tests .................................................................................... 135
5.3 Results and Discussion .............................................................................. 137
  5.3.1 Mechanical properties..................................................................... 137
  5.3.2 Materials characterization............................................................... 140
LIST OF FIGURES

Figure 1.1  Tensile strength vs modulus of different materials and biological tissues………………………………………………………………………………5

Figure 1.2  Seven hierarchical levels of organization in zebrafish bone. Level 1: isolated crystals and a collagen fibril with the triple helix structure, level 2: mineralized collagen fibrils, level 3: array of mineralized collagen fibrils, level 4: two fibril array patterns, level 5: lamellar structure, level 6: a vertebra, level 7: skeleton bone………………………………………………10

Figure 1.3  Non-calcined femoral head showing the transition from a compact outer cortical bone (corticalis) to a porous spongy interior (spongiosa) …………………………………………………………………………………11

Figure 1.4  Crystal structures of nano-HA, (a) stereoscopic and (b) plane diagram-13

Figure 1.5  TEM images of nano-HA as Np 20 (diameter of 20±5 nm), Np 40 (diameter of 40±10 nm) and conventional HA; fluorescence images showing different proliferation of bone marrow mesenchymal stem cells cultured on the HA …………………………………………………15

Figure 1.6  (A) TEM images of CDHA nanoparticles synthesized in the absence of amino acids. High-resolution images of particles with the c-axis oriented either (B) parallel or (C) perpendicular to the image plane …………………………………………………………………………………18

Figure 1.7  Schematic illustration of complementarity between CTAB and phosphate ……………………………………………………………………………19

Figure 1.8  Calculated stability field diagram for HA system at 200 °C and 25 bars with a Ca/P ratio of 1.24…………………………………………………………20

Figure 1.9  Schematic illustration of sequential reactions after implantation of one biomaterial in a living system…………………………………………………………22

Figure 1.10  Schematic illustration of the mechanism by which nanomaterials are better than conventional materials for bone regeneration ……………………23

Figure 1.11  (A) Density of human primary osteoblasts after 90 min incubation, and
(B) osteoblasts proliferation for 1, 3, 7 days on sintered nano-HA (NHA), micro-HA (MHA) and glass control 23

Figure 1.12 Comparison in mechanical properties of human cortical bone with HA-reinforced polymer composites. The mechanical properties of cortical bone parallel and perpendicular to longitudinal anatomic axis are also shown for comparison 24

Figure 1.13 Molecule structure and melting temperatures of PEEK and PSU 25

Figure 1.14 Tensile properties of HDPE/HAw and PEEK/HAw composites in longitudinal specimen direction versus HAw volume fraction 26

Figure 1.15 Flow charts of (A) oleic acid modification of nano-HA in PCL/HA nanocomposite and (B) silane coupling agent in HDPE/HA composite 29

Figure 1.16 Osteoblasts cultured on (A) spherical and (B) rod-like HA nanocrystals 30

Figure 1.17 Manufacture of biocomposites via polymer solution casting technique 32

Figure 1.18 Scheme of self-assembly of HA/collagen nanocomposite 32

Figure 1.19 Manufacture of biocomposites using plastics processing technologies 33

Figure 1.20 (A) Schematic diagram of a SCORIM device and (B) micro-hardness and polarized light microscopy along the cross section diameter of HDPE/HA composites produced by conventional injection molding (CM) and SCORIM 34

Figure 1.21 Schematic diagrams of (A) hydrostatic extrusion and (B) CIM device combining a twin screw extruder with an injection molding 35

Figure 1.22 (A) Wear areas of Co-Cr-Mo-C cups paired with metal balls, and PE cups paired with metal and ceramic balls, respectively, and (B) steady state wear rates of UHMWPE/HDPE/CNT nanocomposites against metallic counterpart 37

Figure 1.23 More apatite deposited on (A) PSU/nano-HA than (B) PSU/micro-HA after immersion in SBF for 10 days 39

Figure 1.24 (A) Growth of HOB cells on 20wt.% (ncom20) and 40wt.% (ncom40)
nano-HA/PHEMA/PCL composites cultured for 2, 4 and 7 days (Corresponding to the three columns from left to right) via alamar-Blue™ assay. Tissue culture plastic was used as control (Ctr), and (B) Mechanism of MTT assay.

Figure 2.1    Flow chart of micelle-hydrothermal synthesis …………………… 59
Figure 2.2    XRD patterns of hydrothermal products synthesized at 150 °C with different CTAB amounts. (Inset is standard pattern of HA) ……….. 63
Figure 2.3    XRD patterns scanned (a) at 1.2 °/min for nHA discs sintered from 600 to 900 °C and (b) at 0.6 °/min for nHA sintered at 700 and 800 °C … 63
Figure 2.4    FTIR spectra of HA synthesized at 150 °C with different CTAB contents ……………………………………………………………… 65
Figure 2.5    TGA traces of HA synthesized at 150 °C with different CTAB contents ……………………………………………………………… 66
Figure 2.6    TEM images of HA synthesized with 1.25 mmol CTAB at (a) 120 °C, (b) 150 °C and (c) 180 °C……………………………………………67
Figure 2.7    Schematic illustration of the nanorods formation by single hydrothermal process and micelle-hydrothermal process …………………..68
Figure 2.8    (a) Schematic illustration of complementarity between CTA⁺ cation and phosphate anion and (b) crystal structure of CaHPO₄ oriented along c-axis ……………………………………………………………… 71
Figure 2.9    Plot of pH of SBF versus immersion time for nHA and mHA powders. (Inset is the morphology of mHA sphere) ……………………..72
Figure 2.10   Surface morphologies of nHA discs sintered at 600 °C after (a) 7 and (b) 21 days immersion ………………………………………………… 72
Figure 2.11   Schematic description of apatite formation on the surface of sintered nHA disc after immersion in SBF ……………………………….72
Figure 2.12   Morphologies of osteoblasts adhered on sintered nHA discs after seeding for 18 h…………………………………………………………...73
Figure 3.1    XRD patterns of the as-synthesized particles ……………………..81
Figure 3.2    FTIR spectra of as-synthesized particles……………………………82
Figure 3.3    TGA curves of as-synthesized particles……………………………83
Figure 3.4   Raman spectra of as-synthesized HA particles…………………………83
Figure 3.5   FE-SEM micrographs of HA synthesized at (a) 37 °C and (b) 55 °C … 84
Figure 3.6   XRD patterns of nHA sintered at different temperatures ………………85
Figure 3.7   SEM micrographs showing surface morphology of HA sintered at 550 °C
after immersion in SBF for (a) 2 and (b) 3 weeks …………………86
Figure 4.1   Morphology of as-received hydroxyapatite nanorod …………………93
Figure 4.2   Schematic diagram of the pin-on-disk tribometer …………………….97
Figure 4.3   DSC cooling curves of HDPE/nHA nanocomposites………………….99
Figure 4.4   TGA curves of HDPE/nHA nanocomposites……………………….101
Figure 4.5   Typical tensile curves of HDPE/nHA nanocomposites…………….103
Figure 4.6   Variation of COF with sliding distance for HDPE/nHA nanocomposites
under an applied load of 100 N…………………………………………105
Figure 4.7   Variations of (a) COF, and (b) $W_s$ with nHA content for HDPE/nHA
nanocomposites slid for 1000 m under different applied loads……….107
Figure 4.8   Cryo-fracture surface of HDPE/20 wt% nHA nanocomposite showing
nHA agglomerates (indicated by the arrows) and drawn HDPE fibrils …………………….109
Figure 4.9   Surface morphologies of (a) HDPE, (b) HDPE/2wt% nHA and (c)
HDPE/6wt% nHA nanocomposites after sliding for 1000 m under an
applied load of 100 N. Arrow indicates sliding direction ….. 109-110
Figure 4.10  SEM micrographs showing surface morphologies of the steel pin
counterpart slid against (a) HDPE/2wt% nHA, (b) HDPE/6wt% nHA and
(c) HDPE/20wt% nHA nanocomposites for 1000m under 100 N-111-112
Figure 4.11  FE-SEM images of (a) and (b) PP/2.42 vol% nHA nanocomposite, (c)
and (d) PP/6.67 vol% nHA nanocomposites, (e) and (f) PP/10.91 vol%
nHA nanocomposites………………………………………………113-115
Figure 4.12  XRD patterns of PP/nHA nanocomposites ………………………..116
Figure 4.13  DSC curves of PP/nHA nanocomposites …………………………117
Figure 4.14  TGA curves of PP/nHA nanocomposites…………………………118
Figure 4.15  (a) Storage modulus and (b) loss tangent vs temperature plots for pure
PP and PP/nHA nanocomposites ……………………………. 119
Figure 4.16  Typical tensile curves of PP/nHA nanocomposites ............................ 120
Figure 4.17  SEM micrographs of (a) PP/4.80vol% nHA and (b) PP/10.91vol% nHA nanocomposites after SBF immersion for 60 days ................. 122-123
Figure 4.18  Variation of storage modulus with immersion time at 37 °C for PP/nHA nanocomposites .............................................................. 124
Figure 4.19  SEM micrographs showing the morphologies of osteoblasts cultured on (a) PP/4.80vol% nHA, (b) and (c) PP/10.91vol% nHA nanocomposites for 48 h ................................................................. 125-126
Figure 5.1   FTIR spectra of PA6 and its nanocomposites .........................140
Figure 5.2  Fractographs of (a) PA6/8wt% and (b) PA6/15wt% nHA nanocomposite ..............................................................140-141
Figure 5.3  Schematic illustration showing interactions between nano-HA and PA6 .............................................................................. 142
Figure 5.4  (a) Storage modulus and (b) loss tangent as a function of temperature for PA6/nHA nanocomposites .......................................142-143
Figure 5.5  Variations of pH of SBF and weight gain with immersion time for PA6/8wt% nHA nanocomposite .................................................. 145
Figure 5.6  Water absorption vs immersion time for PA6, PA6/8wt% nHA and PA6/15wt% nHA specimens .......................................................... 146
Figure 5.7  Surface morphologies of PA6/8wt% nHA nanocomposite after SBF immersion for (a) 2 and (b) 8 weeks ................................. 146-147
Figure 5.8  SEM micrographs showing the morphologies of MC3T3-E1 osteoblasts cultured on (a) PA6/8wt% nHA and (b) PA6/15wt% nHA nanocomposites for one and three days ........................................ 148
Figure 5.9  MTT results showing osteoblast proliferation on PA6/8wt% nHA and PA6/15wt% nHA nanocomposite surfaces ......................... 149
Figure 6.1  Fracture surfaces of (A) PEEK/ micro-HA_p composite showing the decohesion of HA particles from the matrix and (B) PEEK/micro-HA_w composite showing whisker pullout ........................................ 153
Figure 6.2  (a) Morphologies of as-received PEEK powders, and (b) tensile bars and discs before and after sintering ........................................... 155
Figure 6.3 XRD patterns of nHA/PEEK nanocomposites ………………….159
Figure 6.4 FESEM micrographs showing cryo-fracture surfaces of (a) and (b) 15.1 vol% HA/PEEK, (c) and (d) 38.2vol% nHA/PEEK nanocomposites ……………………………………………………………….160-161
Figure 6.5 Tensile stress-strain curves of nHA/PEEK nanocomposites ………. 162
Figure 6.6 Tensile modulus vs microhardness plot for nHA/PEEK nanocomposites ………………………………………………………………………….165
Figure 6.7 DSC (a) secondary melting and (b) cooling scans for nHA/PEEK nanocomposites ……………………………………………………………….166
Figure 6.8 Thermo-mechanical behaviors of nHA/PEEK nanocomposites……..167
Figure 6.9 SEM micrographs showing deposition of apatite mineral layer on 15.1vol% nHA/PEEK nanocomposite after SBF immersion for (a) 7 and (b) 21days……………………………………………………………………….168
Figure 6.10 SEM micrographs showing deposition of apatite mineral layer on 29.2vol% nHA/PEEK nanocomposite after SBF immersion for (a) 7 and (b) 21 days ………………………………………………………………………….169
Figure 6.11 (a) SEM cross-sectional micrograph and (b) FTIR spectrum of precipitated apatite layer formed on 29.2vol% nHA/PEEK nanocomposite after SBF immersion for 35 days. FTIR spectrum of as-received nHA is also shown for comparison ………………….. 170
Figure 6.12 Morphology of osteoblasts cultivated on 15.1 vol% nHA/PEEK nanocomposite for (a) 24 h and (b) 48 h……………………………………. 172
Figure 6.13 Morphology of osteoblasts cultivated on 29.2 vol% nHA/PEEK nanocomposite for (a) 24 h, (b) and (c) 48 h ……………………………..173
Figure 6.14 Cellular viability assay showing osteoblasts proliferation on the positive control, 15.1vol% nHA/PEEK and 29.2 vol% nHA/PEEK nanocomposites after 2, 4 and 7 days cultivation (p ≤ 0.05)………. 174
Figure 6.15 Cellular viability of positive controls showing a linear correlation between optical absorbance and cell concentration for 2 day cultivation……………………………………………………………………….175
# LIST OF TABLES

| Table 1.1 | Examples of polymers used as biomaterials | 2 |
| Table 1.2 | Properties of typical calcium phosphate compounds | 4 |
| Table 1.3 | Mechanical properties of metallic and ceramic materials | 6 |
| Table 1.4 | The composition of bones | 8 |
| Table 1.5 | Mechanical properties of various bone tissues | 12 |
| Table 1.6 | Recent development of nano-HA synthesis | 16 |
| Table 1.7 | Mechanical properties of PA66/HAp nanocomposites and microcomposites | 21 |
| Table 1.8 | Mechanical properties of nondegradable polymer/HAp microcomposites | 25 |
| Table 1.9 | Mechanical properties of polymer/HAp nanocomposites | 27 |
| Table 1.10 | Mechanical properties of HDPE/HAp and HDPE/HAw composites | 30 |
| Table 1.11 | Mechanical properties of HDPE composites processed via various melt compounding techniques | 36 |
| Table 1.12 | Ion concentrations of SBF solutions and human blood plasma | 39 |
| Table 4.1 | Processing parameters for Polyolefin/HAp nanocomposites | 94 |
| Table 4.2 | Crystallization properties of HDPE/nHA nanocomposites | 100 |
| Table 4.3 | Thermal properties of HDPE/nHA nanocomposites | 101 |
| Table 4.4 | Mechanical properties of HDPE/nHA nanocomposites | 102 |
| Table 4.5 | Mechanical properties of micro- and nano-HA/HDPE composites | 104 |
| Table 4.6 | Crystallization properties of PP/nHA nanocomposites | 117 |
| Table 4.7 | Thermal properties of PP/nHA nanocomposites | 118 |
| Table 4.8 | Mechanical properties of PP/nHA nanocomposites and PP/HAp microcomposites | 121 |
| Table 5.1 | Properties of PA/HAp nanocomposites | 131 |
| Table 5.2 | Mechanical properties of PA6/nHA nanocomposites | 137 |
| Table 5.3 | Mechanical properties of in-situ PA6/nano-HA composites | 139 |
| Table 5.4 | Thermal properties of PA6/nHA nanocomposites | 144 |
| Table 6.1 | Chemical compositions and density of nHA/PEEK nanocomposites | 156 |
| Table 6.2 | Mechanical properties of nHA/PEEK nanocomposites | 163 |
Table 6.3    Tensile properties of PEEK reinforced with micro HA_p………………164
Table 6.4    Crystallization properties of nHA/PEEK nanocomposites …………166