

## Supplementary Information

### Facile and controllable synthesis of carbon-encapsulating carbonate apatite nanowires from biomass containing calcium compounds such as $\text{CaC}_2\text{O}_4$ and $\text{CaCO}_3$

Namjo Jeong,<sup>\*ab</sup> Seong Ok Han,<sup>a</sup> Heeyeon Kim,<sup>a</sup> Kyo-sik Hwang,<sup>b</sup> SeungCheol Yang,<sup>b</sup>

Kahee Kim<sup>c</sup> and Sung-kook Hong<sup>a</sup>

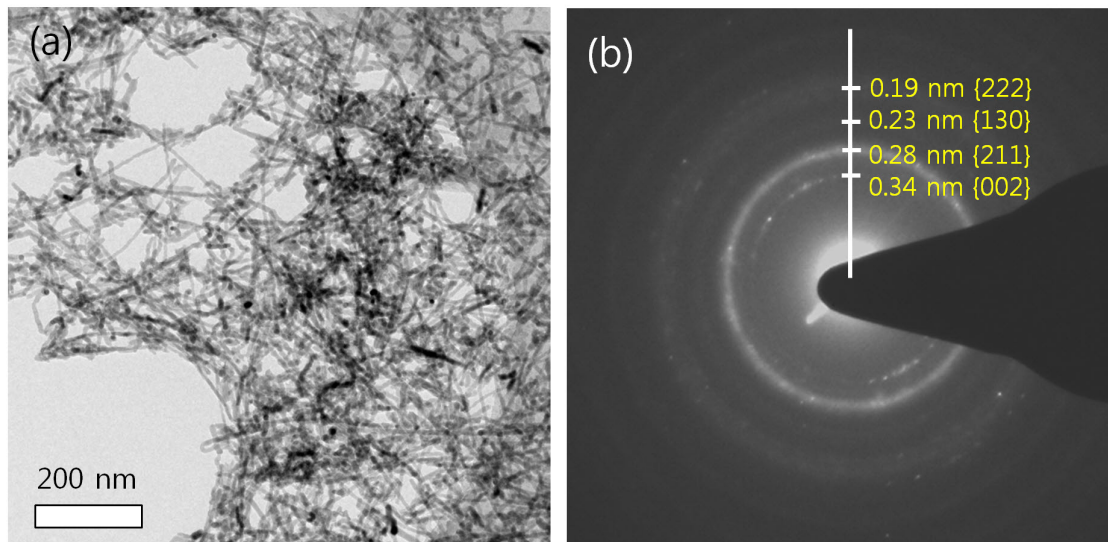
<sup>a</sup>Energy Materials and Convergence Research Department, Korea Institute of Energy Research, 71-2 Jang-dong, Yuseong-gu, Daejeon 305-343, Republic of Korea

<sup>b</sup>Jeju Global Research Center, Korea Institute of Energy Research, 200, Haemajihae-an-ro, Gujwa-eup, Jeju Special Self-Governing Province 695-971, Republic of Korea

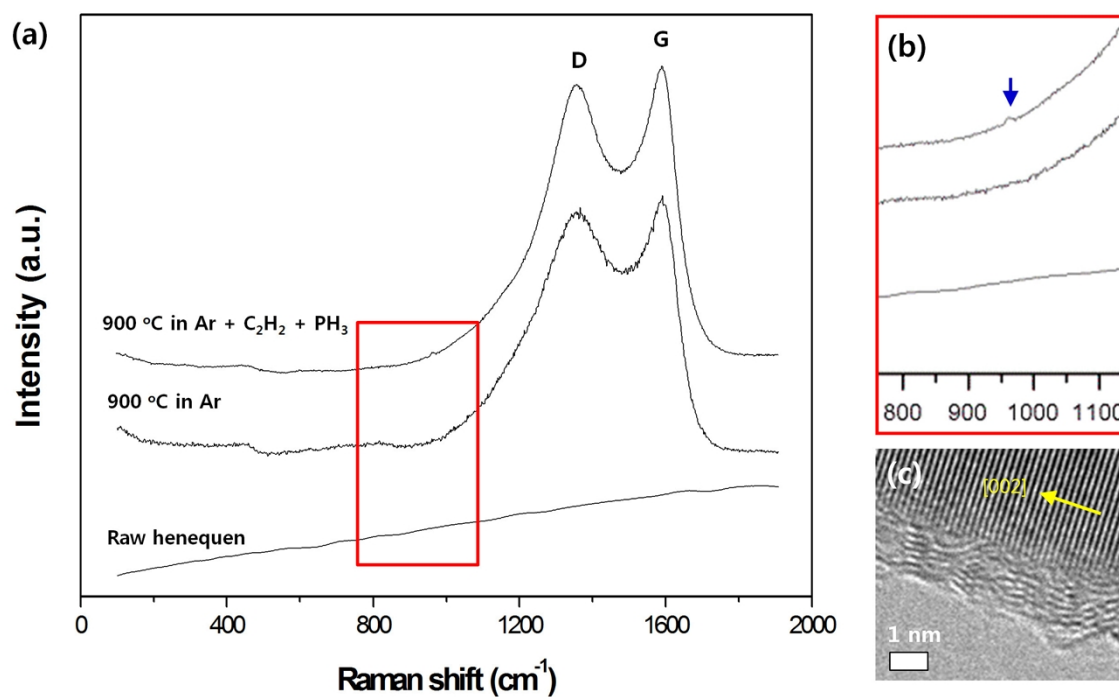
<sup>c</sup>Materials and Analysis Division, National Nanofab Center, 291 Daehak-ro, Yuseong-gu, Daejeon 305-806, Republic of Korea

<sup>d</sup>Measurement and Analysis Team, Korea Advanced Nanofab Center, 960-10, Iui-dong, Yeongtong-gu, Suwon 443-270, Republic of Korea

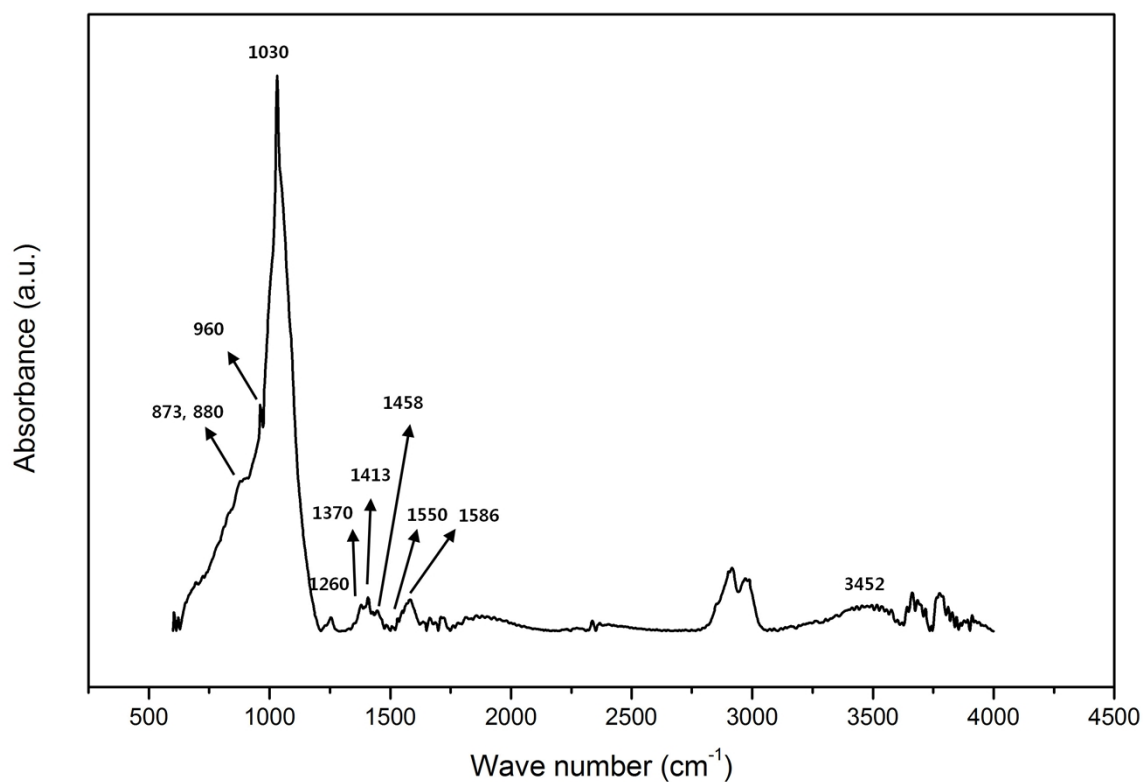
## Additional results



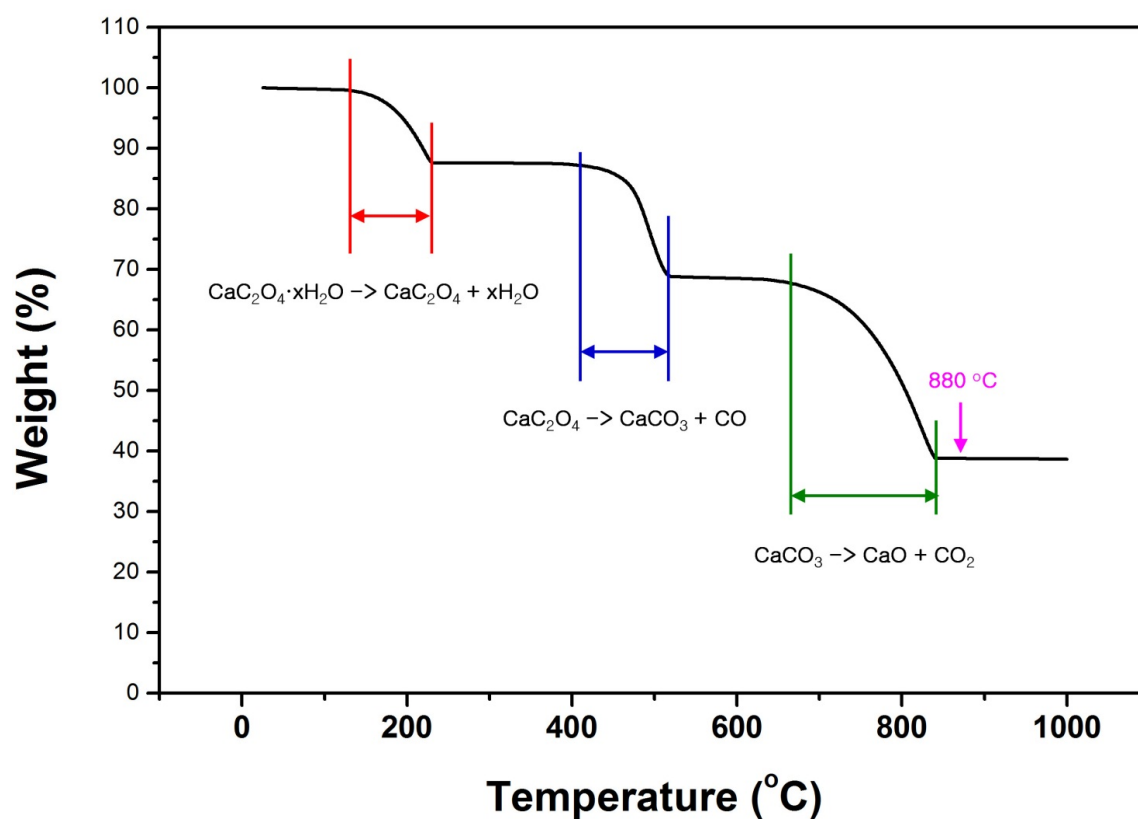
**Fig. S1** (a) TEM image and (b) SAED pattern of the nanowires.



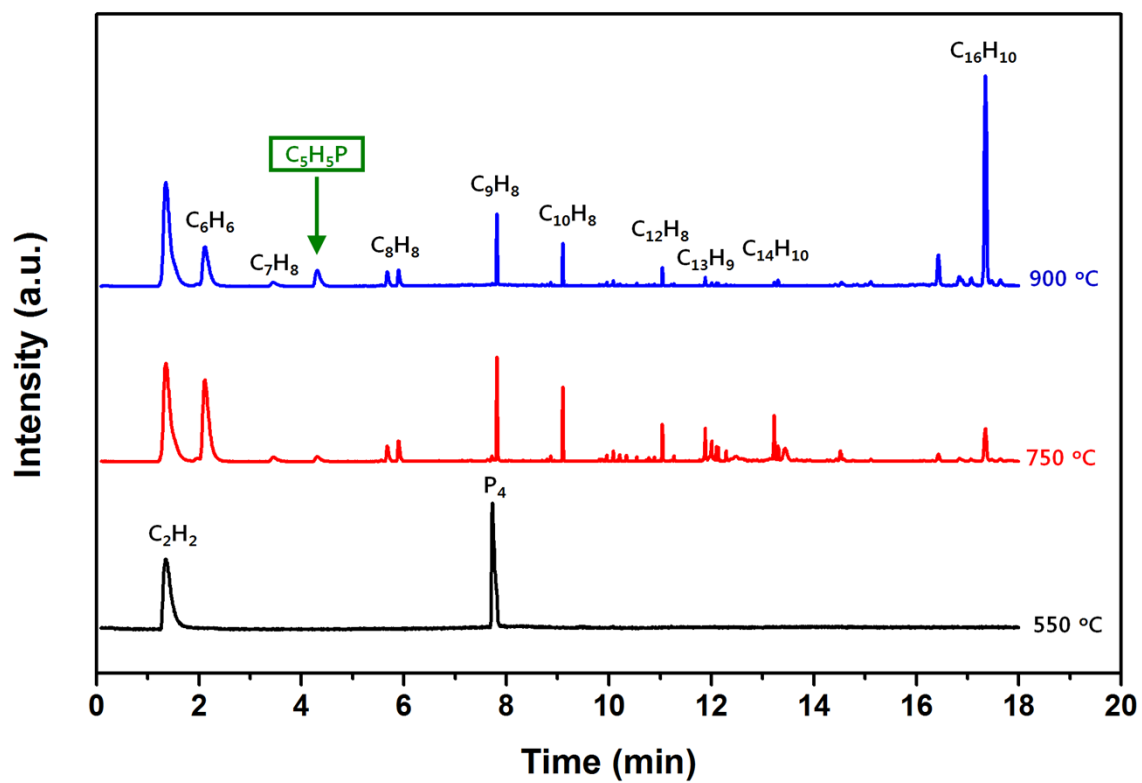
**Fig. S2** (a) Raman spectra of the samples prepared before and after 1 h of heat treatment at 900°C with an Ar only or Ar + PH<sub>3</sub>/Ar + C<sub>2</sub>H<sub>2</sub> atmosphere. (b) The detailed spectrum measured from 800 to 1200 cm<sup>-1</sup>. A peak corresponding to phosphate was detected at 960 cm<sup>-1</sup>. (c) HRTEM image showing the core-shell configuration of the nanowire.



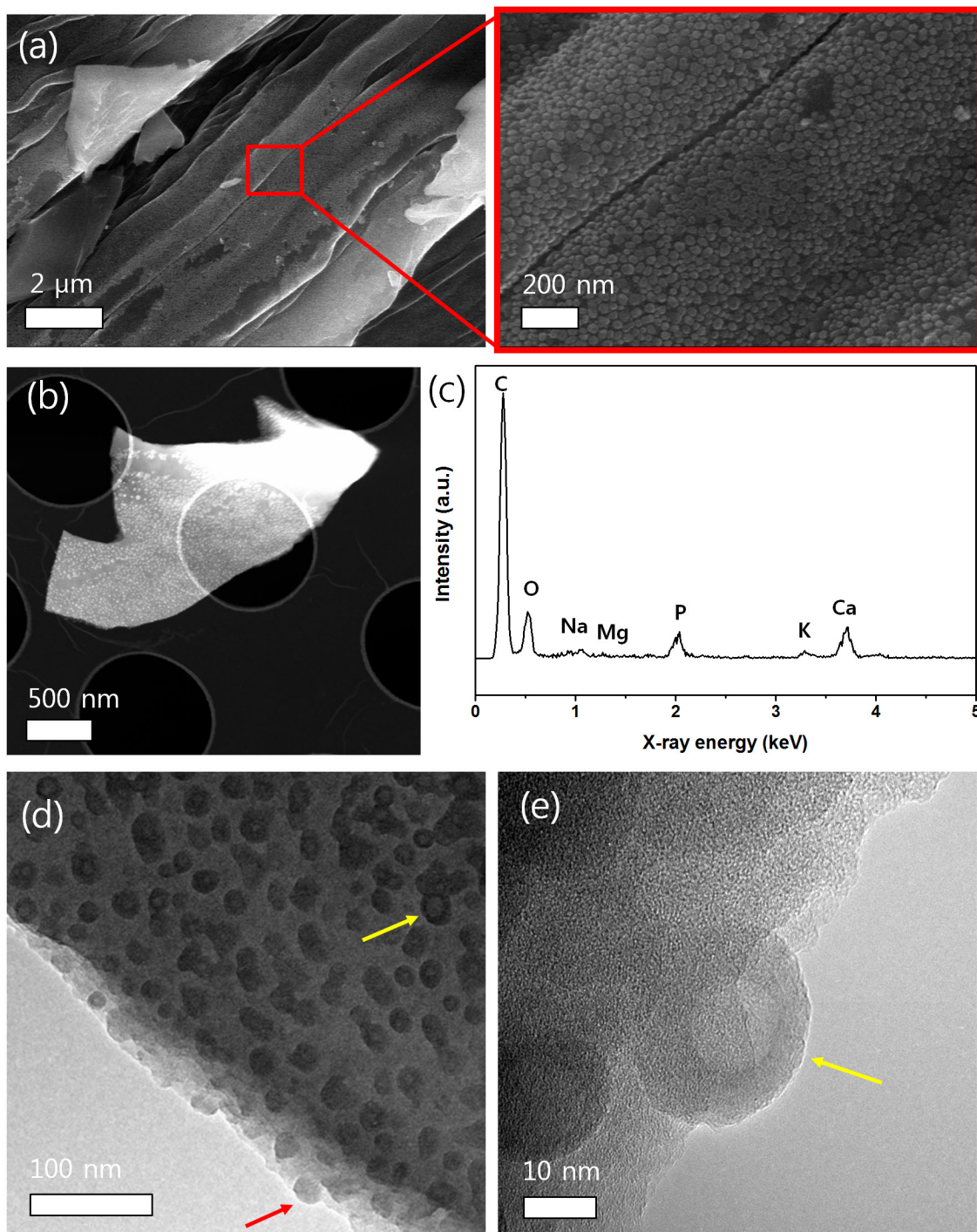
**Fig. 3** FTIR spectra of the samples prepared before and after 1 h of heat treatment at 900°C with an Ar only or Ar + PH<sub>3</sub>/Ar + C<sub>2</sub>H<sub>2</sub> atmosphere.



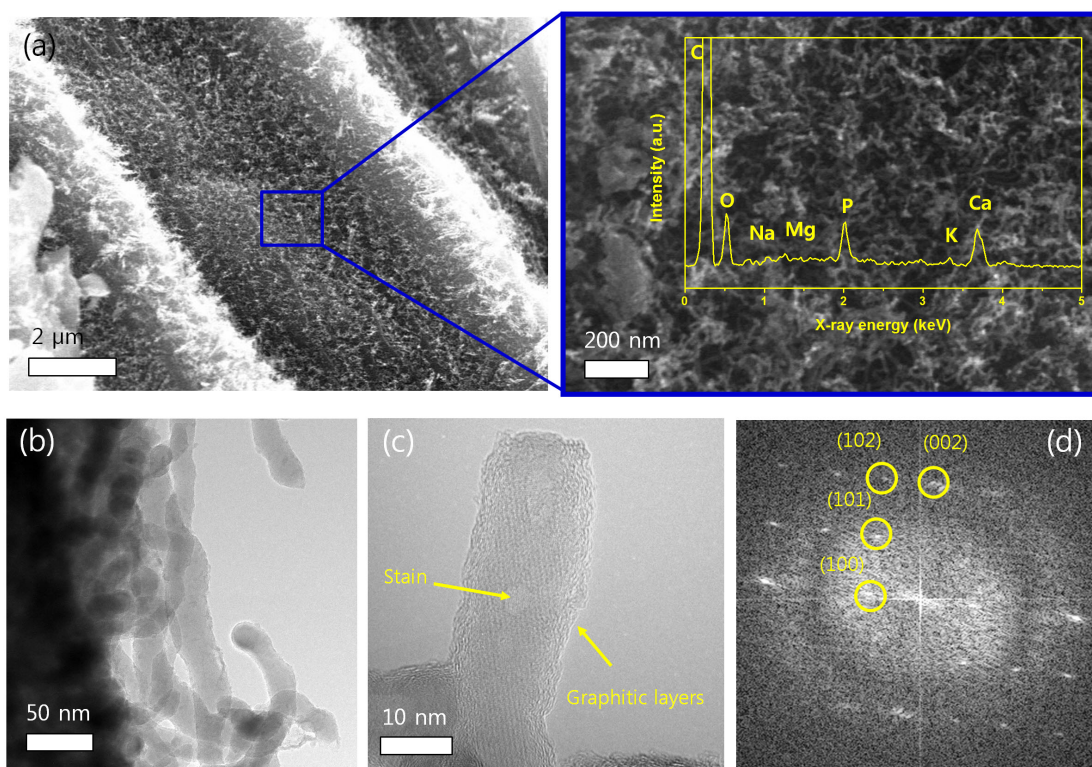
**Fig. S4** TGA result for  $\text{CaC}_2\text{O}_4 \cdot x\text{H}_2\text{O}$ . The temperature increased at the rate of 15 °C/min, and Ar was supplied at the rate of 100 ml/min. It is noteworthy that the decomposition of  $\text{CaCO}_3$  was completed at approximately 880 °C.



**Fig. S5** GC-MS spectrum for thermal pyrolysis under a gas mixture of Ar + 0.01% PH<sub>3</sub> + 1 % C<sub>2</sub>H<sub>2</sub> at 550, 750, and 900°C.

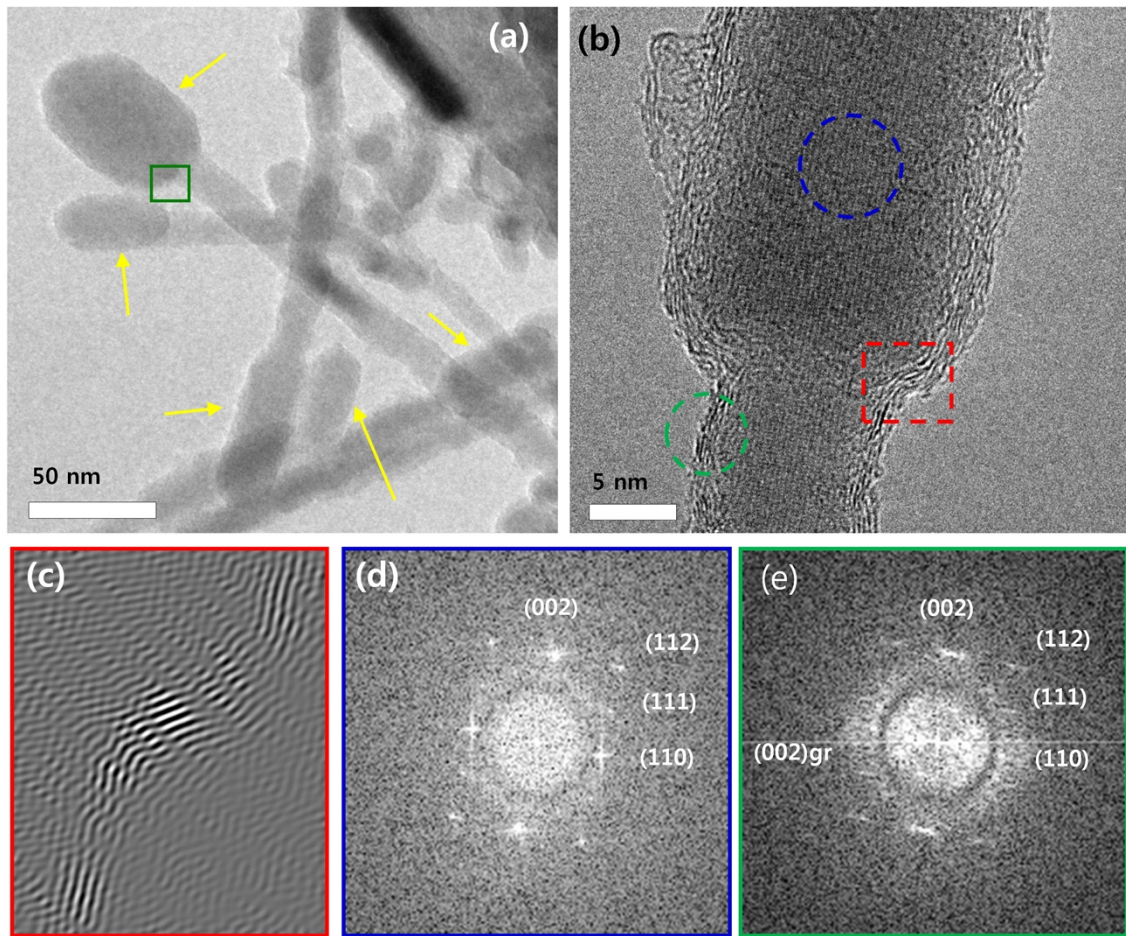


**Fig. S6** (a) SEM image, (b) STEM image, and (c) EDX spectrum of carbon fiber obtained at 550°C. The surface was covered with nanoparticles smaller than 50 nm. (d) TEM and (e) HRTEM images of the nanoparticles. The cores of the nanoparticles easily disappeared during TEM observations, indicating that they have unstable amorphous structures. The insets show high-magnification SEM images of the as-formed nanoparticles. The supplied gas composition was Ar + 0.01% PH<sub>3</sub> + 1 % C<sub>2</sub>H<sub>2</sub>. Red and yellow arrows indicate hollow and filled carbon nanoparticles, respectively.

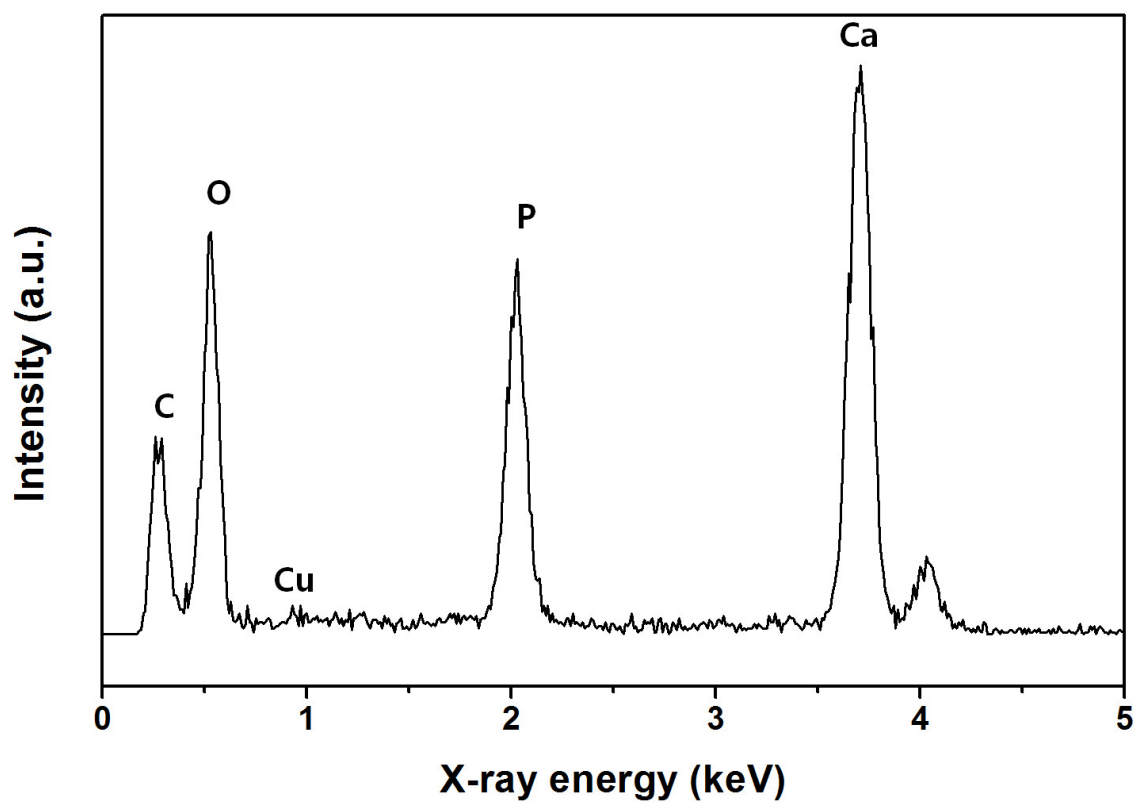


**Fig. S7** (a) SEM, (b) TEM, (c) HRTEM, and (d) FFT images of the tiny, wavy nanowires formed at 750°C. The insets show a high-magnification SEM image and its EDX spectrum. The supplied gas composition was Ar + 0.01% PH<sub>3</sub> + 1 % C<sub>2</sub>H<sub>2</sub>. The yellow arrows indicate the stains generated during TEM observation. The lattice spacings of the core were calculated to be 3.2, 5.2, 8.2, and 3.4 Å, which can be assigned to the (102), (101), (100), and (002) planes of hexagonal apatite.





**Fig. S8** (a) TEM, (b) HRTEM, (c) virtual images of a nanowire with an enlarged head. (d) and (e) show the FFT images corresponding to blue and green circles in (b).



**Fig. S9** EDX spectrum of the nanowires. The experiment was performed for 1 h at 900°C in a gas mixture of Ar + 0.01% PH<sub>3</sub> + 1% C<sub>2</sub>H<sub>2</sub>.