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Characterization of calcium oxide derived from cockle shells for carbon dioxide capture

Supattra Wongsaenmai*
Program in Materials Science, Faculty of Science, Maejo University, Chiang Mai, 50290 Thailand
***Corresponding Author**: wongsaenmai@yahoo.com

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Abstract

Global warming resulting from the emission of greenhouse gases, especially CO_2, has become a widespread concern in the recent years. The use of carbonation/calcination cycles of $CaO/CaCO_3$ is emerging as a viable technique for the capture of CO_2 generated in the combustion of coals for power generation. In this work, waste cockle shell was used as raw material for calcium oxide-based sorbent production. The thermal behaviour of waste cockle shell was characterized by thermogravimetric analysis (TGA) to obtain the calcination temperature range. Chemical property analysis using x-ray fluorescence (XRF), shows cockle shell is made up of 98.10% Calcium (Ca) element and CaO is produced after decomposition is conducted, as been analyzed by x-ray diffusivity (XRD) analyzer. Morphology of the waste cockle shell and the calcined waste cockle shell were characterized by scanning electron microscopy (SEM). It has been found that calcined waste cockle shell can absorb CO_2 in the temperature range of 500 ºC to 800 ºC. The results indicated that the CaO derived from waste cockle shell showed good usability to be used as CO_2 sorbent.

Keywords: Calcium Oxide; Cockle Shell; Carbon Dioxide; Sorbent

1. Introduction

Carbon dioxide is the major greenhouse gas, which is the largest contributor to global warming. The emission of carbon dioxide to the atmosphere has been identified as a major contributor to global warming [1 – 4]. A promising alternative for reducing the CO_2 emissions is the separation and/or capture and concentration of the gas and its subsequent chemical transformation. The solid absorption method is expected to have a large mass capacity for CO_2 separation, and is superior in cost and handing compared with liquid absorption method [5]. Alkaline metal oxides and alkaline earth metal oxides are easily reacting with CO_2 to form carbonates. CaO is the most studied because it sorption capacities at high temperatures (above 600 ºC). CaO absorbents produced by biomass materials is technically feasible, costly effective and advantageous to a certain extent in CO_2 capture. Since the waste of a cockle shell is found to contain around 98 % calcium, it can be a good source for $CaCO_3$ and yield CaO through the high temperature calcination process. In this study, the wasted cockle shells were used as a calcium source and CO_2 efficiency of CaO was procedure.

2. Materials and methods

The waste cockle shells were rinse with water to remove dust and impurities and were soaked for 24 hours in the hydrogen peroxide solution (50 % w w^{-1} in water) and then dried in an oven. The dried waste shell was calcined at 700 – 1000 °C in air atmosphere with a heating rate of 5 °C min^{-1} for 2 h. The solid were crushed and sieved to pass 100 – 200 mesh screens.

The thermal behavior of waste cockle shell was characterized thermogravimetric analysis (TGA) to obtain the calcination temperature range and chemical property analysis using x-ray fluorescence (XRF). The calcined powder was analyzed by x-ray diffusivity (XRD) and scanning electron microscopy (SEM), for phase formation and morphology, respectively. Afterwards, the carbonation stage was carried out at several temperatures between 500 °C and 800 °C. The overall carbonation time was set at 20 min for each of the tests. An atmosphere of pure CO_2 was used maintaining a constant flow rate of approximately 10 NmL min^{-1} at a pressure of 1 bar. A CO_2 analyzer was used to measured quantify CO_2 remained from CaO absorption.

3. Results and Discussion

Chemical analysis using XRF has been conducted to estimate the mineral composition in cockle shell. The finding demonstrates that cockle shell is made up of calcium, which have concentration of CaO 98.10 wt.%.

Table 1 Chemical analysis of waste cockle shell by XRF**.**

Sample	**Chemical content (wt.%)**					
	Al_2O_3	**SO_3**	**CaO**	**TiO_2**	**Fe_2O_3**	**SrO**
waste cockle shell	0.72	0.20	98.10	0.31	0.24	0.43

Thermogravimetric analyze of the waste cockle shell powder was performed. Fig. 1 Illustrates the weight losses of the sample analyzed during the process. The sample was continuous weight loss and then decomposed in three steps. The first step was the initial process, which started with a very small weight loss of 0.47% due to the moisture content in the samples [6]. Second, a rapid weight loss of 7.73% from 350 °C to 450 °C, which may be due to the removal of water molecules from the carbonate lattice. Third, the continuous change of weight loss from 450 to 1000°C were observed; in this temperature range, volatile minerals in the sample began to decompose, thereby releasing CO_2.This result indicates the total decomposition of calcium carbonate to CaO and signify the release of CO_2 from calcium carbonate. This assumption derived from the TGA analysis is also supported by the XRD data shown in Fig. 2.

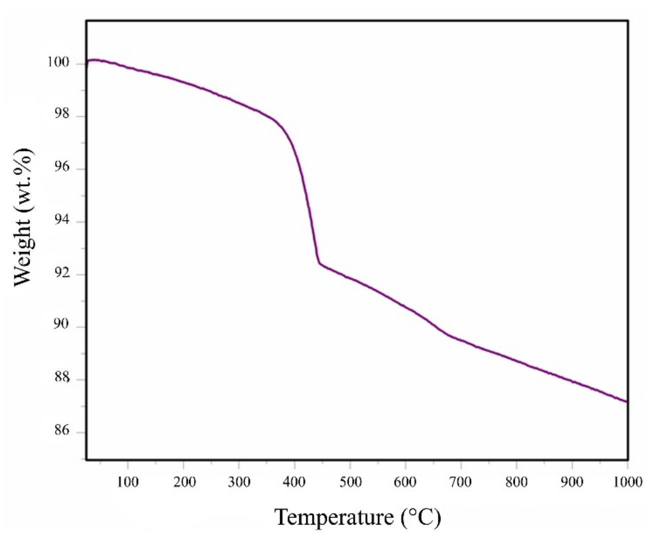


Fig. 1 TGA pattern of waste cockle shell.

XRD patterns of natural and calcined waste cockle shell are given in Fig. 2. XRD results revealed that the natural cockle shell mainly consists of $CaCO_3$ calcite (JCPDS file no. 05-0586) with the absence of CaO peak, as indicated by diffraction at 2θ around 29.29° [8]. However, with the increase in calcinations temperature, $CaCO_3$ completely transforms to CaO (JCPDS file no. 78-0649) by evolving the carbon dioxide (CO_2) at temperature 800 ºC. The calcined cockle shell at above 950 ºC mainly consists of the CaO along with low intensity peak of $Ca(OH)_2$ (JCPDS file no. 44-1481) that are attributed to the absorption of moisture due to the hydroscopic nature of the materials.

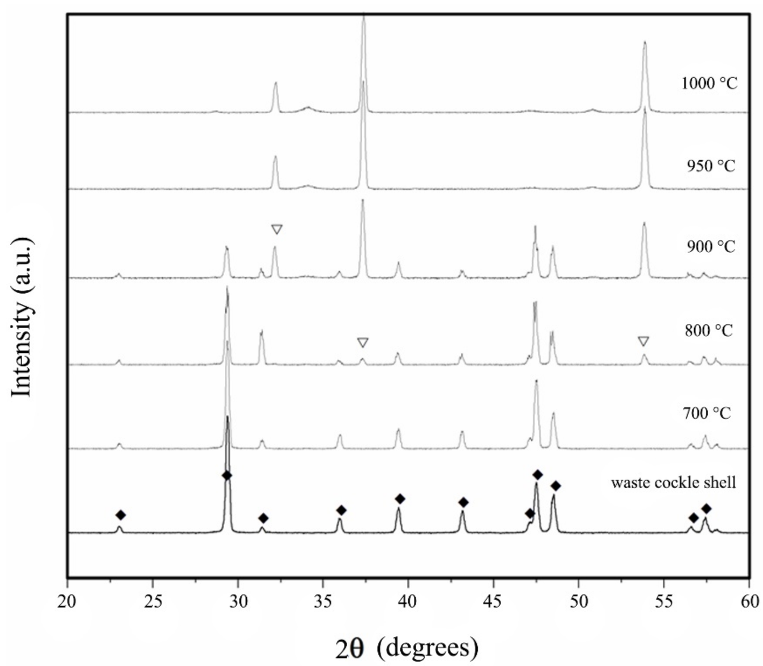
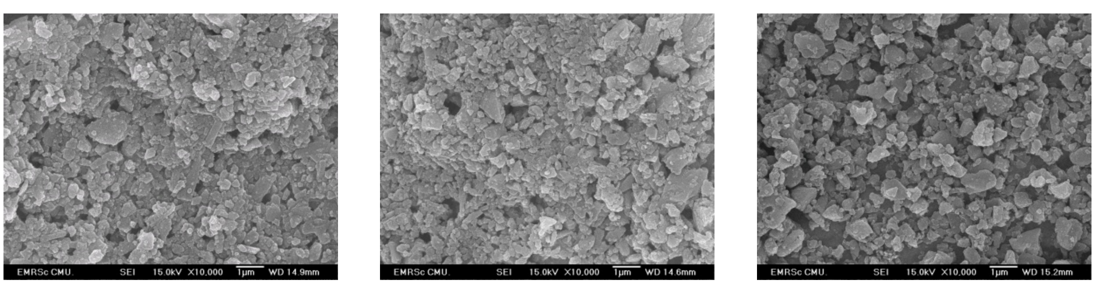


Fig.2 XRD patterns of waste cockle shell at difference calcinations temperature. (◆$CaCO_3$, ▽CaO)

The morphology of natural, cockle shell calcined at 950 ºC and calcined cockle shell treat CO_2 atmosphere at 700 ºC was examined by SEM (Fig. 3). The natural cockleshell displays spherical and needle-like grain shape [9]. The small amount of rod-like known as aragonite phase however it cannot detect by XRD technique. With the calcination temperature 950 ºC, the microstructures of cockle shell are similar to natural cockle shell. The microstructure changed after treat CO_2 atmosphere at 700 ºC which exhibits platelets and spherical grain.



(a) (b) (c)

Fig. 3 SEM images of (a) waste cockle shell, (b) calcined cockle shell and (c) cockle shell under CO_2 atmosphere

To investigate the influence of temperature on carbonation of CaO which derived from calcined cockle shell at calcination temperature 950 ºC. Fig. 4 shows XRD patterns of calcined cockle shell at difference temperatures under CO_2 atmosphere. The combination of $CaCO_3$ and CaO are observed to overall temperature. It confirm that the reaction between CaO and CO_2 to form $CaCO_3$. In addition, the maximum intensity of $CaCO_3$ peaks was identified at temperature 700 ºC [10]. According to amount of remained CO_2 measurement indicate that the minimum CO_2 remained from reaction at temperature 700 ºC.

Table 2 Carbon dioxide concentration of cockle shells by CO_2 analyzer.

CO_2 remained from reaction	Treat temperature (ºC) 500	600	700	800
CO_2 concentration (%)	46.58	25.56	10.90	70.44

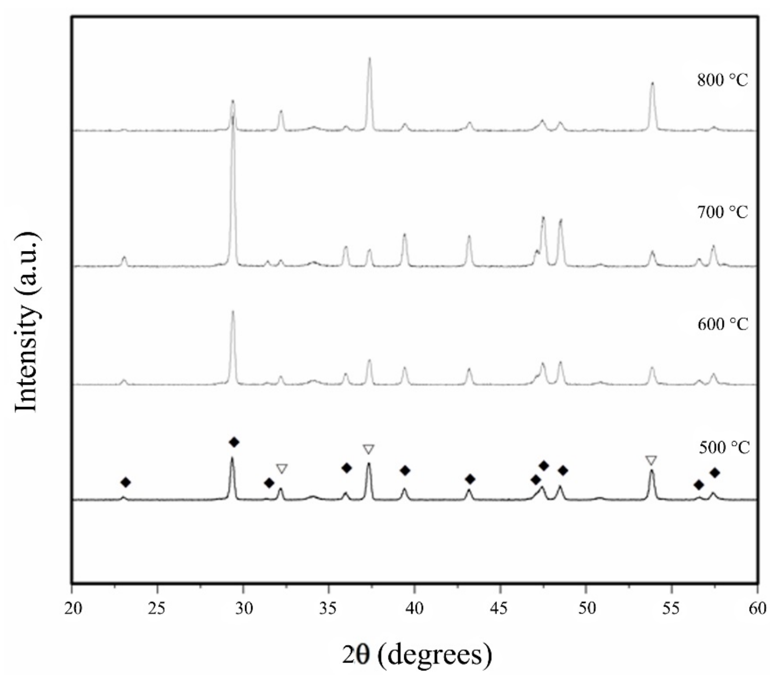


Fig. 4 XRD patterns of calcined cockle shell at difference heat temperature under CO_2 atmosphere (◆$CaCO_3$, ▽CaO).

4. Conclusion

The waste cockle shell absorbent was successfully synthesis and employed for carbon dioxide absorption. It found that chemical property analysis using x-ray fluorescence (XRF), shows wasted cockle shell is made up of 98.10% Calcium (Ca) element. The single phase CaO was obtained at temperature of 950 ºC, whereas other calcinations temperatures were found the secondary phase as $CaCO_3$. The efficiency of carbon dioxide absorption of CaO powders were performed by XRD and CO_2 analyzer. It has been found that CaO powders can absorb CO_2 in the temperature range of 500 ºC to 800 ºC. The best efficiency of carbon dioxide absorption was temperature at 700 ºC.

5. Acknowledgement

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