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New composite adsorbent for solar-driven fresh water production from the atmosphere

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Abstract

In this paper, a new highly-efficient water-selective composite adsorbent for solar-driven fresh water production from the atmospheric air is presented. It is synthesized by a patented ultra-large pore crystalline material MCM-41 as host matrices and calcium chloride as a hygroscopic salt. Experimental data demonstrate that adsorption capacity of the new composites is as high as 1.75 kg/kg dry adsorbent, which is higher than composites synthesized by silica-gel and calcium chloride, and the adsorption rate of the new composites is also found attractive. The desorption characteristics of the new composites are also studied, and it demonstrates that it can desorb more than 90% of the adsorbed water at lower heating temperature at about 80ºC. A solar-driven water production test unit using the new adsorbent is also presented and tested. The experimental tests of this developed unit demonstrated a feasibility of the fresh water production with the daily water productivity more than 1.2 kg/m^2 solar collector area.

Keywords: Adsorbent; Adsorption; Desorption; Solar energy; Water production from air

1. Introduction

It is well-known that sustainable water supply is of vital importance for many regions where the deficiency in natural water resources is getting serious. Yet the global atmosphere is a huge and renewable water resource which contains about 14,000 km^3 of water vapor.

The extraction of water from atmospheric air can be accomplished by three major principles including condensation method, absorption–regeneration method and adsorption–desorption method [1,2]. Water production by condensation requires multiple energy conversion processes when cooling is applied, and a large volume of air to be cooled that results in significant energy losses. In the absorption–regeneration method, there are some disadvantages which need electric energy

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because liquid absorbent needs to be circulated by a pump, and corrosion may occur because the liquid desiccant has highly corrosive characteristics. Adsorption–desorption method is based on adsorption of water vapor from atmospheric air during the night using solid adsorbent and recovery of the extracted water by heating the adsorbent and condensing the water desorbed. The advantages of the adsorption–desorption method include the following: no electricity required, simpler structure and lower cost. Furthermore, it should be noted that this system enables to operate at lower temperature and also has a capability of utilizing renewable energy such as solar energy. Fig. 1 illustrates a schematic of a solar-driven water production system from air by this method.

Based upon the advantages mentioned above, the adsorption–desorption method has been receiving an increasing attention. Bulang [3] has proposed a method with silica gel as adsorbent and found that about 30 g of water can be adsorbed by 100 g of silica gel. Sofrata [4] conducted experiments in Riyadh, Saudi Arabia, with an open cycle unit developed for water collection based on the adsorption–desorption principle using gasoline-fired furnace as heat source. A similar system using composite material for extraction of water from air is reported by Alayli et al. [5]. They have reported that evaporation was accomplished by solar energy and 1 kg of water per m^2 of the composite material was produced. Gordeeva et al. [6] and Aristov et al. [7] reported an application of newly developed water-selective adsorbents which consist of porous host matrices and hygroscopic substance impregnated into pores for fresh water production from the atmospheric air.

In the present paper, we present experimental results on the water adsorption and desorption characteristics for a new highly-efficient water-selective composite adsorbent [8] synthesized by a patented ultra-large pore crystalline material, MCM-41 [9] as host matrices and calcium chloride as hygroscopic salt. The test results have shown that the new adsorbent has better water-adsorption performance than conventional silica gels or composites synthesized by silica gel and hygroscopic substance.

2. Experimental study

2.1. Sample preparation

The confined “calcium chloride–MCM-41” composites were synthesized by filling the MCM-41 pores with aqueous solutions of calcium chloride with different concentrations. Firstly, four different $CaCl_2$ aqueous solutions with 20%, 25%, 30%, 35% in mass concentration were prepared by dissolving dry $CaCl_2$ into water. The solutions were cooled down to ambient temperature under airproof condition for avoiding water absorption. Then the ultra-large pore crystalline material MCM-41 was dried at 200ºC until its mass remained unchanged and cooled down to room tem-

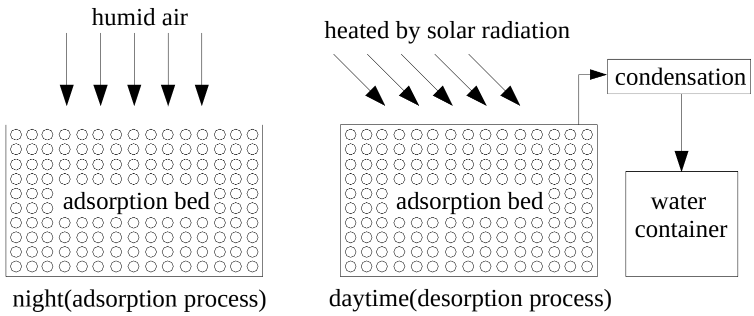

Fig. 1. Schematic of the solar-driven water production system from air.