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Mini Review

Development of Polymers Coated with Immobilized Carbonic Anhydrase for CO_2 Capture and its Application

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Abstract

The rocketing CO_2 emissions has caused intensified global warming effect to human beings. Although several approaches have been proposed to reduce atmospheric CO_2 emissions, high temperature condition and high energy consumption make those approaches hard to carried out in industrial application. Carbonic Anhydrase (CA) catalyzed hydration reactions or aqueous solvents are a potential alternative in conventional amine-based CO_2 capture, for its energy saving and excellent performance. However, free CA will significantly increase the CA amounts and system cost, as well as decreasing the system efficiency. To face the mentioned issues, some new methods of immobilization of CA are introduced, which can help to provide new ideas for alleviating greenhouse effect and global warming.

Keywords: Polymer; Carbonic anhydrase immobilization; CO_2 capture; Greenhouse effect control

Introduction

Human beings have been lived on fossil fuels, like oil, coal and nature gas, since the Industrial Revolution, leading to sharping increasing of atmospheric greenhouse gas [1]. The increasing greenhouse gas in atmosphere has aroused severe global warming and threatened creature livings on Earth. To alleviate greenhouse effect and global warming, many governments and organizations have taken action to reduce artificial greenhouse gas emission, especially CO_2 [2]. Research show that amine-based chemical absorption technology [3] is the most prevailing approach in CO_2 control. However, it is also pointed out that amine-based chemical absorption technology not only needs intensified energy to regenerate but leads to degrade and toxicity issue. As a result, amine-based chemical absorption technology might not seem like the best solution for CO_2 control.

Recently, CA catalyzed CO_2 control technology have entered scholars' vision [4]. Due to CA's activity, it can catalyze CO_2 hydration reactions, greatly improving CO_2 absorption rate than those non- catalyzed. Besides, its end products are very stable and are environmentally friendly. Therefore, CO_2 capture using CA is the most promising method at present. But CA also has its one disadvantages. Free CA is a kind of vulnerable enzyme and easily turns to deactivated under extreme working condition, like high temperature and amine environment [5]. What's more, free CA is also hard to recover and recycle. Therefore, immobilized CA on certain material can greatly improve CA performance and lower cost of whole system. This review describes several methods, immobilizing CA on certain polymer materials, that improving CA performance. Those methods in improving CA performance will become a prevailing way in application.

Discussion

Polyurethane (PU)

Bovine Carbonic Anhydrase (BCA) was immobilized within PU foam, and the kinetic parameters of the immobilized enzyme K_m decreased from 12.2mmol/L to 9.6mmol/L, compared with the free enzyme [6]. However, the thermal stability of the immobilized enzyme was significantly enhanced (Figure 1). After 7 cycles of continuous operation in the reactor or 45 days of storage at room temperature, the enzyme activity remained 100%, while the free enzyme was completely inactivated even after 45 days of storage at 4 °C. There was also other paper pointed out that immobilized SspCA on PU foam had an excellent thermal stability It could survive for 48h at 100 °C and work for a long time at 70 °C and could be used in the reactor of high-temperature CO_2 capture in thermal power plants [7].

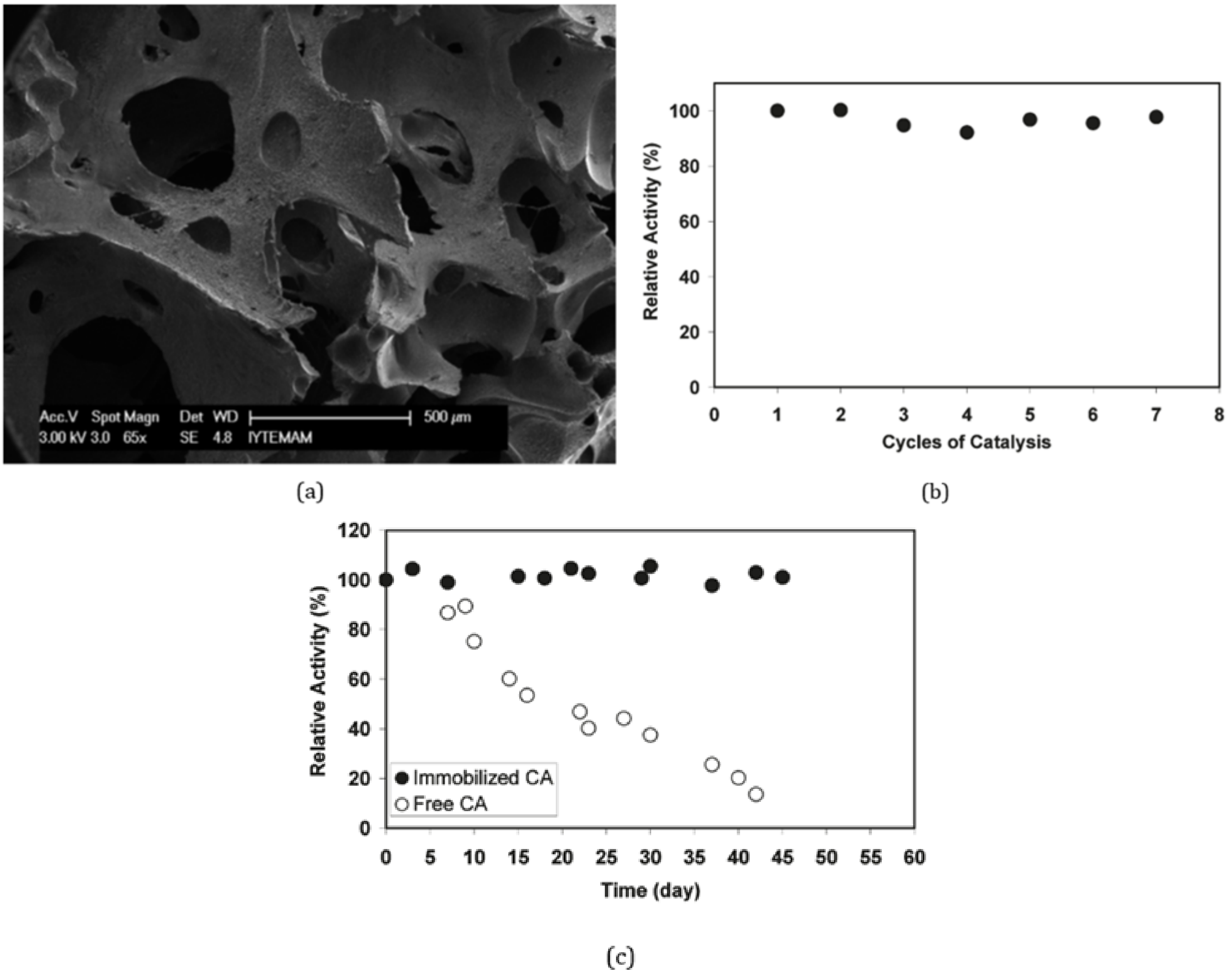

Figure 1: Performance of immobilized CA on PU foam:(a) SEM image of the PU foam, (b) Cycle of usage for CA immobilized within PU foam, (c) Stability of the free (at 4 °C) and immobilized (at room temperature) CA in Tris buffer.

Chitosan

CA enzyme from Bacillus Pumilus could be immobilized on the surface of chitosan at room temperature, and the stability of the immobilized enzyme to heat and inhibitor was improved [8]. After holding at 50 °C for 90 days under the same conditions, the immobilized enzyme could maintain 60% activity of the initial enzyme, while the free enzyme was only 30%. Meanwhile, the precipitation rate of $CaCO_3$ was twice as that of free enzyme within 5min (Figure 2).

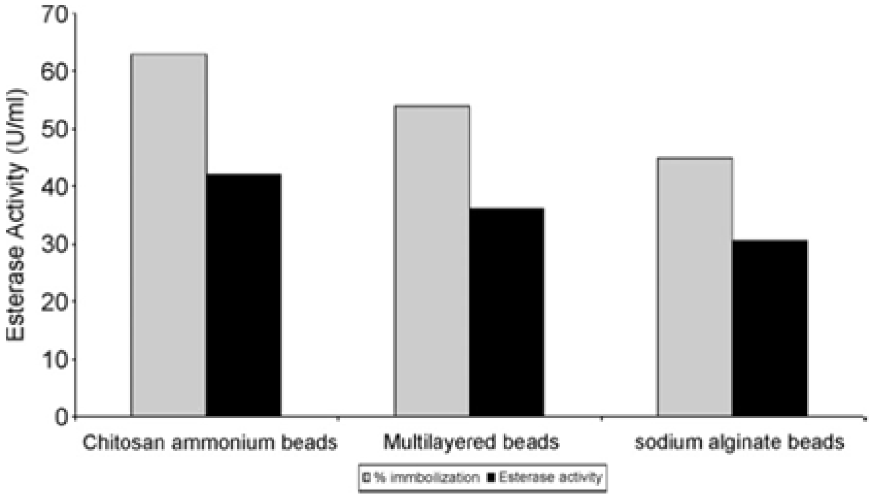

Figure 2: Percent immobilization and esterase activity of *Bacillus pumilus* on matrices.

Nanoparticles

Bovine Carbonic Anhydrase (BCA) could be covalently immobilized onto chemically treated Fe_3O_4/SiO_2 nanoparticles by using glutaraldehyde as a spacer [9]. The CO_2 capture capacity of the immobilized enzyme was 26 times that of the free enzyme after 30 cycles in the reactor. The immobilized enzyme could retain 82% activity of the original enzyme after 30-day storage at room temperature (Figure 3). The magnetic nano biocatalyst was shown to be an excellent reusable catalyst for CO_2 capture. Besides chemically treated nanoparticles, alginate nanoparticle was another option for CA immobilization [10]. The immobilized CA showed a better operational stability, retaining nearly 67% of its initial activity even after six cycles. Besides, the microspheres with the smallest particle size had the highest enzyme activity. What's more, compared with free enzyme, the thermal stability of immobilized enzyme was significantly enhanced, and its optimal temperature was increased by nearly 10 °C (Figure 4).

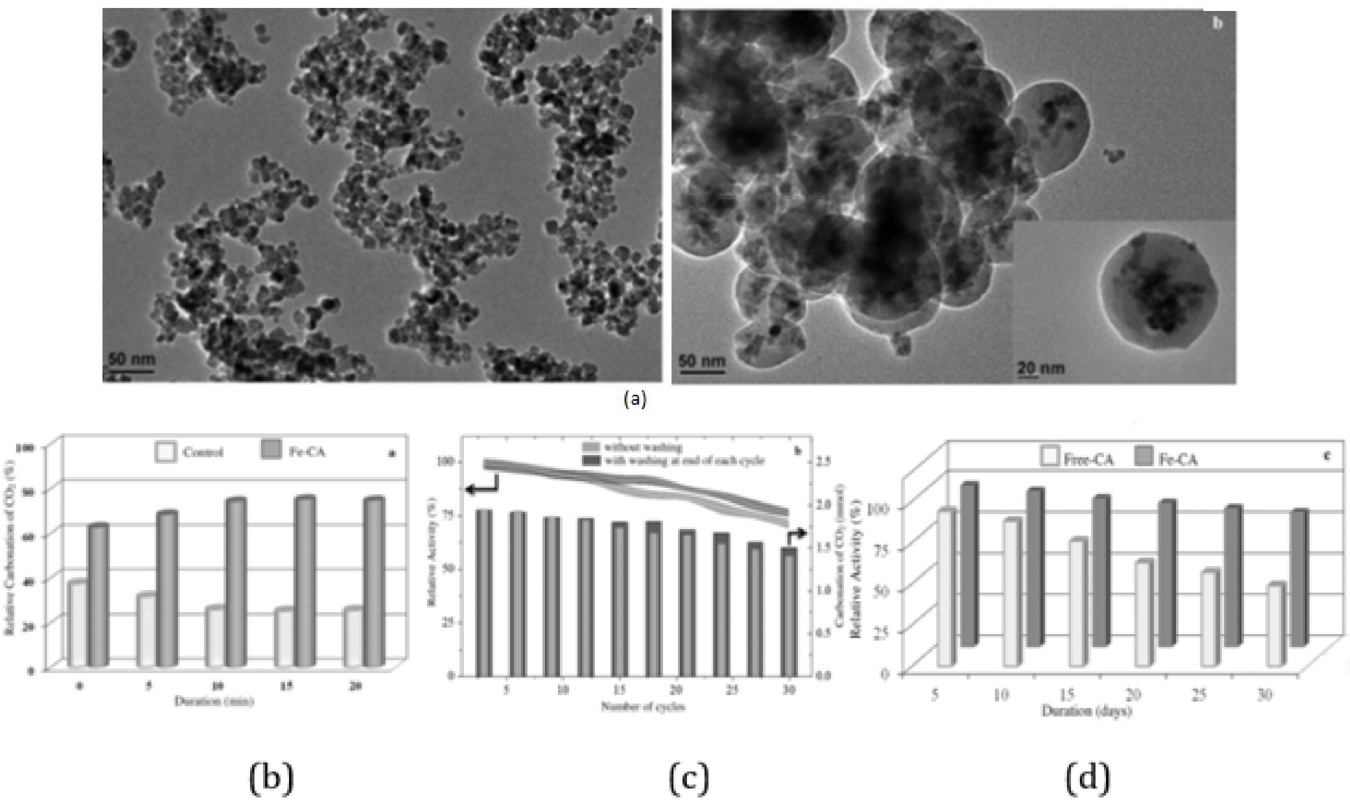

Figure 3: Performance of immobilized CA on nanoparticles (a) HRTEM images of Fe_3O_4 and $Fe_3O_4/SiO_2/OAPS$, (b) Optimization of control experiments, (c) Reusability of Fe-CA, (d) the effect of storage stability.

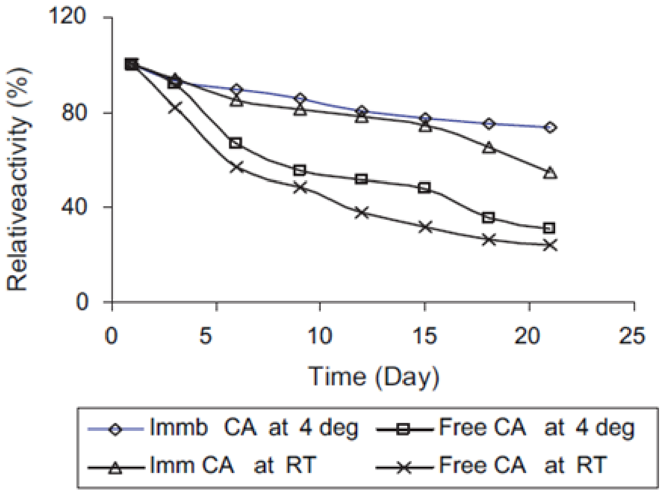

Figure 4: Stability profile of CA at various conditions.

Conclusion

In conclusion, although CA is potential catalyst in CO_2 capture, the stability and reusability of CA is still too poor for application. Much research has confirmed that immobilized CA on certain material can greatly improve CA performance and lower cost of whole system, especially some polymer material. Polyurethane, chitosan and even nanoparticles are possible immobilization material for CA and those immobilization material can greatly improve CA performance in CO_2 capture, which can greatly promote the industrial application of CA-based CO_2 capture.

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