Nonthermal Plasma Treatment of Solid Adsorbents for CO_2 Capture

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Abstract: In this work, we report the effects of three different radiofrequency (RF) plasma compositions on the hydrophobicity of solid adsorbents. We show that surface treatment using nonthermal plasma (NTP) is a viable method for improving the hydrophobicity of solid adsorbents to increase their selectivity for CO_2 uptake.

1. Introduction

As CO_2 emissions rise, adsorption technology has quickly gained interest. However, one of the main challenges is the cost of CO_2 capture technologies [1]. As a result, development of novel materials and modification techniques is required to reduce the cost of carbon capture while providing a feasible route for meeting the net-zero target. Solid adsorbents, such as carbon-based materials, have offered a promising alternative to combat the energy and regeneration requirements of traditional CO_2 adsorption [2,3]. It has been shown that gas separation and uptake can be optimized by controlling pore size and surface functionality of these materials [4]. Nonthermal plasmas (NTPs) provide the low-temperature, highly reactive environment required for surface modification without the risk of thermal degradation [5]. In this work, we explore the enhancement of spherical activated carbon (SAC) hydrophobicity through exposure to three different NTP environments.

2. Methods

The NTP used is a low-pressure continuous wave capacitively coupled radio-frequency (RF, 13.56 MHz) plasma. The reaction chamber, enclosed in a Faraday cage, consists of a glass tube with five copper strap electrodes which alternate between live and ground (see Figure 1). The solid adsorbents are placed on a porous frit in the centre of the glass tube. The surface functionality and hydrophobicity are altered through exposure to three different plasma environments: Ar, NH_3, and O_2.

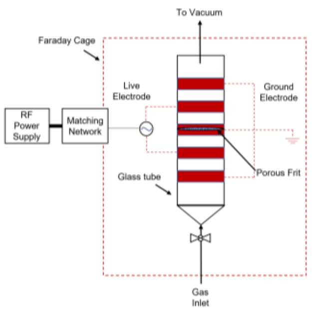

Fig. 1. Schematic of custom-made RF NTP.

3. Results and Discussion

Optical emission spectroscopy (OES) was used to identify the chemical species generated by the plasma with varying plasma gas compositions. Figure 2 (left) shows the typical spectrum obtained for Ar, NH_3, and O_2 plasmas.

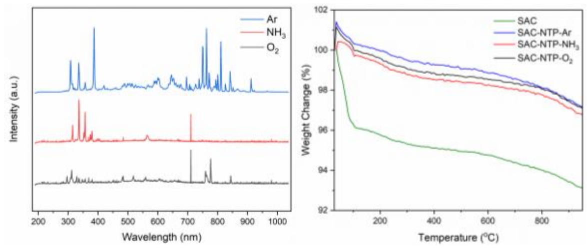

Fig. 2. OES (left) and TGA (right) data for three different plasma compositions.

Thermogravimetric analysis (TGA) was used to evaluate the plasma conditions that resulted in the highest degree of surface change. From the TGA oxidation data shown in Figure 2 (right), the mass loss at 100 °C reduced from 4 % to less than 1 % with plasma treatment, with Ar plasma having the greatest effect. This mass loss is due to the desorption of water; thus, the decrease reflects a reduced amount of physisorbed water on the plasma treated SAC, suggesting an increase in surface hydrophobicity.

4. Conclusion

This work demonstrates that NTP treatment of solid adsorbents can be used to improve material hydrophobicity, predicted to result in an increase in CO_2 capture. This process can be customized for various solid adsorbents, providing a promising approach for overcoming the high cost and energy requirements of typical CO_2 adsorption methods.

Acknowledgement

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