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Post-combustion carbon dioxide capture: Evolution towards utilization of nanomaterials

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ABSTRACT

Carbon dioxide (CO_2) is not the gas that gives the most severe global warming impact among the greenhouse gases (GHGs). However, its highest annual emission into the atmosphere makes it the most imperative anthropogenic GHG. This elevated emission is primarily coming from fossil fuel power plants. Hence, post-combustion CO_2 removal from power plants becomes crucial in global warming mitigation as it can be retrofitted directly into an existing plant. CO_2 removal technology nowadays is utilizing solvent-based sorbents, such as amine solutions and ionic liquids. Many extensive research works have been carrying out to improve the constraints of existing technology. In this paper, a general review on existing CO_2 removal technologies, existing research works on CO_2 removal sorbents was done. In conjunction with that, we will look into the potential and development of nanomaterials as CO_2 removal sorbents in the future. Nanomaterials have shown their potentials in CO_2 capture with its high surface area and adjustable properties and characteristics. Many limitations in existing technology were found improvable by nanomaterials.

Contents

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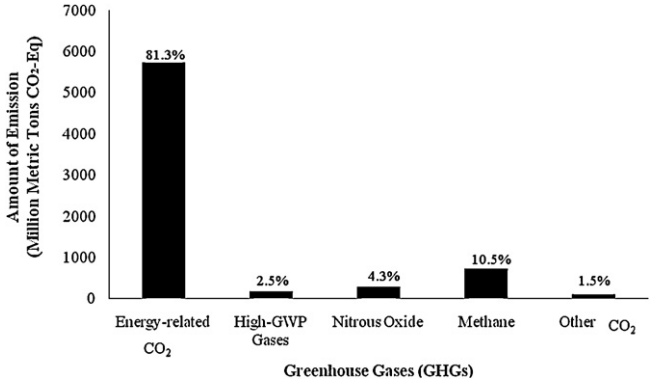

Fig. 1. GHGs emissions in United States by year 2008 [3]. High-GWP gases referred to high global warming potential gases, e.g. hydrofluorocarbons (HFCs), perfluorocarbons (PFCs), and sulfur hexafluoride (SF_6).

1. Introduction

Carbon dioxide (CO_2), methane (CH_4), nitrous oxide (N_2O), hydrofluorocarbons (HFCs), perfluorocarbons (PFCs) and sulphur hexafluoride (SF_6) have been listed in Kyoto Protocol 1998 as greenhouse gases (GHGs) [1]. CO_2 are the most important GHG because it emission is notably high compare to the others. CO_2 emission was recorded at 29.6 billion metric tons by year 2007 compared to 21.9 billion metric tons by year 1997 [2] and yet the figure is increasing from time to time. In United States, one of the highest CO_2 emission country, CO_2 emission is 81.3% of the total GHGs emitted [3]. By 2007, global CO_2 concentration hit 383 ppm which was 37% higher than pre-industrial period level [4]. Other GHGs concentrations are relatively low. For instance, concentration of CH_4 and N_2O in the atmosphere were only 1774 part per billion (ppb) and 319 ppb, respectively, during 2005 [5]. Fig. 1 shows the comparison of the anthropogenic GHG emission in United States by year 2008. The data is reported in unit CO_2-equivalent (CO_2-eq), which is used to compare emission of different GHGs by counting their accumulated radiative forcing towards global warming effects over a given time period. Apparently, CO_2 gave highest impact to global warming among all the listed GHGs.

In nature, CO_2 will be absorbed by earth, either by weathering of rocks, photosynthesis of plants or ocean sinks by photosynthesis of marine plankton [6]. These natural sinks phenomena have balanced the natural source of CO_2 emission into the atmosphere over centuries. Excessive emission of CO_2 since industrial era has made these natural removals became not sufficient anymore to maintain the CO_2 concentration in the atmosphere. CO_2 which was not being absorbed accumulated in the atmosphere and result in a drastic raise in CO_2 concentration. Every 3–5 gigatonnes of carbon will contribute to 1 ppm raise of CO_2 concentration in the atmosphere [7]. During the 1970s, CO_2 concentration in atmosphere increased by 1.3 ppm per year and this figure became 2.2 ppm per year by 2007 [4]. Fig. 2 shows the increasing trend of global CO_2 emissions and its concentrations over years. Intergovernmental Panel of Climate Change (IPCC) predicted 2–3 °C of temperature increase from now [8] is dangerous, while Hansen et al. [9] argued that 1 °C rise of global temperature is the maximum tolerance for global warming to prevent the melt of the ice sheet and precious species extinction. To prevent global warming from endangering the world, climate models estimated that CO_2 concentration cannot exceed 450 ppm [9]. Scientist predicted the safe value for CO_2 concentration in atmosphere is 350 ppm while CO_2 concentration of the atmosphere is 383 ppm nowadays [4]. Hence, ideally, no more daily emission of CO_2 is allowed yet the live-long GHG in the atmosphere need to be removed.

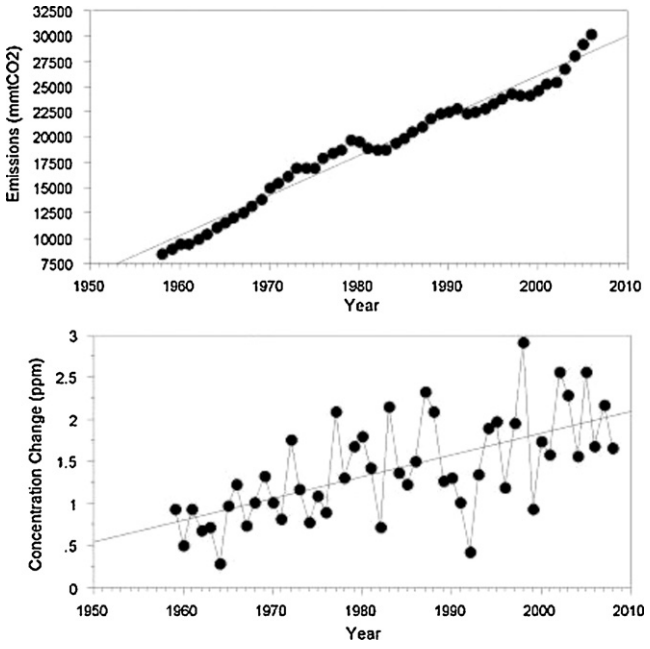

Fig. 2. (Top) Annual total global CO_2 emission; (bottom) annual change in CO_2 concentration [84].

1.1. Main CO_2 sources

Energy supply sector contributed apparently higher emission (26%) compared to the other sectors in GHGs emission as shown in Fig. 3a. This sector is particularly referred to fossil fuel (including coal, natural gas and oil) power plants which are dominant in generating and supplying electricity (Fig. 3b). As second major CO_2

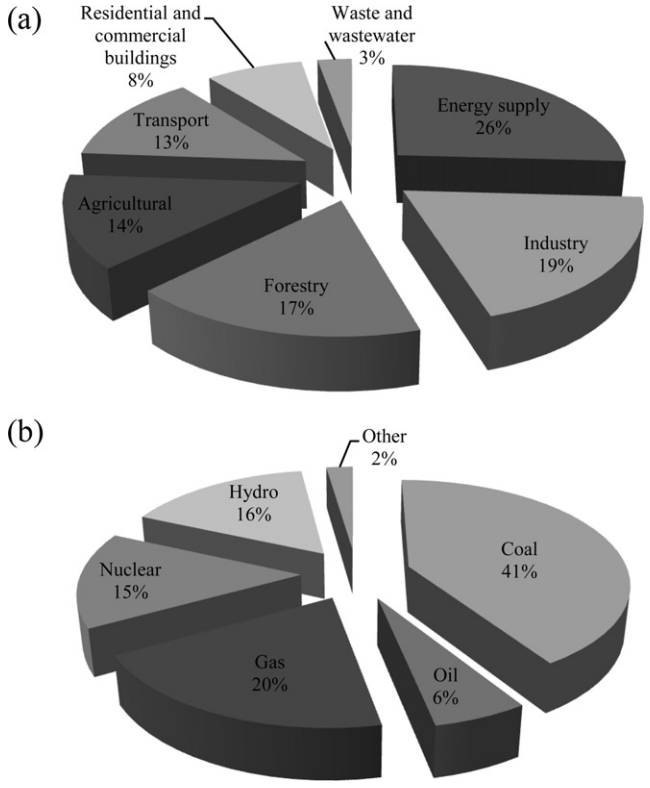

Fig. 3. (a) Total anthropogenic GHG emissions from different sectors in 2004 (in terms of CO_2-eq) [5]. (b) Total world electricity generation in 2006 [22].