Post Combustion Carbon Capture Using Polyethylenimine Functionalized Titanate Nanotubes: Review and Preliminary Work

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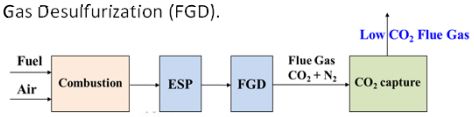
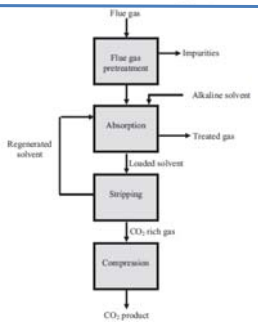
Introduction

- The increasing CO_2 emissions have a critical impact on climate change and global warming, and have become a matter of great concern.
- Effective CO_2 emission abatement strategies such as carbon capture and storage (CCS) are required to combat this trend.
- Additional energy is required for CO_2 capture, and thus it is critical to capture CO_2 efficiently.
- Three major approaches for CCS are pre-combustion capture, post-combustion capture and oxyfuel process capture.

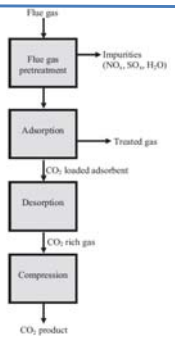
Post-Combustion Capture[1,2]

- In post-combustion capture, CO_2 is removed from the flue gas after the combustion of the fossil fuel with air. The flue gas has low CO_2 content and low pressure (about 1 bar).
- Usually the pre-removal of NO_x and SO_2 from a flue gas is required before carbon capture.
- Main challenge: the low CO_2 partial pressure in the flue gas. 12-14% CO_2 in a flue gas for coal fired power plants and about 3.2-4.2% for natural gas based power plants.
- Big Advantage: Post-combustion carbon capture is especially desirable due to its potential to retrofit existing power plants with reasonable cost.
- CO_2 is captured after the flue gases are cleaned up by Electro Static Precipitator (ESP) and Flue Gas Desulfurization (FGD).





Absorption (liquid phase) [3]



Adsorption (solid phase) [3]

Absorption Technologies

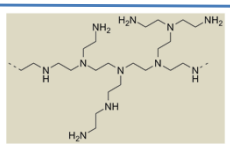
- **Amine absorption which is commercially available**
- **Aqua ammonia absorption**

Adsorbents for Post Combustion CO_2 Capture

Zeolites, activated Carbon, amine functionalized adsorbents and metallic organic frameworks[4,5]

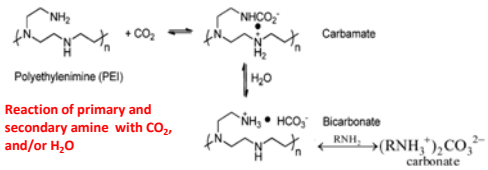
Polyethylenimine (PEI)

- Linear PEI fragments
- Branched PEI fragments
- Dendrimer

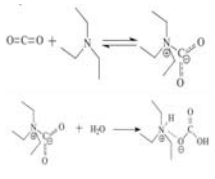


CO_2 is captured when PEI is combined with different support materials like mesoporous silica, mesoporous alumina, zeolites, carbon nanotubes, porous polymer, titanate nanotubes, clay and metal organic frames (MOF) [6-9]

Possible Mechanisms of CO_2 Reactions with Branched PEI[6-9]



Reaction of primary and secondary amine with CO_2, and/or H_2O



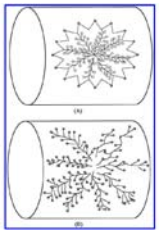
Reaction between CO_2, H_2O and tertiary amine

First Application of PEI Polymer on CO_2 Capture[10]

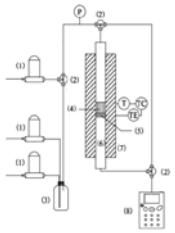
- Able to remove low concentration of CO_2 (~1 Torr) under ambient temperatures and pressure.
- Release CO_2 at low temperature (40°C) in vacuum

PEI-Modified Mesoporous MCM-41[11]

adsorbents	temperature (°C)	adsorption capacity (mg/g-adsorbent)	desorption capacity (%)
MCM-41 only	50	14.3	100
MCM-41 only	75	8.6	100
MCM-41 only	100	6.6	99
MCM-41-PEI-15	75	19.4	101
MCM-41-PEI-30	75	68.7	98.3
MCM-41-PEI-50	50	44	24.7
MCM-41-PEI-50	75	112	99.8
MCM-41-PEI-50	100	110	84.1
MCM-41-PEI-75	75	133	101
PEI	75	109	56.4



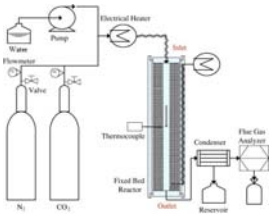
PEI functionalized Protonated Titanate Nanotubes (PTNTs) [12]



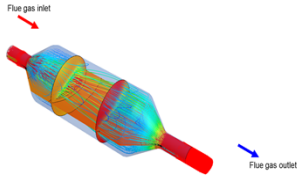
- PTNTs are self-assembling nanostructures and have uniform pore size suitable for absorbents and catalysts supports.
- PEI-PTNTs were prepared by wet impregnation method.
- Experiments of PEI-PTNTs-50 exhibited high adsorptions at 75 and 100°C.
- Strong chemical bonding between PEI and PTNTs may guarantee the stability of nanostructures in CO_2 capture from power plant flue gas.

Our Research Plan and Experimental Setup

- Develop optimized protocols for synthesis of TiO_2 nanotubes impregnated with PEI.
- Characterize the impregnated nanotubes and use it for refining the parameters for synthesis such as temperature, concentration and time.
- Develop computational fluid dynamic (CFD) simulations of the carbon capture process in the reactor to optimize the reactor conditions for high carbon capture efficiency.
- Demonstrate the efficiency of impregnated TiO_2 tubes for carbon capture under various environmental conditions such as temperature and concentration.
- Establish a validated CFD model and a standard operating procedure for carbon capture using PEI impregnated TiO_2 nanotubes.



Schematic of experimental setup



CFD modeling : Porous media

Summary

- Discussion of post combustion CO_2 capture
- Comparison of absorption and adsorption for post combustion CO_2 capture
- Different promising technologies associated with branched PEI for CO_2 capture
- We prefer to further develop **PEI Functionalized Protonated Titanate Nanotubes** for post combustion CO_2 capture based on our investigation of current solid adsorbent technologies with PEI.

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