Time for a new paradigm on carbon dioxide as a valuable carbon source: Polymer-silica hybrid adsorbents for extracting CO_2 from the air

Miklos Czaun, Alain Goeppert, G. K. Surya Prakash, George A. Olah

Loker Hydrocarbon Research Institute and Department of Chemistry, University of Southern California, University Park Campus, Los Angeles, CA 90089-1661, USA

The intensive consumption of fossil fuels has resulted in a rapid increase of carbon dioxide concentration in the atmosphere from 270 ppm before the industrial revolution to the present 400 ppm. There is a clear consensus that anthropogenic CO_2, due to its role as a greenhouse gas, is the major contributor to global warming and climate change. Other consequences of these increasing emissions such as melting of ice caps, rising of sea level, ocean acidification, alterations in the hydrologic cycle, frequent occurrence of climate extremes and unpredictable changes in biodiversity are also becoming increasingly apparent and worrisome.

However, we may approach this obvious problem in a different way. It is time for a new paradigm on CO_2! We should consider carbon dioxide as an ultimate raw material and C1 feedstock of the future rather than a harmful greenhouse gas bearing in mind that fossil fuel reserves are finite (Figure 1). The recovery of CO_2 directly from the air, coined as 'air capture', can be a solution to our carbon conundrum.

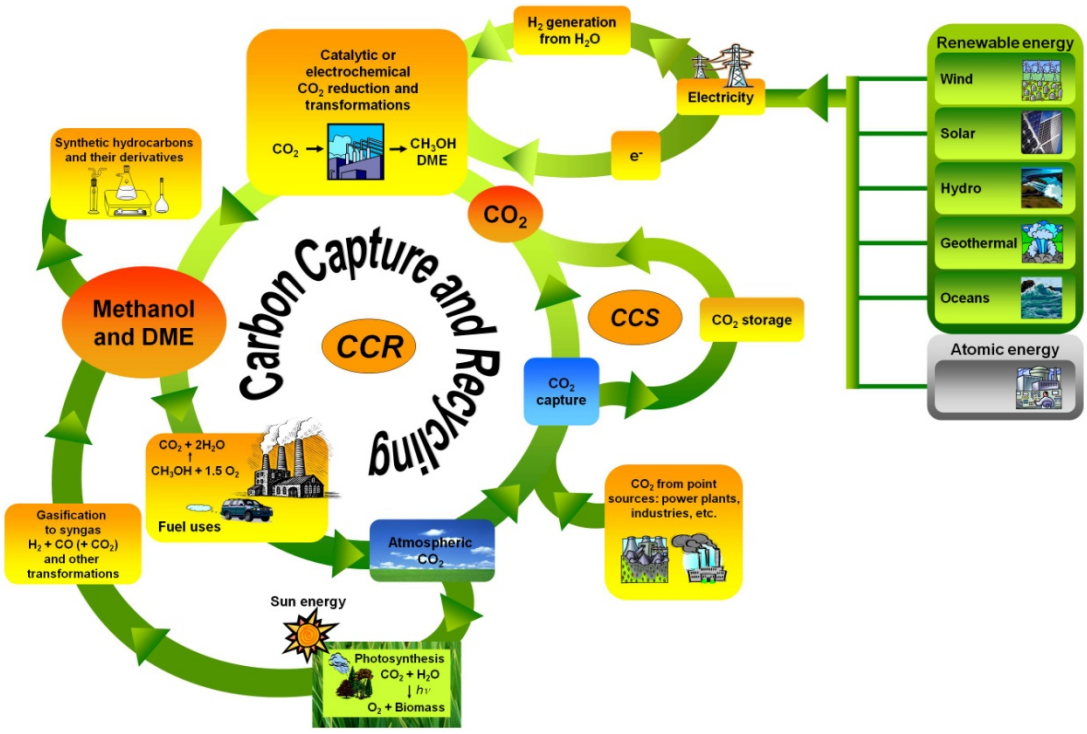
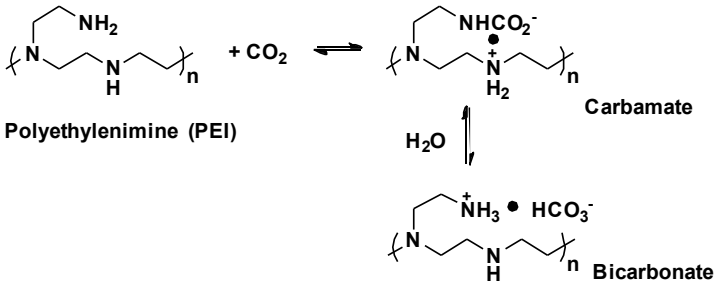


Figure 1. Anthropogenic carbon cycle.

Developing more feasible alternatives for CO_2 adsorption is part of our ongoing efforts (Methanol Economy®)[1] on CO_2 capture and its conversion to value added products such as methanol,[1-3] dimethyl ether,[2] formic acid[4-5], methyl formate and eventually to most of the important petrochemical intermediates such as ethylene and propylene, which are presently produced from natural gas or petroleum oil.

Silica-organoamine hybrid materials with amine components[6-7] were applied to recover carbon dioxide from air via temperature-swing or pressure-swing adsorption/desorption or the combination of thereof (Scheme 1).



Scheme 1. Chemisorption of CO_2 with polyethyleneimine (PEI).

The newly developed polyethyleneimine (PEI) on fumed silica (FS) adsorbents are easy to prepare from cost effective materials and they are able to reversibly adsorb and desorb CO_2 under mild conditions in repeated cycles (Scheme 1). The novel adsorbents can operate under both dry and humid conditions which is a great advantage compared to zeolites *viz*. zeolitic materials lose most of their CO_2 adsorption capacity in the presence of water.

Present adsorption capacity values under humid conditions (e.g. 78 mg/g adsorption for FS-PEI-33) are among the highest reported for CO_2 adsorption from the air!

Some important methods (e.g. dry reforming, bi-reforming, CO_2 hydrogenation) to convert the captured carbon dioxide to value added intermediates and products such as syngas, methanol and formic acid will be highlighted. In addition, advanced techniques (e.g. direct methanol fuel cell) to recover the stored energy from methanol will also be discussed.

References

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