Chemical Research Gruop

Chemical Group Activity

Extensive usage of fossil fuels is causing CO_2 emission increase and rapidly increasing the atmospheric CO_2 concentration which causes the global warming. The atmospheric CO_2 concentration should be stabilized at a low level to mitigate the global warming.

There are two measures for the atmospheric CO_2 stabilization. One is to reduce CO_2 emissions and the other is to sequestrate emitted CO_2 into the land or ocean (Carbon Capture and Storage, CCS).

A scenario of the CO_2 stabilization determines scales and schedules of the implementation of measures. A stabilization level of 550ppm at 2100 which is two times higher than the CO_2 concentration before the industrial revolution is generally considered.

It is difficult to stabilize at 550ppm only by the implementation of technologies of energy efficiency improvement and of fuel switching to renewable energy sources.

Therefore, as additional stabilization options CCS technologies which have high potential for the stabilization should be developed for a practical use. Reduction of the energy consumption and also cost of CCS system is essential for its practical use.

For that purpose, basic technologies ranging to three fields of material, process and system are necessary for innovative technology elements.

Our chemical group has worked for establishing and accumulating those technologies and also is advancing them.

At present, we are focusing our research activity to establishment of a CCS system in ten years using our technology elements.

Our R&D work on them relates to not only CCS, but also new energy systems enabling the construction of sustainable carbon cycle society.

Chemical Absorption Process

A new CO_2 capture project by chemical absorption process has been started with collaboration of three Japanese companies since fiscal year 2004 as a five-year project.

The project aims at reducing a CO_2 capture cost to half and includes two main research objectives: One is to develop higher-performance chemical absorbents and the other is to utilize low-grade waste heat in integrated steel works in order to provide CO_2 capture process with low-cost energy.

RITE has especially worked on developing the new absorbents. Both experimental and theoretical studies on the reaction characteristics of amine compounds with CO_2 are carried out and clarifying chemical structure of hopeful absorbents is done. The newly-developed absorbent will be graded as the highest-performance one.

Practical development of membrane /absorption hybrid separation technique

Membrane/absorption hybrid method has been studied as a new CO_2 separation technology. (The work was supported by NEDO and guided by Prof. Teramoto, Kyoto Inst. of Technology, in 2001-2003 fiscal year.) In this method, CO_2 is absorbed in the absorbent liquid in one side of the porous membrane and emitted in the other side with the liquid permeation under the reduced pressure. This method is characterized by drastically little energy consumption compared to the current separation method and highly concentrated CO_2 obtained. At present, cooperation with the companies is promoted for applying this method to the separation of CO_2 from flue gas, chemical process, bio-process, etc.

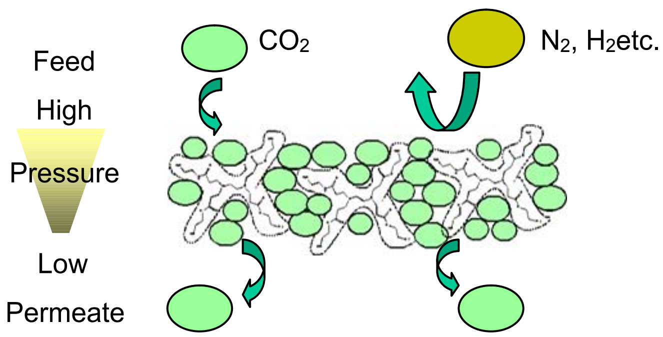
Polymeric membrane

One promising means of lowering the cost of CO_2 separation is the development of new, high-performance CO_2 separation membranes that allow CO_2 recovery via membrane separation. RITE is now involved in developing just such polymeric separation membranes.

Cardo polyimide having fluorene moiety was modified in the chemical structure for good CO_2 separation properties. The asymmetric hollow fiber membrane of the cardo polyimide shows the largest CO_2 permeance among existing asymmetric membranes and the top level of CO_2 selectivity in various polymeric membranes. A module of the membrane can recover CO_2 from an exhausted gas of 25 % CO_2 concentration at a comparable expense to amine solution by a system involving CO_2 liquefaction. For a higher CO_2 concentration flux, the membrane separation will have an advantage over amine solution in the system.

RITE is currently developing a CO_2 molecular gate membrane with the goal of producing a new, high-performance separation membrane. Figure shows the basic outline of the CO_2 molecular gate function. The pathway for gas molecules is occupied solely by CO_2, which acts as a gate to block the passage of other gases. Consequently, the amount of N_2 or H_2 leaking to the other side of the membrane is greatly limited and high concentrations of CO_2 can be obtained. The membrane of RITE dendrimer shows excellent CO_2 selectivity of more than 1000, which would have a potential to replace amine solution.

CO_2 Molecular Gate Membrane:



In developing this CO_2 molecular gate membrane, RITE conducted joint research with the US Department of Energy's National Energy Technology Laboratory (NETL) and the University of Texas at Austin (UTA).

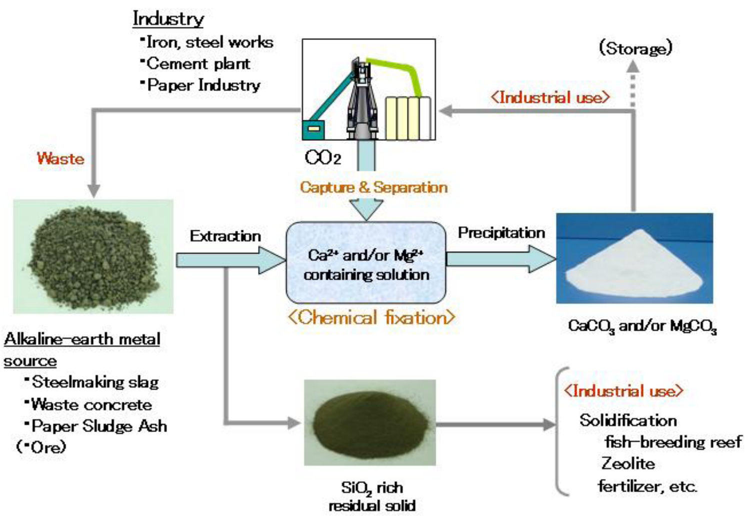
Partially carbonized membrane is a fresh subject under a founding from Global Climate and Energy Project (GCEP) in Stanford University.

Inorganic membrane

Since zeolites and mesoporous silicas possess well defined micro/meso-pores, considerable attention has been focused on the production of membranes that are capable of separating gases with high selectivities. Polymer membrane shows good affinity for CO_2, however, thermal expansion/mobility of polymer at high temperature causes degradation of CO_2 selectivity. Since mesoporous slicas have uniform and large pores as well as high surface area, a large number of active sites or adsorption sites can be introduced uniformly on inorganic rigid pore wall by chemical grafting of surface OH group with organosilane molecules. We have studied surface functionalization of the pore wall of various mesoporous silicas that are specialized for CO_2 capture and separation; already reporting that the CO_2 adsorption capacities of aminosilane modified SBA-15 mesoporous silicas. Based on this study, we have started fabrication of organic-inorganic hybrid type membranes using zeolite or mesoporous solids. If such a material is prepared in the thin film, a molecular movement of the functional group connected with a rigid inorganic pore wall is restricted, and it seems that the decrease in the CO_2 selectivity because of an increase in a free volume by thermal expansion/movement of polymeric material in the high temperature region can be controlled. This research proposal was awarded by GCEP(Global Climate & Energy Project) of Stanford University, and the project research will start in September, 2005.

CO_2 fixation as carbonates

Fixation of carbon dioxide as carbonate by the reaction with calcium and magnesium sources containing waste materials, such as iron- and steelmaking slag, waste concrete and minerals has recently been paid attention as one of the CO_2 sequestration method. The major advantages of this process are, long term stabilized and environmentally safe $CaCO_3$ and/or $MgCO_3$ production. Additionally, the overall carbonation process is exothermic and hence, has the potential to become economically feasible. However, the development of a new system with simple process, short reaction time, and lower energy consumption is necessary for practical use. We have proposed and investigating a new process of CO_2 fixation via carbonation of calcium contents in waste concrete or slag by using a solution of NH_4Cl. Studies for the new process have been carrying out to verify the possibility of the system.



Development of an Innovative After Treatment System for Diesel Vehicles: A Non-Thermal Plasma System

(A NEDO project from FY2004, joint study with Daihatsu Motor Co. Ltd.)

RITE had developed a plasma technology for natural gas (methane) conversion to acetylene and hydrogen using a high-frequency pulsed plasma in a R & D project of environmental friendly catalysis technology supported by funds from NEDO (FY1991-2000). In 2001, RITE started a three-year plasma particulate matter (PM) removal study financially supported by the Ministry of Education, Culture, Sports, Science and Technology, in which the pulsed plasma technology was used to establish a plasma PM removal system. This plasma PM removal system included a plasma reactor and a pulse power supply.

Recently, the emission control is becoming extremely severe for diesel vehicles, although no satisfied PM removal technologies have been found yet. The plasma PM removal technology has potential as an innovative technology for the after treatment of the exhausts from diesel vehicles. We then began a new project supported by NEDO (project of comprehensive technological development of innovative, next-generation, low-pollution vehicles, R&D of innovative after treatment systems) to continue the plasma PM removal study from 2004. This new project is a joint study with Daihatsu Motor. RITE is to develop a small plasma reactor and pulse power supply that can be loaded on a small diesel car.