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New Amine-Based Membranes for H_2 Purification and CO_2 Capture

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Abstract：

This presentation covers new advances in amine-containing membranes for hydrogen purification for fuel cells, post-combustion CO_2 capture from flue gas in coal- and/or natural gas-fired power plants, and pre-combustion CO_2 capture from synthesis gas derived from coal and/or natural gas. We have synthesized highly CO_2-selective membranes comprising fixed-site and mobile carriers, involving the facilitated transport mechanism based on reversible CO_2 reactions with amine carriers. The membranes remove H_2S even faster than CO_2 (~3 times). In general, the membranes need to be tailor-made and tuned specifically for those applications. For example, hydrogen purification for fuel cells demands the membrane with a very high CO_2/H_2 selectivity of 100 along with a modest CO_2 permeance of about 100 GPU (1 GPU = 10^{-6} cm^3 (STP)/(cm^2 ·s · cmHg)) or greater. We have synthesized composite membranes exhibiting about 200 GPU CO_2 permeance with 200 CO_2/H_2 selectivity at low pressure. On the other hand, post-combustion carbon capture requires a high CO_2/N_2 selectivity of 140 together with a very high CO_2 permeance of greater than 700 GPU in order to use a stand-alone membrane process. We have synthesized composite membranes showing a high CO_2 permeance of about 1500 GPU and a high CO_2/N_2 selectivity of more than 180, which are well above the 2008 Robeson upper bound. The membrane was scaled up successfully to 14 inches in width, and it was fabricated into spiral-wound membrane modules up to a membrane area of about 3 m^2. Three modules each with 1.4 m^2 were tested with real flue gas at the U.S. National Carbon Capture Center, and they showed the same performance as those tested at OSU using simulated flue gas, including excellent membrane stability. In a similar way as hydrogen purification, pre-combustion carbon capture requires the membrane with a very high CO_2/H_2 selectivity of 100 along with a modest CO_2 permeance of about 100 GPU. We have synthesized composite membranes exhibiting 206 GPU CO_2 permeance with 103 CO_2/H_2 selectivity at 31.7 bar. Based on the synthesized membranes with tuned H_2S/CO_2 selectivities, a one-stage membrane process for pre-combustion carbon capture has been designed, indicating 6 ppm H_2S in the H_2 product achievable and an attractive increase in the cost of electricity (15.66%).

Biography

Dr. W.S. Winston Ho is a Distinguished Professor of Engineering in the William G. Lowrie Department of Chemical and Biomolecular Engineering and the Department of Materials Science and Engineering at The Ohio State University. Before teaching for about 20 years, he had 28 years of industrial R&D experience in membranes and separation processes, working for Allied Chemical, Xerox and Exxon, and serving as Senior Vice-President of Technology at Commodore Separation Technologies. He was elected to the National Academy of Engineering, USA in 2002 in recognition of his distinguished contributions to engineering. A New Jersey Inventor of the Year (1991), Dr. Ho holds more than 55 U.S. patents, generally with foreign counterparts, in membranes and separation processes. He received the 2006 Institute Award for Excellence in Industrial Gases Technology from the American Institute of Chemical Engineers (AIChE), and he was the 2007 recipient of Clarence G. Gerhold Award, from the AIChE Separations Division, one of the highest honors bestowed to those working on separations. He received the 2012 Lawrence B. Evans Award in Chemical Engineering Practice from AIChE. In 2014, he was elected to Academia Sinica, the highest form of academic recognition in the Republic of China in Taiwan. He obtained his B.S. degree from National Taiwan University and his M.S. and Ph.D. degrees from the University of Illinois at Urbana-Champaign, all in Chemical Engineering.