Mathematical Modeling of Carbon Capture by Carbonic Anhydrase-Displaying *Escherichia coli* in A Foam Bioreactor

Stuart Watson, Eunsung Kan
Department of Molecular Biosciences and Bioengineering
University of Hawaii at Manoa
Honolulu, HI 96822

Recently, a foam bioreactor for carbon capture has been developed. The foam bioreactor relies on an actively growing culture of carbon anhydrase (CA)-displaying *E. coli*, made into a fine foam with the CO_2-containing air. The foam bioreactor with CA-displaying *E. coli* showed excellent removal of CO_2 at short gas contact time with high stability at mild operating conditions (i.e., 2,800-3,800 g $CO_2/m^3_{reactor}$-h with the removal of 68-91%, at contact time of 30 s and cell density of 2 g_{dwt} L^{-1}). A conceptual mathematical model based on diffusion, mass transfer and biological reaction was developed for the systematic study of mass transfer and biodegradation kinetics for carbon capture by a foam bioreactor which will help reactor design and scale-up. All model parameters including characteristics of foams and biokinetics were determined by independent experiments or taken from the literature and thus the model was fully predictive. The physical characteristics of foam (foam size, liquid film thickness) and gas hold-up in the bioreactor were empirically correlated with gas velocity. The biokinetics for CO_2 consumption was developed using a Michaelis–Menten kinetics with bicarbonate-driven inhibition. The model predictions were a good agreement with experimental data over a wide range of operating conditions (gas velocity, cell density, CO_2 concentration). The model allowed simulation of CO_2 removal at several key operating parameters. The model also simulated CO_2 concentration over the height of the bioreactor, and within the depth of the liquid film of the foam. The model simulations indicated that most of the CO_2 is removed near the inlet port of the foam bioreactor and near the gas-liquid interface, and that bioconversion by carbonic anhydrase in the *E.coli* is the principal mechanism for CO_2 removal. Further studies of the model will include detailed insights on the model parametric sensitivity and on the performance limits of the foam bioreactor.