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A green plastic formed directly from carbon dioxide and sunlight

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Poly(3-hydroxybutyrate) or PHB is an eco-friendly thermoplastic synthesized by some microbial species from renewable carbohydrates. A conventional production route of PHB therefore includes two stages: (1) agricultural farming to produce carbohydrates (CH_2O) from CO_2, water and sunlight via natural photosynthesis ($CO_2 + H_2O \rightarrow CH_2O + O_2$), and (2) microbial conversion of the organic carbonaceous substrates into PHB. The green plastic can now be produced directly from CO_2, water and sunlight via an artificial photosynthesis system, consisting of a photovoltaic panel, a water electrolysis cell, and a dark fermenter. The intermittent solar radiation is captured and converted into electricity that immediately splits water into H_2 and O_2 for direct use and/or storage.CO_2 is fixed continuously in dark conditions by a Knallgas bacterium that grows on CO_2, H_2 and O_2.A laboratory facility was demonstrated including: a solar panel with 17% efficiency of sunlight to electricity, a membrane water electrolyzer with 84% efficiency of electricity to H_2, and a bioreactor in which microbial cells fixed CO_2 by using H_2 and O_2 with an efficiency of 20-50%, depending on gas composition. The overall energy efficiency therefore ranged from 2.9 to 7.1, or an average efficiency of 5% from solar energy to biomass (CH_2O), which is much higher than the efficiency of conventional photosynthesis of plants (<1%) and microalgae (2-3%). About 50% of cell mass formed from CO_2 was PHB. The microbial residues, after PHB recovery, can be reused in dark fermentation as a nutrient source.The mass transfer of gas molecules to microbial cells in bioreactor was the rate-limiting step and characterized with a volumetric mass transfer coefficient (k_La). The productivity of PHB in a conventional bioreactor with a moderate k_La was improved by 57% in a novel bioreactor. More importantly, the PHB yield per amount of H_2 fed is increased by 475%.

Biography

Jian Yu is a full professor in the School of Ocean and Earth Science and Technology at the University of Hawaii at Manoa. He graduated from Zhejiang University of Technology (BEng. Chemical Engineering, 1982) and Zhejiang University (MSc, Chemical Engineering, 1985) in China. He continued his graduate education at the University of British Columbia, Canada, and earned his PhD in Biochemical Engineering in 1991. After post-doctoral training in industry and academia, he joined the Hong Kong University of Science and Technology in 1994 as an assistant professor. He taught undergraduate and postgraduate courses in chemical, biochemical and environmental engineering. His research explored novel biocatalysts and their application in industrial wastewater treatment. Dr. Yu joined the University of Hawaii at Manoa in 2001 and became a faculty of a NSF-funded engineering research center. Since then, he has developed teaching and research activities in the areas of bioprocessing engineering, bioreactor engineering and downstream processing for bio-based chemicals, plastics and fuels supported by federal grants and industrial contracts. He has supervised numerous projects of undergraduate students, postgraduate students and post-doctoral fellows, published more than seventy research papers in peer-reviewed journals and authored five book chapters. Three patents from his research on bio-based polymers and plastics have been licensed to companies in US, Asia and Europe. A green technology of producing bioplastics from agricultural by-products has been successfully scaled up to pilot plant and further to commercial production.

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