Enhanced Carbon Dioxide Photoconversion Efficiency by 1D Structured Platinized TiO$_2$ Films

Wei-Ning Wang, Woo-Jin An, Balavinayagam Ramalingam, Somik Mukherjee, Dariusz M. Niedzwiedzki, Shubhra Gangopadhyay, and Pratim Biswas

1Department of Energy, Environmental and Chemical Engineering, Washington University in St. Louis, St. Louis, MO 63130
2Center for Micro/Nano Systems & Nanotechnology, University of Missouri, Columbia, MO 65211
3Photosynthetic Antenna Research Center, Washington University in St. Louis, St. Louis, MO 63130

The carbon capture and sequestration (CCS) technology has been proven to be a sophisticated solution to reduce CO$_2$ emissions from fossil fuel sources. However, the CCS technology is currently not widely acceptable due to their high cost and potential risks. A better alternative is to reuse the carbon dioxide and convert it to useful products. Due to the energy intensive pathway of reducing CO$_2$ to useful products, electrochemical or photocatalytic reduction processes are a promising alternative. Processes can be designed to simultaneously capture CO$_2$ and convert it into value-added compounds, such as carbon monoxide (CO), methane (CH$_4$), and formic acid (HCO$_2$H). A major issue associated with CO$_2$ photoreduction is the electron-hole recombination. To solve the issue, depositing metal particles (e.g. Pt, Cu, Fe or Au) on photocatalyst surfaces is a popular method. Electrons can be trapped by the metals to slow down electron-hole recombination. Reports on the performance of these metal particles, however, vary significantly in the literature. In addition to trapping electrons, metal particles may also consume holes, serving as recombination centers.

In the presentation we will report a facile development of highly efficient platinized titanium dioxide (Pt-TiO$_2$) thin films with unique one dimensional (1D) structure by using versatile gas phase deposition methods. The pristine TiO$_2$ films were deposited by an aerosol chemical vapor deposition method, composed of highly oriented crystal phase at (112) plane having high surface energy for surface catalytic reactions. Ultra-small Pt nanoparticles (NPs) were coated on the surfaces of the TiO$_2$ single crystals by a radio frequency tilt target sputtering method. The particle diameters of the Pt NPs were controlled from 0.5 to 2 nm with very narrow size distribution, while the particle number concentrations were kept at the same. The Pt-TiO$_2$ thin films demonstrated excellent CO$_2$ photoreduction efficiency with a maximum quantum efficiency of about 2.41%. Carbon dioxide was selectively converted into CH$_4$, with an optimal CH$_4$ yield of 1361 µmol/g-cat/hr, that is due to the synergistic effects of high surface area and minimized charge barriers by highly oriented single phase crystallinity of the TiO$_2$ thin films, and efficient electron-hole separation by the ultra-small Pt NPs.

References: