Enhanced Carbon Dioxide Photoconversion Efficiency by 1D Structured Platinized TiO_2 Films

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The carbon capture and sequestration (CCS) technology has been proven to be a sophisticated solution to reduce CO_2 emissions from fossil fuel sources.[1] 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_2H).[2] 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.[3]

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.[4] The pristine TiO_2 films were deposited by an aerosol chemical vapor deposition method,[5] 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.[6] 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:

1. Metz, B.; Davidson, O.; de Coninck, H.; Loos, M.; Meyer, C. *IPCC Special Report on Carbon Dioxide Capture and Storage*; New York, 2005.
2. Wang, W. N.; Park, J.; Biswas, P. *Catal. Sci. Technol.* **2011,** 1, (4), 593-600.
3. Sadeghi, M.; Liu, W.; Zhang, T. G.; Stavropoulos, P.; Levy, B. *J. Phys. Chem.* **1996,** 100, (50), 19466-19474.
4. Wang, W.-N.; An, W. J.; Ramalingam, B.; Mukherjee, S.; Niedzwiedzki, D. M.; Gangopadhyay, S.; Biswas, P. *J. Am. Chem. Soc.* **2012,** 134, (27), 11276-11281.
5. An, W. J.; Thimsen, E.; Biswas, P. *J. Phys. Chem. Lett.* **2010,** 1, (1), 249-253.
6. Yun, M. S.; Ramalingam, B.; Gangopadhyay, S. *Nanotechnology* **2011,** 22, (46), 465201.