# Atomic Level *In Situ* TEM Observation of Water Splitting Photocatalysts

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Photocatalysis, photoelectrocatalysis and solar thermochemical materials have potential applications for solar fuel generation through water splitting or $CO_2$ reduction. Most current photocatalysts systems are based on semiconducting materials and to function efficiently they must be effective light absorbers, be able to transport electrons and holes to the semiconductor surface and perform oxidation and reduction processes to convert reactants into products. Co-catalysts play a critical role for the last two steps and must be integrated with the semiconductor to enhance charge separation and transport as well as suppressing the back reaction. To improve performance each step must be understood and optimized for maximum efficiency and it is critical to understand structure-reactivity relations. Advanced transmission electron microscopy is a powerful approach for understanding the local structure and chemistry of photocatalysts. *Ex situ* experiments can provide important information of the overall evolution of catalyst structure under water splitting conditions and this can be correlated with reactor data. *In situ* TEM methods can allow more subtle changes in catalyst structure to be determined in the presence of water and light illumination. We have modified an environmental transmission electron microscope so that changes in catalyst structure can be directly observed as a result of exposure to water and light. The system allows us to study the structure of photocatalysts subjects exposed to several Torr of water vapor and broadband light illumination with a total intensity 1430mW/cm$^2$ and a UV part which can be absorbed by anatase (200nm-800nm) intensity 122mW/cm$^2$. We are developing this approach and also exploring the application of aberration corrected TEM and ultra-high energy resolution monochromatic electron energy-loss spectroscopy to map out the structure and electronic structure of model photocatalysts. We are currently focusing on titania and tantalate based systems because of their relatively high activity under UV irradiation and their higher stability makes them suitable model systems. Co-catalysts such as Pt, NiO, Ni, Ru and Ag are currently under investigation. Results will be presented and discussed in terms of overall system evolution under liquid and vapor reaction conditions, correlation with $H_2$ production and challenges associated with *in situ* observations.