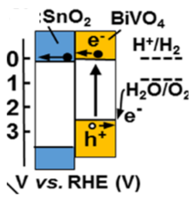
Photoluminescence Spectroscopy of photoexcited carriers in $BiVO_4$ and $BiVO_4$/(m)SnO_2

Shaniah Greene, Kateryna Kushnir , Teng Shi, Maryam Masroor Shalmani, Binod Giri, Pratap M. Rao and Lyubov Titova
Department of Physics Worcester Polytechnic Institute, Worcester MA 01609
Department of Chemistry Fitchburg State University Chemistry Department, Fitchburg MA 01420

WPI Ultrafast THz & Optical Spectroscopy Lab

Motivation

$BiVO_4$ is a promising photoanode material. It has a moderate bandgap, high photochemical stability, and band edge positions favorable for water oxidation [1].
For efficient separation of photoexcited electrons and holes, it is used in a heterojunction with an electron transport material such as SnO_2.



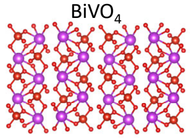
Our objective: Optimize the injection of electron from the solar absorber layer($BiVO_4$) into the electron transport layer(SnO_2)
Research question: Can photoluminescence spectroscopy be used to monitor electron injection from $BiVO_4$ into SnO_2?

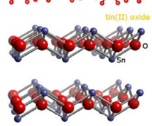
Sample Preparation

5 µL of $BiVO_4$ drop-casted on mSnO_2.
- 0.1225g add what material is?
- 0.0663g
- 5µL of acetic acid
- .25µL of acetylacetone

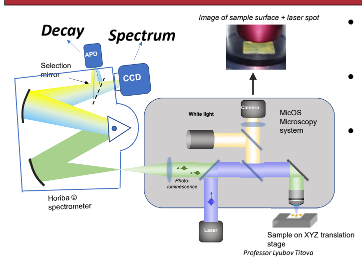
Mesoporous SnO_2
- 1.0g SnO_2 in 8mL ethanol for 24hr
- 0.2ml acetic acid, 3.0g terpineol
- 0.5g ethyl cellulose to from slurry
- Dilute 2mL of slurry in 8mL of ethanol

$BiVO_4$





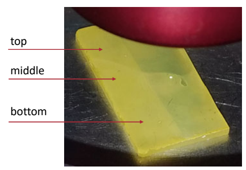
Photoluminescence spectroscopy

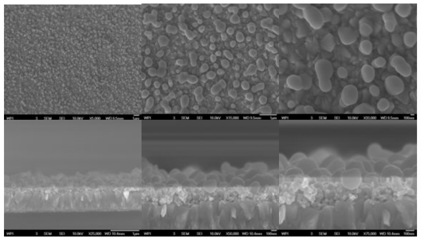


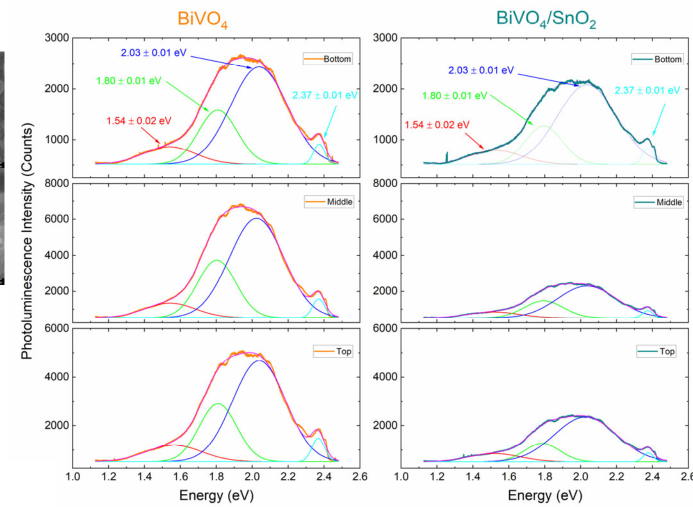
- PL spectroscopy is a nondestructive method of characterizing materials
- PL spectrum provides information about energy structure
- PL decay: a histogram of times between optical excitation and PL emission at a given wavelength; provides information about emission probability

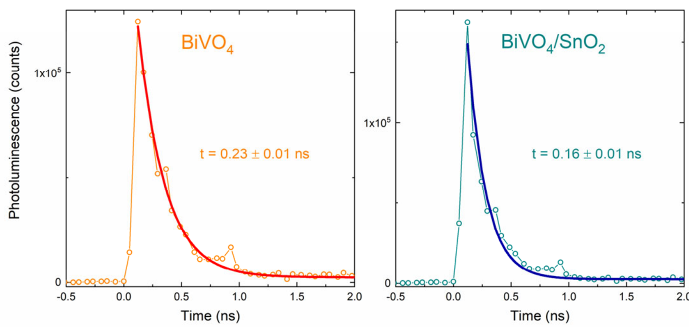
- In $BiVO_4$, emission can occur due to recombination of electrons and holes across the band gap, or by recombination of carriers at defect state
- Processes that compete with PL: non-radiative recombination when surplus energy goes to the crystal lattice (heat), or ***spatial separation of electrons and holes across $BiVO_4$/SnO_2 interface [2]***
- If separation is efficient, ***we expect lower PL intensity and shorted PL decay time***

Results and Discussion









- PL spectra and decays were taken at 485nm wavelength, 20MHz repetition rate and power ~0.4mW
- $BiVO_4$ emission spectra are composed of band gap emission (~ 2.37 eV), and defect emission at lower energy.
- When a thin layer of $BiVO_4$ with thickness comparable to carrier diffusion length of ~ 70nm [3] is deposited on SnO_2, spectral shape does not change but intensity is reduced.
- PL from $BiVO_4$ decays faster when it is deposited on SnO_2

Conclusion: both the reduction in PL intensity and decay time support our hypothesis that carrier injection is an informative tool to assess carrier injection across $BiVO_4$/SnO_2 interface

Future Research

- We will use this approach to optimize the fabrication of $BiVO_4$/SnO_2 heterojunctions for maximal carrier separation
- We will then apply in-situ PL spectroscopy to study carrier injection in working devices under bias

References

[1]. Lite Zhou, Chenqi Zhao, Binod Giri, Patrick Allen,Xiaowei Xu, Hrushikesh Joshi, Yangyang Fan, Lyubov V. Titova, and Pratap M. Rao, Nano Letters 16, 3463 (2016).
[2] SocMan Ho-Kimura, Savio J. A. Moniz, Albertus D. Handoko and Junwang Tang, J Mater Chem A 2, 3948 (2014)
[3] Fatwa F. Abdi, Tom J. Savenije, Matthias M. May, Bernard Dam, and Roel van de Krol, J Phys Chem Lett 4, 2752 (2013)