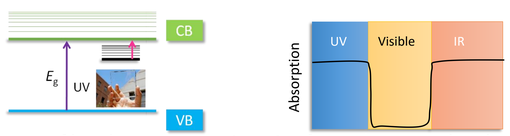
Inorganic Light Absorber for Transparent Solar Cells

Donovan Dugger, Reem Zaher, and Dr. Fan Zuo
Department of Chemistry and Physics, Indiana State University, Terre Haute, IN 47809

- **Introduction**

Traditional Si solar cell and emerging technology in photovoltaic have pushed the power efficiency approaching to its theoretical value (33.16%). Currently, solar panels are mainly implemented on top of roofs of residential houses or in wild field as solar farms to harvest as much sun light as possible. This implementation strategy limits their application in cities, where massive tall buildings fail to offer enough roof area. Meanwhile, the buildings sector account for 76% electricity usage and 40% greenhouse gas emission in United State due to the high density of population. To achieve sustainable and energy efficient buildings which helps the goal of greener world, replacement of the windows with transparent solar cells will be a promising solution. Here we report an inorganic transparent light absorber (TLA), modified TiO_2. By carefully engineering its band structure, it can selectively absorb UV and IR lights, while transmits the visible lights. EQE tests show the UV and IR photons effectively generate electrons from TiO_2, demonstrating its great potential for transparent solar cell. We proposed a mechanism for this unique U-type light absorption. Particularly, this inorganic based study shed lights to long-term stability of transparent solar cell application, which is crucial to meet the requirements for implementation in buildings.



Scheme of band structure engineering for transparent absorbers.

- **Motivation**
  - Sustainable and energy-efficient buildings
  - Self changing mobile devices and automobiles
  - Cleaner sky with less light pollutions from spacecrafts

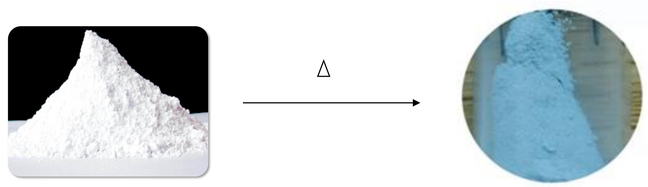
Mobile devices:
- Transmittance > 80-90%

Automobiles windows:
- Windshield transmittance > 80-90%
- Front side transmittance > 70%
- Back side and rear > 55%

Building windows:
- Transmittance 70 - 90%

Solar panels for space crafts:
- ideally transmittance > 80-90%

- **Synthesis**



(1) $2Ti\ (powder) + 6H^+ \longrightarrow 2Ti^{3+} + 3H_2$

(2) $Ti^{3+} + H_2O \longrightarrow TiOH^{2+} + H^+$

(3) $TiOH^{2+} \longrightarrow e^- + Ti(IV)\ oxo\ species \longrightarrow TiO_2$

(4) $TiO_2 + 3H_2 \longrightarrow TiO_{2-x} + H_2O$

TiO_{2-x} represents the final product where the 2-x indicates that the oxygen vacancy. Therefore, the TiO_{2-x} is TiO_2 doped with Ti^{3+}, i.e. coexistence of Ti(IV) and Ti(III).

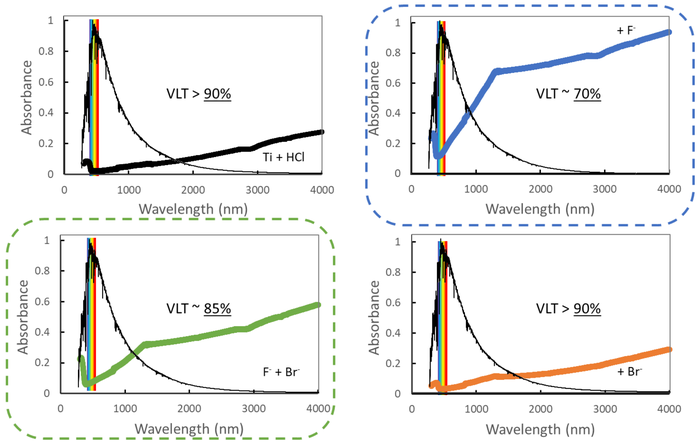
- **Characterization**

The light absorption properties were studied from UV-Visible absorption spectroscopy (measured on a Shimadzu UV-2600 UV-Vis-NIR spectrophotometer operating in the diffuse mode), and IR-NIR absorption spectroscopy (recorded on Thermo Fisher Scientific Nicolet spectrometer in the transmittance mode), and then combined to observe the overall light absorption.

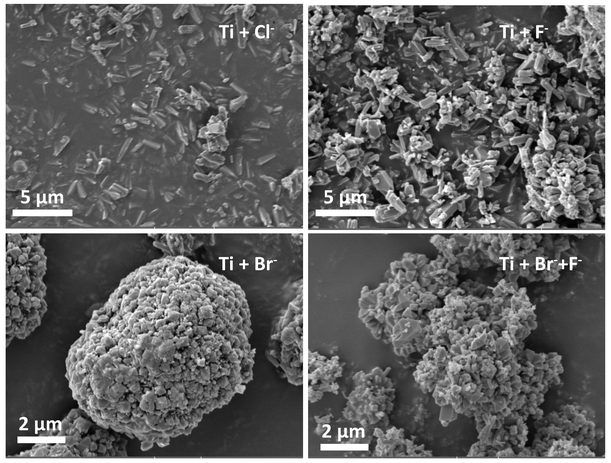
- **Results and discussion**

To achieve desirable band structure and optical properties, various series of synthetic parameters were tested, including temperature and composition, so that we could extensively study the critical steps in the products growing process, such as nucleation, crystallization and surface reconstruction, and how these processes affected the optical properties of our final products.
Our UV-Vis study showed that F^- could significantly increase the overall absorption while Br^- could suppress the visible light absorption. Therefore, we mixed F^- and Br^- to fine tune the optical properties.

- *Anions effect on overall light absorption*

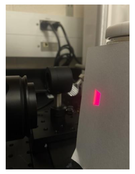


- *Morphologies by Scanning Electron Microscopy (SEM)*



- *External quantum efficiency (EQE)*

To test our samples efficiency as a photon absorber, we must test their external quantum efficiency (EQE). EQE is the ratio between the number of photon-generated electrons and the number of photons striking to the surface of light observer. EQE system consists of a solar lamp, a monochromator, and a power meter. The lamp will simulate the solar spectrum and all its wavelengths of light, the monochromator will selectively choose between the wavelengths to output a specific color (wavelength), and the power meter will allow an accurate measurement of the number of photons. As stated previously, our goal is to synthesize a material that will absorb IR and UV light, but transmit visible, so it is inherent to have an instrument that is able to alter the light to input as specific of a wavelength as possible. (as pictured below to show the monochromator change the color of output light, i.e., blue and red for instance.)



- **Conclusion**

Through introduction of F^- to increase the UV and IR absorption, while addition of Br^- to suppress the visible light absorption, TiO_{2-x} showed engineered light absorption and great potential towards to transparent light absorber.

- **Acknowledgements**

We would like to thank the INSGC for their financial support. We would also like to acknowledge the 2022 SURE program and Department of Chemistry and Physics of ISU.