Transparent Photon Absorber (TPA) for "Seeing Through" Photovoltaic Cells

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

Introduction

Traditional photovoltaic cells (PVCs), or so-called solar cells, are opaque, because they use dark colored semiconductor as absorbers, in order to achieve high harvest efficiency in broad range of solar spectrum. Recently, transparent solar cells are receiving rapidly increasing attention for their perspective to convert skyscrapers to giant solar farms and mobile devices to mini solar generators. More interestingly, these transparent solar cells could be used to design next generation of space probes and crafts, assisting to address some challenging problems, such as light pollution, which is now causing increasing concerns of astronomers.

Our goals

The goal for this project is to find appropriate transparent photon absorbers (TPAs). The critical issue for inorganic TPAs are their band structure, which show a band-like absorption spectrum (as shown in Fig. 1a and 1b), limiting their light absorption to near infrared (IR) region only and result in low efficiency. The research goal of this proposal is to address this issue, by designing a new type of inorganic TPAs, harvesting most photons of UV and IR light, while transmitting photons of visible light, i.e. "U" type absorption spectrum as shown in Fig. 1c. Specifically, a miniband (collective states) adjacent to the regular conduction band (CB) will be created through doping chemistry as shown in Fig. 1d. Band gap absorption will contribute to the UV photons capture. Meanwhile, electrons inject into the miniband thus greatly improve the probability of transition from miniband to nearby conduction band, creating IR absorption.

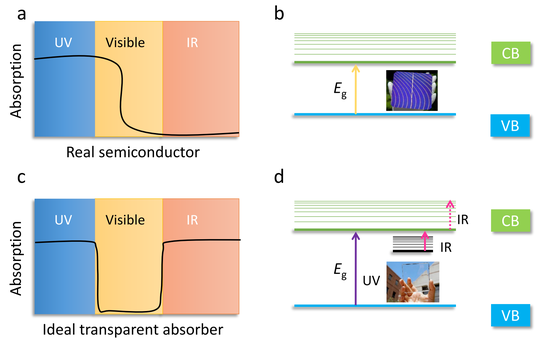


Figure 1 Scheme of band structure engineering for transparent absorbers.

Synthesis

In a typical synthetic procedure, titanium powder (0.300 g) and hydrochloric acid (10 mL, 2m) were mixed in a 50 mL pyrex beaker and magnetically stirred for 15 min. This mixture was then transferred to the Teflon-lined stainless-steel autoclave (23 mL capacity) and hydrothermally treated for 12 h under 220 °C. The sample was then collected and washed by distilled water and ethanol three times.
The overall reactions in this hydrothermal process are proposed as below:

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

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

(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+}.

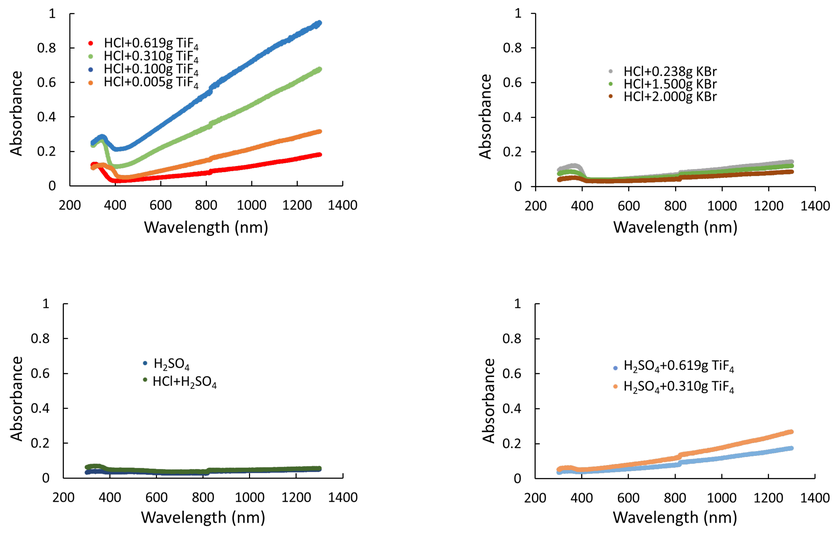
Characterization

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 learn the overall light absorption.

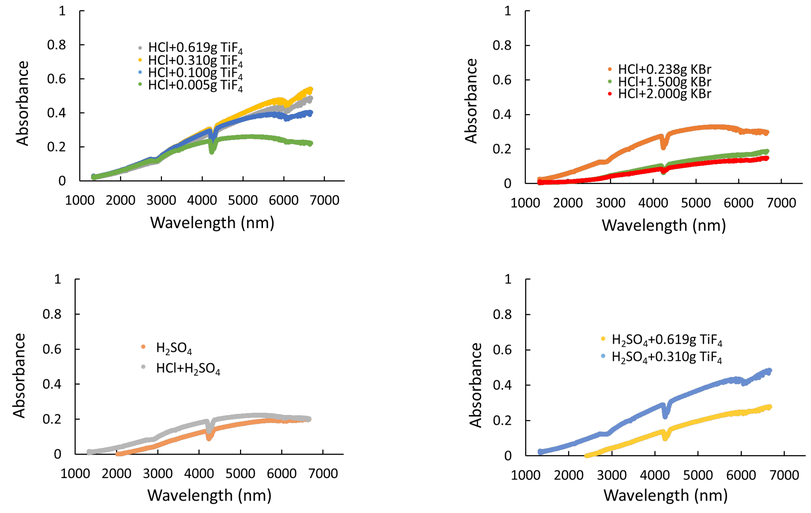
Results and discussion

To achieve desirable band structure and optical properties, series of synthetic parameters were tested, including temperature and composition, so that we could extensively study the critical steps in products growing process, such as nucleation, crystallization and surface reconstruction, and how these process affected the optical properties of final products.

Anions effect on UV-Vis absorption

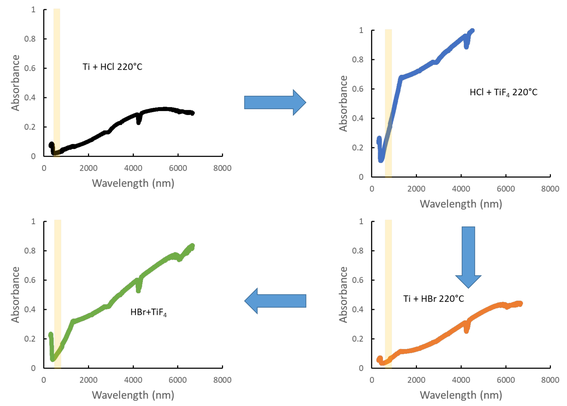


Anions effect on NIR-IR absorption



Anions could effectively control the crystallization process and the surface reconstruction, and therefore change the light absorption properties. 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



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

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