Vid. Proc. Adv. Mater., Volume 3, Article ID 2208307 **(2022)**

Development of Green Energy Materials: Role of Synchrotron X-ray Spectroscopy

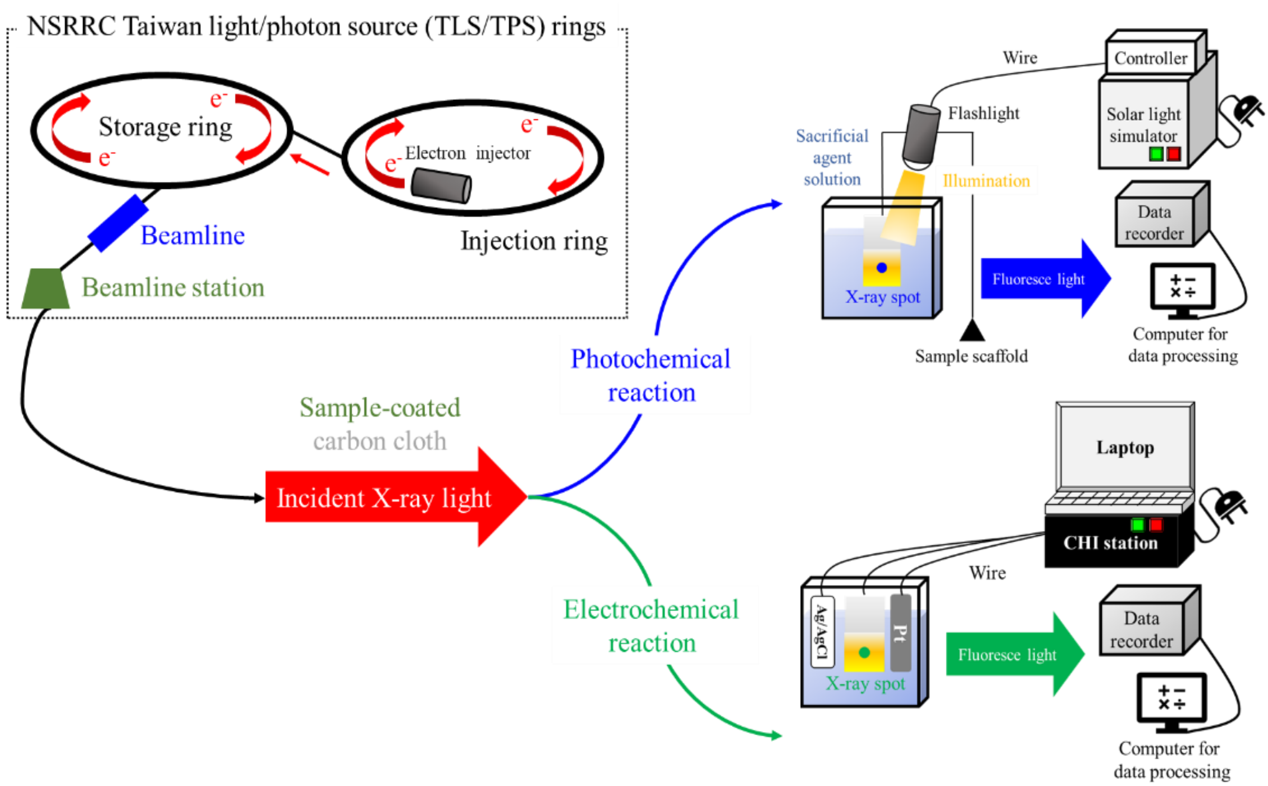
Chao-Lung Chiang*, Yan-Gu Lin

National Synchrotron Radiation Research Center, 30074, Taiwan

*Corresponding author: E-mail: scottchiang198805216@gmail.com
DOI: 10.5185/vpoam.2022.08307

Graphical Abstract

Synchrotron radiation X-ray light generated from the injection ring is accelerated in storage ring upon to light speed, and then transferred to beamline and beamline station in downstream as an incident X-ray light for photoelectrochemical material characterization. The incident X-ray light can be focused via lens with various reflection angles on the catalyst-coated conduct substrate such as carbon cloth to accept the applied potentials or solar light from various controllers and transfer the generated electrons for photoelectrochemical reactions. In the period of photoelectrochemical reactions, the fluoresce light passes through the reaction unit and be recorded by data recorder for further data processing by software-installed computers to reveal the variations of photoelectrochemical materials during the heterogenous reactions.



Abstract

The development of green and clean energy materials has got the significant processing with the aids of promotion from government and raising environmentalism. Global nations have signed with Glasgow Climate Pact in UK (COP26) under the frameworks of UNFCCC in 2021 to declare the termination of coal era and the beginning of green-clean energy, the development of green and clean energy materials becoming an unstoppable trend. In this article, several works done with self-assembled experimental mode and beamline stations in National Synchrotron Radiation Research Center (NSRRC) were introduced to explain the variations of material composition, crystal structure, phase transition, electron configuration, valence, and coordination environment from the modifications or photoelectrochemical reactions measured by synchrotron radiation spectroscopy. Herein, we used an in-situ X-ray diffraction (XRD) beamline to observe the phase transition mechanism of a lithium anode battery material, $Bi_2Mo_3O_{12}$ (BMO) during a charge-discharge cycle, which comprised three steps, including (1) $BMO+6Li^++6e^-\rightarrow 3Li_2MoO_4$ (LMO)+2Bi, (2) $LMO+xLi^++xe^-\rightarrow Li_2+xMoO_4$, and (3) $Bi+3Li^++3e^-\rightarrow Li_3Bi$ (BL). A photocatalyst, $SrTiO_3/TiO_2$ (STO/TiO_2), was compared with pristine TiO_2 and characterized using soft X-ray absorption spectroscopy (XAS) beamline to reveal the existence of unique electron configuration at outer orbitals in STO/TiO_2. From the collected Ti $L_{2,3}$-edge XAS spectra, the ratio value differences in t_{2g}/e_g and $d_z^2/d_{x^2-y^2}$ between STO/TiO_2 and TiO_2 revealed that the addition of STO leads to the increase of unoccupied state and generation of electrons holes, following a structural asymmetry, stretching, and distortion, thus enhanced the electron-hole separation efficiency, electron transition, and further photocatalytic performances. Moreover, the metal valence and coordination of a supercapacitor material, NbN@C, was also measured with hard XAS spectra. In comparison with niobium standards, Nb and NbN, the niobium valence of NbN is $Nb^{3.59+}$ which is higher than Nb^{3+} in NbN standand, revealing the existence of niobium vacancy and surface oxidation. The coordination number of first-shell (Nb-Nb) and second-shell (Nb-N) in NbN@C were 4.95 and 9.90 that are smaller than that of NbN ones (first-shell: 6.00; second-shell: 12.00), demonstrating the existence of intrinsic structural defects. This structural defects provide an external transition channel for lithium ions to improve the performances of supercapacitor. In summary, these synchrotron radiation spectroscopy-based findings in various energy materials development were described to explain the meanings for the composition design of green energy materials and the terminal modular of materials.

Keywords: Synchrotron X-ray spectroscopy; Photoelectrochemical reaction; Green-energy materials; Reaction mechanism.

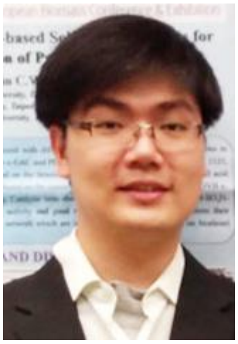
Acknowledgements

We highly appreciate for the supports from managers in beamline stations in NSRRC and the fund supports.

References

1. K. Tian, H. Lu, L. Bu, X. Huang, C. L. Chiang, S. Yang, Y. Zhao, Y. G. Lin, J. Zhao; *Batteries & Supercaps*, **2021**, *3(12)*, 1260.
2. T. T. Wang, C. L. Chiang, S. Narra, J. L. Lin, S. W. Chien, J. C. Yu, E. W. G. Diau, Y. G. Lin, and M. C. Lin; *J. Phys. Chem. C*, **2021**, *125(44)*, 24340.
3. S. Zhou, C. L. Chiang, J. Zhao, G. Cheng, T. B. Bashir, W. Yin, J. Yao, S. Yang, W. Li, J. Wang, X. Wang, Y. G. Lin, and L. Gao; *Adv. Funct. Mater.*, **2022**, 2112592.

Biography of Presenting Author



Chao-Lung Chiang is now a post-doctoral researcher at National Synchrotron Radiation Research Center and also a reviewer for many SCI journals including *Groundwater for Sustainable Development*, *Journal of Natural Gas Science and Engineering*, *Fuel*, *Chemical Engineering Journal*, *Environmental Pollution*, *Journal of Hazardous Materials*, *Diamond and Related Materials*, *Journal of Cleaner Production* since 2018. He received a bachelor's degree in chemical and material engineering from Chang Gung University in 2011, a master's and doctoral degree in chemical engineering and materials science from Yuan Ze University in 2013 and 2018. He was a guest researcher in Australian Nuclear Science and Technology Organization (ANSTO) for soft biomedical matter development in 2017. His current research fields are photoelectrochemical materials for hydrogen and oxygen generation from water splitting and synchrotron radiation X-ray absorption spectroscopy for material characterization. He is also interested in the fields of carbon capture, storage, and utilization (CCSU), heterogeneous catalysis, environmental contaminant treatment, and antibacterial material. Since past 10 years, he has published 45 SCI articles and 80 conference abstracts in proceedings, participated 13 research projects with his supervisors, and awarded for The Phi Tau Phi Scholastic Honor Society Honorary Membership and other certificates in conferences owing to his outstanding performances in academia.

Citation of Video Article

Vid. Proc. Adv. Mater., Volume 3, Article ID 2208307 **(2022)**

Full Video Article www.proceedings.iaamonline.org/article/vpoam-2208307

Open Access