Seminars by Prof. Zhanglin Guo and Dr. Tianhao Wu

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Location Seminar Room L5D23 (Lab5)

Description

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Perovskite Photovoltaics for Outdoor and Indoor Applications

Halide perovskite solar cells (PSCs) have been attracting incredible attention in recent years due to their high potential as an alternative to the currently dominant silicon solar cells. PSCs offer advantages over silicon solar cells, including low cost, lightweight, easy fabrication process, and flexibility. These attributes enable diverse applications that Si PV cannot achieve, such as building-integrated photovoltaics (BIPVs), automotive integration, and indoor IoT applications. Thanks to the efforts of a large global research community of >40,000 researchers and insights gained from other PV technologies, the power conversion efficiency (PCE) of PSCs has increased dramatically from 3.8% in the first report in 2009 to over 26% today.1 Further improvements in PCE can be achieved by combining two PV technologies with different bandgaps (Eg) to utilize sunlight more efficiently, such as perovskite/Si tandem solar cells, enabling better cost-effectiveness for commercialization. Another critical factor for the practical application of PSCs is ensuring their long-term durability, as they are sensitive to environmental stimuli like moisture, UV light, and high temperatures.

In this talk, besides providing a general background of PSCs (including the history and progress), I will talk about my work on developing wide-Eg perovskite PVs, which are essential for creating tandem solar cells. Compared to narrowEg perovskite PVs, the wide-Eg ones face the challenge of significant open circuit voltage (Voc) loss,2 which is the main reason for their unsatisfactory PCE. To address this issue, I have developed techniques that significantly reduce Voc loss, achieving world-record Voc and PCE performance.3-5 By reaching 92% of the theoretical Voc limit, the problem of large Voc loss for wide-Eg perovskite PVs has been solved, thereby advancing the development of tandem PVs. On the other hand, wide-Eg perovskite PVs are suitable for indoor applications (potential power source for IoT) due to their bandgap matching with the indoor light spectra (visible light only). I have studied the

indoor performance and stability of these wide-Eg perovskite PVs, achieving ultra-high Voc, which has never been obtained by any other indoor PV technologies.6 It is believed that much milder indoor conditions can avoid the harsh stimuli existing outdoors, thereby being a solution to enhancing the long-term durability of perovskite PVs. In conclusion, the advancements in wide-Eg perovskite PVs improve their suitability for tandem solar cells and open up new possibilities for efficient indoor photovoltaics, contributing to the broader adoption and commercialization of PSC technology.

Reference：

1. A. Kojima, K. Teshima, Y. Shirai and T. Miyasaka, J. Am. Chem. Soc., 2009, 131, 6050-6051.
2. Z. Guo, A. K. Jena, G. M. Kim and T. Miyasaka, Energy Environ. Sci., 2022, 15, 3171-3222.
3. Z. Guo, A. K. Jena, I. Takei, G. M. Kim, M. A. Kamarudin, Y. Sanehira, A. Ishii, Y. Numata, S. Hayase and T. Miyasaka, J. Am. Chem. Soc., 2020, 142, 9725-9734.
4. Z. Guo, A. K. Jena, I. Takei, M. Ikegami, A. Ishii, Y. Numata, N. Shibayama and T. Miyasaka, Adv. Funct. Mater., 2021, 31, 2103614.
5. Z. Guo, S. Zhao, N. Shibayama, A. Kumar Jena, I. Takei and T. Miyasaka, Adv. Funct. Mater., 2022, 32, 2207554
6. Z. Guo, A. K. Jena and T. Miyasaka, ACS Energy Lett., 2022, 8, 90-95.

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Metal halide perovskite solar cells: stability issue and lead-free devices

Perovskite solar cells (PSCs) emerging as a promising photovoltaic technology with high efficiency and low manufacturing cost have attracted the attention from all over the world. Stability issues are the major bottleneck for their commercialization. The weak chemical interactions of metal halide perovskite induce the irreversible decomposition of PSCs under moisture, light, and thermal stress. In this talk, I will present our recent works on improving the long-term stability of PSCs based on efficient defect passivation, introducing aprotic sulfonuim buffer layer, and developing the graphene-like self-assembled monolayer hole-selective contact.[1-5] Based on these strategies, we recently reported a record operational lifetime for both small-sized solar cell and large-area solar module. We also combined the in situ mass spectroscopy technique and theoretical simulations to clarify the light-induced degradation mechanism of the perovskite film under operational condition. Furthermore, we extended our stability studies to the eco-friendly tin perovskite solar cells towards the application of indoor photovoltaics and wearable electronic devices, which includes

suppressing the Sn^{2+} oxidation by antioxidant additives, and developing new device structure to improve thermal stability and minimize charge recombination loss.[6-10] The results provide a fundamental basis to achieve long-term stable PSCs towards commercialization and industrial production.[11]

Reference:

1. T Wu, S. Mariotti, P. Ji, L. K. Ono*, T. Guo, I. Rabehi, S. Yuan, J. Zhang, C. Ding, Y. B. Qi*, Adv. Funct. Mater. 2024, 34, 202316500
2. T. Wu, Y. Wang, Z. Dai, D. Cui, T. Wang, X. Meng, E. Bi, X. Yang, L. Han*, Adv. Mater. 2019, 31, 1900605.
3. T. Wu, Y. Wang, X. Li, Y. Wu, X. Meng, D. Cui, X. Yang, L. Han*, Adv. Energy Mater. 2019, 9, 1803766.
4. T. Wu, L. K. Ono, R. Yoshioka, C. Ding, C. Zhang, S. Mariotti, J. Zhang, K. Mitrofanov, X. Liu, H. Segawa, R. Kabe, L. Han, Y. B. Qi*, Energy Environ. Sci. 2022, 15, 4612.
5. T. Wu, X. Xu, L. K. Ono, T. Guo, S. Mariotti, C. Ding, S. Yuan, C. Zhang, J. Zhang, K. Mitrofanov, Q. Zhang, S. Raj, X. Liu, H. Segawa, P. Ji, T. Li, R. Kabe, L. Han, A. Narita*, Y. B. Qi*, Adv. Mater. 2023, 35, 2300169.
6. T. Wu, X. Liu, X. He, Y. Wang, X. Meng, T. Noda, X. Yang, L. Han*, Sci. China Chem. 2020, 63, 107-115.
7. X. He, T. Wu, X. Liu, Y. Wang, X. Meng, J. Wu, T. Noda, X. Yang, Y. Moritomo, H. Segawa, L. Han*, J. Mater. Chem. A 2020, 8, 2760-2768.
8. T. Wu, D. Cui, X. Liu, X. Meng, Y. Wang, T. Noda, H. Segawa, X. Yang, Y. Zhang, L. Han*, Solar RRL 2020, 4, 2000240.
9. X. Liu, T. Wu, C. Zhang, Y. Zhang, H. Segawa, L. Han*, Adv. Funct. Mater. 2021, 31, 2106560.
10. T. Wu, X. Liu*, X. Luo, H. Segawa, G. Tong, Y. Zhang, L. K. Ono, Y. B. Qi, L. Han*, Nano Micro Lett. 2022, 14, 99.
11. T. Wu, X. Liu, X. Luo, X. Lin, D. Cui, Y. Wang, H. Segawa, Y. Zhang, L. Han*, Joule 2021, 5, 863.