

Report on MERIT Long-term Overseas Dispatch

Hiroyuki Kaneko

Domen-Minegishi laboratory, Department of Chemical System Engineering

Outline

I have visited the research group of Assoc. Prof. Lydia Helena Wong, Nanyang Technological University (NTU), Singapore from 24th January to 1st May and carried out a joint research.

Research activity

Wong's group has achieved remarkable reports on development of novel semiconductor materials for photovoltaics and photoelectrodes for water splitting, and analysis of these materials. She kindly accepted my request to visit the laboratory to perform material analysis and investigate performance improvement on $(\text{ZnSe})_{0.85}(\text{Cu},(\text{In},\text{Ga})\text{Se}_2)_{0.15}$ photocathodes, which had been developed in my research last year, realizing the dispatch. The $(\text{ZnSe})_{0.85}(\text{Cu},(\text{In},\text{Ga})\text{Se}_2)_{0.15}$ is a promising material for photocathode because it shows a wide range of working potential and a large theoretical maximum photocurrent value estimated from the absorption edge wavelength. On the other hand, there has been little knowledge about its semiconductor properties. In an attempt to improve the photocurrent to the theoretical value, I have performed the analyses and experiments described below.

We measured current-voltage property, current-voltage property, photoluminescence spectra and so on. The group has wide experience in analyzing chalcogenides including Zn-related compounds, which is a great help to clarify each property of the $(\text{ZnSe})_{0.85}(\text{Cu},(\text{In},\text{Ga})\text{Se}_2)_{0.15}$. The most noteworthy measurement is AC Hall measurement using a parallel dipole line system¹⁾. The system realizes a high signal-noise ratio due to lock-in amplification of Hall voltage with a reference of oscillating magnetic field obtained by rotating two cylinder-type magnets. As a result, it was found that the $(\text{ZnSe})_{0.85}(\text{Cu},(\text{In},\text{Ga})\text{Se}_2)_{0.15}$ shows the same or higher mobility than that of other novel photovoltaic materials such as $\text{Cu}_2\text{ZnSnS}_4$. Moreover, the current-voltage measurement revealed that the solar cell using this material as a light absorber shows a high open-circuit voltage of >0.8 V. This value is interestingly higher than that of expected value estimated by the band gap. On the other hand, the short-circuit current was found to be lower than expected, which suggested existence of many pinholes and defects at the buffer layer/absorber interface and absorber/substrate interface, respectively.

These results are very helpful to determine the research plan after the dispatch. Also, we are going to perform additional experiments for material analysis to prepare an article for publication along with discussion about origin of the high open-circuit voltage.

In addition, we investigated effects of surface coating of tin-doped indium oxide (ITO) on the photocathode using application the sputtering technique. The ITO-coating was expected to prevent the surface from being oxidized and to improve the stability during photoelectrochemical reaction. Although it was found that the ITO decomposes during reaction, we obtained some pieces of knowledge about surface modification and post-annealing treatment.

Other than my own experiment, I participated in modification of photoelectrochemical measurement system in the group. The conventional system had several problems in flexibility and accuracy, so it required improvement. I discussed measurement methods and helped ordering some equipment to be imported from Japan, which was also a valuable experience for me.

Campus life

Many of the NTU students live in dormitories in the campus. Hence, the campus possesses abundant facilities to support the daily life. For example, there are more than ten food courts, called Canteen, opening from 7 a.m. to 9 p.m. daily, so I could stay in the campus from breakfast to dinner time. Even though there are some strict rules in performing experiment for their safety, the campus is an excellent environment for the students.

When I talk with NTU students, I always notice that they are widely cultured, especially interested in politics. Every time I speak to them about it, they always return their opinions actively, which is very fun for me. In holidays when I cannot do experiment, I enjoyed watching tropical animals and plants in a nature park. The Singapore city is well maintained, the local are kind and genuine, and English is commonly accepted, which are very comfortable for me. I feel that Singapore is one of the best cities to live in.



Figure 1. A photo of the school building

Acknowledgements

I have received many supports for the dispatch. I'd like to thank the host professor, Assoc.

Prof. Lydia Helena Wong. I express my thanks for Mr. Tay Ying Fan, Dr. Prince Saurabh Bassi, Mr. Stener Lie, Mr. John Rohit Abraham and Mr. Li Wenjie, who also have supported the research and daily life. I'd like to thank the MERIT program, Prof. Domen, Assoc. Prof. Minegishi and Ms. Asano, who have supported the dispatch from Japan.

[1] Gunawan, O., Virgus, Y. & Tai, K. F. "A parallel dipole line system." *Appl. Phys. Lett.* **106**, 62407 (2015).