REPORT

on my Stay at Kyoto University as a Visiting Scientist under the Japanese-ASEAN Collective Research Program on Innovative Humanosphere in Sout-East Asia

13 June to 13 July, 2016

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The following report summarizes my experience during my visit at Kyoto University in June/July 2016

I arrived in Osaka on Monday, 13 June in the morning and managed to find the reserved shuttle taxi which brought me smoothly to Kyoto, where I reached the Seifu Kaikan Guesthouse at around noon. I could immediately check into my room. After I had a shower and had organized my things, I made my way to the university to meet Professor K. Ishihara in his office. We had an initial discussion of the project, and Professor Ishihara introduced me to his collaborator, Dr Ai Leon.

On Tuesday, 14 June, I officially started to work on the project: Environmental impact assessment and energy payback time of flexible organic photovoltaic cells. This project is part of the project "A greenhouse with light-transmitting organic photovoltaics to reduce carbon dioxide emissions from protected horticulture".

Scientific Work:

We started with the analysis of three live cycle assessments that had been reported in the literature [1-3] to understand the methodology. Transparent photovoltaic cells have not yet been analysed in the available literature; the papers deal with solid (glass backed) cells as well as photocells laid down on a flexible polyester support using a prototype roll-to-roll manufacturing process. The Life Cycle Analysis follows the methodology described in ISO 14040/14044.

The first work package was a detailed analysis of the energy requirements for the chemical synthesis of poly-3-hexylthiophene (P3HT). This synthesis proceeds in 4 steps:

(1) Conversion of thiophene into 3-bromothiophene
(2) Conversion of 3-bromothiophene into 3-alkyl thiophene (e.g., 3-hexyl thiophene 3HT)
(3) Conversion of 3HT into 2,5-dibromo-3hexylthiophene
(4) Polymerization to obtain highly regioregular (rr) head-to-tail poly-3-hexylthiophene (P3HT).

Data for the energy content for starting the materials thiophene, bromine, sodium, bromohexane are assumed to be available from existing data banks. The energy requirements for the various steps were calculated from the literature. The reaction (1) is described in Organic Syntheses [4] at a 300 g scale. Since no synthesis of 3-hexylthiophene could be found, it is assumed that the reaction will proceed similar to that described for hexylbenzene [5]. The bromination of 3HT and subsequent polymerization is described in a patent by McCullough, albeit at a small laboratory scale [6]. More recent patents from industrial laboratories [7], [8] describe more atom-economical and more energy

efficient syntheses. The results are deposited in form of an Excel Work Book which can be expanded in future steps of this project. The methodology is similar to that used in "Life Cycle Assessment of Future Photovoltaic Electricity Production from Residential-scale Systems Operated in Europe" by Frischknecht et al. [9]. Additional detail is found in the paper by Anctil et al. [10] and patent [11].

Using this methodology, we also modelled the intrinsic energy content of flat glass and found that our estimate agrees within a factor of 2 with published values.

Other Activities

Furthermore, I regularly attended the group meetings of the Ishihara group which are scheduled for every Thursday afternoon and learnt about ongoing work and student projects.

After I had obtained some samples from my group in Singapore, I used the opportunity to have some measurements of fluorescence emission taken in the laboratory of Professor Takashi Sagawa, Quantum Energy Processes Group in the Fundamental Energy Science Division, Graduate School of Energy Science (30-06-2016).

On Thursday, 23 June 2016, I attended a Welcome Reception at CSEAS and was introduced to the director, Professor Yasuyuki Kono.

On 27 June 2016, I attended the Brain Asia Symposium and gave a presentation on water management and NEWater in Singapore under the title "Let the sunshine in". The other speakers of the symposium were Professor Melanita Pranaja BUDIANTA of the Universitas Indonesia and Dr Kanittha Tambunlertchai of Chulalongkorn University, who presented on "Financial Inclusion in Myanmar". Particularly interesting was Prof. Budianta's tals on "Southeast Asia: From World to Region" where she discussed emerging unifying trends within ASEAN countries against the backdrop of the plebiscite in the United Kingdom on 23 June, where a majority of 51.89% had voted for the BREXIT from the EU. At the symposium I had the opportunity to again meet Prof. Y. Kono and to make the acquaintance of Prof. Shigeo Fujii.

On 29 June, I accidentally got to meet Emeritus Professor Dr. Tadashi OGAWA at Goethe Institute. Professor Ogawa is professor of philosophy and specializes in the work of the German philosophers Edmund Husserl and Ludwig Landgrebe. He speaks fluent German. We had an interesting conversation, followed up by several e-mails. Professor Ogawa had spent time in Wuppertal as guest of Professor Held, who himself obtained his doctorate with Professor Landgrebe, and in Cologne where the Husserl Archive is located. I had grown up in Cologne, and my father was a colleague of Professor Landgrebe at Cologne University even though both were in different faculties.

In the time from 3-8 July, I participated in the 16th International Congress on Catalysis in Beijing. This conference, which takes place every four years, is the major conference for researchers in heterogeneous catalysis. The Beijing meeting was attended by over 2,500 scientists. Notable colleagues from Japan were Professors Masakazu Anpo (Osaka Prefecture University), Kazunari Domen (University of Tokyo), Koichi Eguchi (Kyoto University), Atsushi Fukuoka (Hokkaido University), Michizaku Hara (Tokyo Institute of Technology), Shu Kubayashi (University of Tokyo), Akihiko Kudo (Tokyo University of Science), and S. Ted Oyama (University of Tokyo).

On Friday, 1 July, Professor Kamanion Chattopadhyay of the Department of Materials Engineering, Indian Institute of Science, had visited Professor Ishihara at his institute. We had lunch together and also an enjoyable Japanese Dinner with Sake and other Japanese specialties.

After the return to Kyoto on 2 July late, there were only 3 days left. In this time, two more visitors came to Professor Ishihara's institute: Professor Dariusz Olekzak from the Faculty of Materials Science and Engineering, Warsaw Institute of Technology, and Professor Anatoly Ye. Yermakov of the Applied Magnetism Laboratory, M. N. Miheev Institute of Metal Physics of the Ural Branch of the Russian Academy of Sciences, Ekaterinburg. Professor Olekzak gave a presentation of mechanical alloying and high entropy alloys on Monday, and in a seminar on the following Tuesday, I presented our ongoing work on Visible-light Activated Photocatalysts based on Bismuth Oxy-halides and Metal-Organic Frameworks, and Prof. Yermakov reported on Magnetically Abnormal TiO_2.

With this, the time in Kyoto came to a much too early end. We hope to continue the work on the estimation of intrinsic energy content of organic photovoltaic cells and the energy payback time and carbon footprint of this very promising technology. This will require the extension of the data base on energy investment into the various processing steps that are involved in the manufacture of flexible transparent photovoltaic cells.

Acknowledgements

To conclude, I want to express my sincere thanks to Professors Keiichi N. Ishihara and Hideaki Ohgaki for making this stay possible, to Associate Professor Hideyuki Okumura, and particularly to Dr Ai Leon, who helped a lot. Thanks are also to the secretary, Mrs. Kanoko Muruyama and to the Japan Foundation for the Advancement of Science, who provided funding for the Program for Advancing Stratecic International Networks to Accelerate the Circulation of Talented Researchers.

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