

JSPS Short Term Fellowship, 2019

Prof Shankar Ekkannath Madathil

**Host: Prof S Nishizawa
Research Institute for Applied Mechanics
Kyushu University**

I was invited to spend short time at the Research Institute for Applied Mechanics (RIAM), Kyushu University to discuss and undertake research on “Ultimate Power Devices with Superior Efficiency for Future Energy Society” by Prof S Nishizawa. Prof S Nishizawa and his colleagues (Prof W Saito and Prof Kakimoto) made the visit productive, enjoyable and most memorable. I stayed in a Weekly Inn, which had a small self-contained apartment, which was cost-effective. During the stay at Kyushu University, the following activities were carried out.

1) *Seminar and meetings to establish the collaboration between Kyushu University and Sheffield University:* In Kyushu University, there is a special platform, called Q-PIT (Kyushu University Platform of Inter/Transdisciplinary Energy Research). Q-PIT focuses on energy research and sustainable futures. Mega trends such as renewable energy (Solar, wind, etc.), Energy saving technologies, e-mobility and a network connected society, electricity and its management technologies, power devices and power electronics are all key focus areas. During my stay, we undertook review of related fields to gain common understanding and future perspectives.

2) *Joint Research:* Silicon based Insulated Gate Bipolar Transistor (IGBT) is the key power device of today and remains a key component in a future electronic energy society. In Japan, the host (Prof. S Nishizawa) is now promoting a government-led project on advanced scaling Si-IGBT. In the UK, I have been working on a competing technology called the Clustered-IGBT. In both scaling IGBT and CIGBT, with further improvements, reliability based on semiconductor device physics becomes more important. Therefore, during my stay, the Dynamic Avalanche was picked up as the common emerging topic as it can limit the power density and reliability of these components. Therefore, the necessary investigation was carried out by modeling and analysis. Moreover, gate controllability of IGBT was investigated by simulation. This work has led to new results and we made clear the Dynamic Avalanche physics involved and how to avoid it. These results were submitted to leading international conferences (IEDM, APEC, PCIM and ISPSD) and accepted.

3.) *Discussion with other universities, industries and related organizations:* During my stay, an extensive program of visiting 7 universities/research centres was carried out, as listed below. I took part in seminars and fruitful discussion on the future trends and prospects of research work. Some meetings involved industries and academia and the possibilities of future international collaboration was discussed.

* Institutions visited in addition to RIAM :

- 1) June 24 Tokyo Institute of Technology (Prof Iwai, Prof Tsutsui)
- 2) June 25 Seminar with Tokyo University (Prof Hakimoto) and guests from Tokyo Institute of Technology, Kyushu University, Meiji University, Toshiba, Mitsubishi Electric and NPERC-J)
- 3) June 28 Seminar at the National Institute of Advanced Industrial Science and Technology (Dr Nakajima)
- 4) June 29 Same above with Powdec KK (Dr Yagi and Dr Kawai)
- 5) July 1 Seminar at Kyushu Institute of Technology (Prof Omura and his team)
- 6) July 4 Seminar Nagoya University (Prof Jun Suda)
- 7) July 11 Kyushu University (Q-PIT)

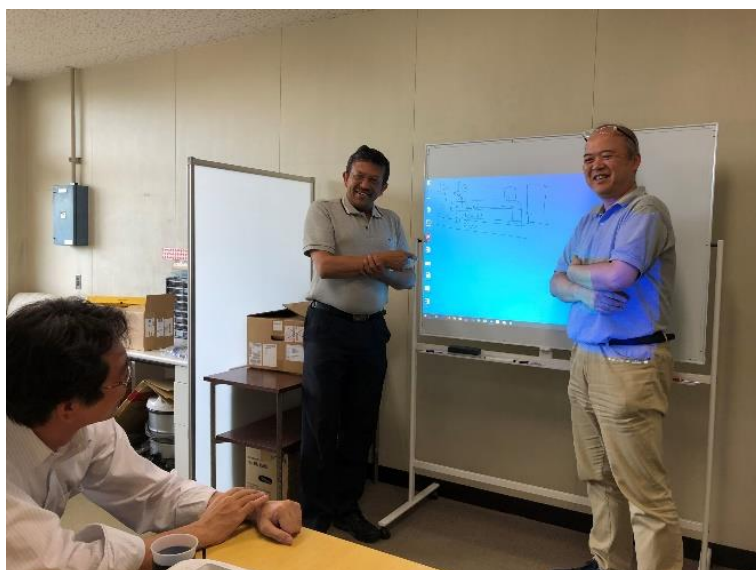


Photo 1: Discussion at RIAM, Kyushu University. (Prof Saito, Prof Shankar and Prof Nishizawa)



Photo 2: Tokyo Institute of Technology. (Prof Nishizawa, Prof Shankar and Prof Tsutsui)



Photo 3: Tokyo Institute of Technology. (Prof Tsutsui, Prof Iwai, Prof Shankar and Prof Nishizawa)

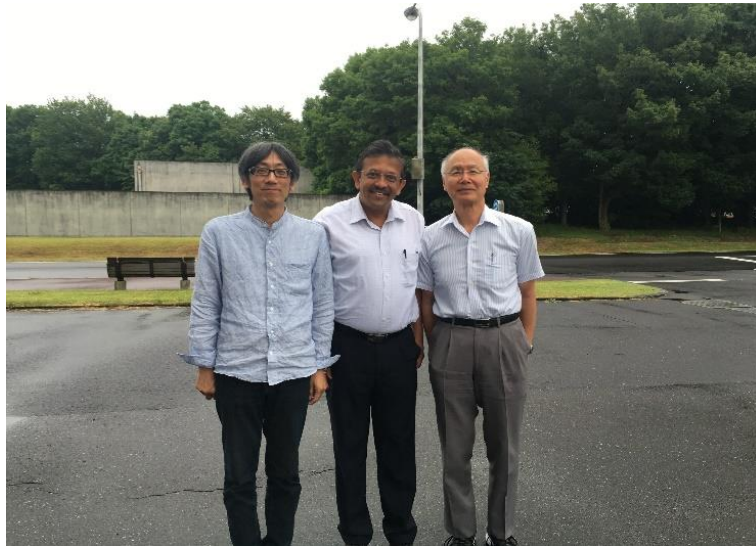


Photo 4: At AIST, Tsukuba with Powdec KK. (Dr Yagi, Prof Shankar and Dr Kawai)

(4) Main Research Publications (accepted)

- Peng Luo, Sankara Narayanan Ekkanath Madathil, Shin-Ichi Nishizawa and Wataru Saito, "Dynamic Avalanche Free Design in 1.2kV Si-IGBTs for Ultra High Current Density Operation", IEEE International Electron Devices Meeting Tech Digest, pp.266-269, December 2019.
- Peng Luo, Sankara Narayanan Ekkanath Madathil, Shin-Ichi Nishizawa and Wataru Saito, "High dV/dt Controllability of 1.2kV Si-TCIGBT for High Flexibility Design with Ultra-low Loss Operation", IEEE Applied Power Electronics Conference, 2020
- Peng Luo, Sankara Narayanan Ekkanath Madathil, Shin-Ichi Nishizawa, and Wataru Saito, "Dynamic Avalanche Free Super Junction-TCIGBT for High Power Density Operation" IEEE ISPSD 2020.
- Peng Luo, Sankara Narayanan Ekkanath Madathil, Shin-Ichi Nishizawa and Wataru Saito, "High dV/dt Controllability of 1.2kV TCIGBT through Dynamic Avalanche Elimination", PCIM, 2020.

5: Remarks: Even within the short period of less than 2 month, the work resulted in 4 international conference papers and further being drafted. These are the based on the results obtained during

the stay. From a social perspective, enjoying the Japanese culture as well several visits to different Onsens in Kyushu were most enjoyable. In order to go to the next step and to continue good collaboration, both sides have applied for the International Exchange 2020 Cost Share Program between the Royal Society and JSPS.