

Report on Visit to the Commonwealth Scientific and Industrial Research Organization (CSIRO) Materials Science and Engineering by International Training Program

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I will report to here because I participated in the International Training Program (ITP) long term dispatch.

I visited to Prof. Ostrikov's researching group of the Commonwealth Scientific and Industrial Research Organization (CSIRO) Materials Science and Engineering, Sydney, the state of New South Wales, Australia for two months of from January 27th to March 28th of 2011, and I was engaged in researching activities. I have researched about development of new alternative fluorocarbon gas, evaluation of interlayer dielectric etching properties, and clarification of etching mechanism at Hori & Sekine Lab., Nagoya University. And in this time, the CSIRO is found a desired place, because the CSIRO conducts research areas of not only plasma processed but also biotechnology, environmental technology and medical applications, and I thought this program is good opportunity to learn new plasma application technology.

I feel that it was possible to concentrate on researching activities by not only Prof. Ostrikov but also Dr. Kumar, Ph. D, and Ph. D students at CSIRO.

And it is convinced that these two months were big steps for it just not to have a very big influence on my life as a researcher in the future in experiencing and the business, and to accomplish growth as the person. Because, it was felt that occupied an important position of this long term dispatch those all of life in inexperienced land where not only research activities in the laboratory but also communications with people met in the laboratory, and so on. And it was very significant.

Moreover, I could feel culture difference between Japan and western countries such as Australia, Asian countries. Because, various countries researchers such as U.S., European, Korean and Chinese study at CSIRO. Especially, there was the difference between Japan and

CSIRO on the life side. In general, it is said that the Japanese is diligent. However, I thought that researchers in other countries are very diligent, and they have studied about there research with confidence and proud. Moreover, I thought they do the usage at very efficient time through two months. And, I felt it concentrated and leisure and private time were produced with the conducting research well.

It was made to feel that it was very important for firmly taking communications to know this cultural difference. It was felt that living for a long term of two months in Australia had been faced greatly and difficultly when there were a difference of the language, difference of the culture, and a lot of uneasy elements even if procedure and meal one of the dwelling were taken, and it started solving these by my one power. Of course, it is felt also that it is one of the major factors to solve them with an own hand facing the difficulty to acquire an international way of thinking, and to grow up to the researcher who passes in the world. And when it is a favor of the cooperation of the people of CSIRO, we wish to express our gratitude for being engaged in research activities by not doing a big inconvenience to life to which it doesn't become accustomed in the foreign country, and concentrating. It is felt that communications were able to be taken well by having positively talked to by using English on that.

Prof. Ostrikov and Dr. Kumar said, "We are busy, so we can't pick up you." But, when I arrived at Australia, it was easy to access CSIRO, because they give information to me about access from airport to my apartment and CSIRO. When I arrived at CSIRO, Dr. Kumar had the procedure of ID card issue for immigration into CSIRO, and introduced to me the experimental facilities and equipment, and member of other researching group in CSIRO. Moreover, he said, "If you experiment using the experiment equipment in CSIRO,

you must undergo training for one month or one and a half months.” After explanations of the rules in CSIRO, I went to Prof. Ostrikov’s office to report about arrival here safety. Prof. Ostrikov learned many things such as a style of researching in Western countries to me. And Prof. Ostrikov told me that researchers have studied about development of new carbon nano materials and evaluation of carbon nano materials at Ostrikov’s researching group.

A client unlike any other because of the need training as described above, I didn’t experiment. And discussion about our researching data, lecture of writing papers, way of good presentations, writing papers as co-authored, and improvement of English communication skills were a main objective this ITP at CSIRO.

On the day of arrival at CSIRO, Prof. Ostrikov said, “I give time of 2 weeks to you. Please make a presentation and talk about your research.” Since I arrived at CSIRO, the first 2 weeks, creation of presentation slide about my research became my work. During 2 weeks of creating presentation slide, Dr. Kumar checked the content of my presentation slide. He gave to me advice about the content of my presentation slide. He asked me, “Why top and lower power supply were MHz range frequency?”, “How did you estimate thickness of fluorocarbon film on dielectric film after plasma etching?” In this time, I discussed with Dr. Kumar in English, and I did a lot of trouble to the discussion because my English skill was poor.

After spending 2 weeks, I presented for Prof. Ostrikov and Dr. Kumar about summarized my researching presentation. Presentation time was just 15 min., and after presentation, Prof. Ostrikov gave some advice to me as the following.

- Presentation time is 1 minute 30 seconds shorter than the time it is available, and we have more time for discussion such as question and answer, the presentation becomes good.
- Talking to the audience and looking to the audience except explaining about the resulting diagram.
- Sentence should be short and written in a slide. Describing sentence at length is not good, and the importance and impact of experimental result are would weaken.
- The reference must be placed in the slide. Especially, if there is no reference in the slide, the significance of

proceeding research would weaken.

Prof. Ostrikov said “Especially, for my research, researching results and experimental data are so good. But, if you don’t give the presentation to be aware of the above, your researching content becomes normal.” When Prof. Ostrikov said the above things, I thought that you’re right, exactly. And I’ve decided that I want to give a presentation with the above things at next national and international conference.

The next day, Prof. Ostrikov and Dr. Kumar taught how to write research paper to me. And we discussed about content of presentation and outline of research paper. For writing excellent paper, Prof. Ostrikov mentioned that you have to write the paper with as the following points.

- The title of paper must be catchy. This is very important.
- Reducing to 150 words about paper’s abstract which summarizes. The quality of paper is determined by abstract. If abstract has a lot of words, the paper is rejected by referees.
- On background of paper, it is important to describe clearly that research has been done in such a process which has any problem with it, or how to solve it.
- To approach of experiment, describing “We got to solve these problems or what method.”, “Why did we use these methods.”
- Describing why these obtained experimental data are very important.
- Finally, describing what kind of process, can these obtained experimental data be expected to apply in actual semiconductor fabrication process.

Before visiting to Australia, I had been writing the paper about my research, I felt that points such as “On background of paper, it is important to describe clearly that research has been done in such a process which has any problem with it, or how to solve it.” and “Describing what kind of process, can these obtained experimental data be expected to apply in actual semiconductor fabrication process.” were not described in my paper.

I mentioned above, discussion about our researching data, lecture of writing papers, way of good presentations, writing papers as co-authored, and improvement of English communication skills were a main objective this ITP at CSIRO in this ITP. But, my research is collaborative

research with a company, Prof. Ostrikov worried that issues such as patent would be involved in writing paper. So, the next day, I discussed about writing paper with a company, Prof. Ostrikov, Dr. Kumar, Prof. Hori and Prof. Sekine in Nagoya University. As a result, in this time, we decided that my researching paper was not co-authored. But, Prof. Ostrikov and Dr. Kumar said, “We will give some advices to you about interpretation of experimental data, outline of paper, and so on.” And I was really happy.

After the end of presentation and discussion about my research, I had been thinking that “What should I obtain data for writing paper?”, “Can I progress my research during ITP?”, “Is there things which might be incorporated into the experimental and evaluating methods?” with reading and looking for various papers on my research. After returning to Japan, I had thought that I want to simulate about gas molecules dissociation and film surface reactions between dielectric films and dissociated species in plasma. So, I read and studied some papers about simulation of reactions between dielectric films and dissociated species in plasma. Bas the follows, I introduce some papers I read.

- “Influence of carbon monoxide gas on silicon dioxide dry etching”, N. Omori, H. Matsuo, S. Watanabe, and M. Puschmann, *Surface Science* 352-354 (1996) 988-992
- “Mass analyzed CF_x^+ ion beam study on selectivity of SiO_2 to SiN etching and a-C:F film deposition”, K. Yanai, K. Karahashi, K. Ishikawa, and M. Nakamura, *Journal of Applied Physics* **97**, 053302 (2005)
- “Modeling the plasma chemistry of C_2F_6 and CHF_3 etching of silicon dioxide, with comparisons to etch rate and diagnostic data”, H. Pauline, J. E. Johannes, R. J. Buss, and Ellen Meeks, *J. Vac. Sci. Technol. A* 19(5), 2001

Ynai’s paper represents reaction between CF_x^+ ions (CF^+ , CF_2^+ and CF_3^+) and SiO_2 , SiN film surface using mass selected ion beam source. In Pauline’s paper, they simulated dissociative reaction of C_2F_6 gas and reaction between dissociated species and SiO_2 film surface using CHEMKIN software.

Next, I had thought that I can experiment something during staying Australia. And I asked Mr. Yusuke Kondo at Hori & Sekine Lab., Nagoya University to measure behavior of

electron density and optical emission spectrum for C_5F_8 , $C_5HF_7/O_2/Ar$ plasma. In general, reaction rate constant $\langle \sigma v \rangle$ is obtained from electron density and Ar emission intensity, reaction rate constant $\langle \sigma v \rangle$ represents the behavior of high energy electrons which contribute to dissociation of gas molecules. And we can discuss about dissociation mechanism of fluorocarbon gas molecules in plasma using reaction rate constant. In this time, we estimated reaction rate constant $\langle \sigma v \rangle$ from the following equation.

$$\langle \sigma v \rangle = I_{Ar} \cdot 1 / (N_e \cdot [Ar])$$

Here, I_{Ar} represents emission intensity of Ar, N_e represents electron density, and $[Ar]$ represents Ar gas molecules density.

I will describe the experimental result and discussion as the follows. A plasma power operating at 60 MHz was applied to the upper electrode and the plasma was generated. A bias power at 2 MHz was supplied to the lower electrode. The etching conditions were maintained at a total pressure of 2 Pa, a VHF power of 1800 W, and a bias power of 1200 W. The fluorocarbon (CF) gases, C_5F_8 or C_5HF_7 were introduced with O_2 and Ar. The CF gas flow rate was changed between 5 – 16 sccm. The flow rate for O_2 and Ar was fixed at 25 and 300 sccm.

Figure 1 represents the dependence of fluorocarbon gas flow rate on electron density. From fig. 1, for both plasmas, electron density decreased with increase of fluorocarbon gas flow rate. From this result, it was considered that Ar gas partial pressure decreased with increase of fluorocarbon gas flow rate and electron density decreased. Moreover, electron density of $C_5HF_7/O_2/Ar$ plasma was lower than that of $C_5F_8/O_2/Ar$ plasma.

Next, fig. 2 represents the dependence of fluorocarbon gas flow rate on reaction rate constant $\langle \sigma v \rangle$. For $C_5F_8/O_2/Ar$ plasma, reaction rate constant $\langle \sigma v \rangle$ increased with increase of fluorocarbon gas flow rate. On the other hand, for $C_5HF_7/O_2/Ar$ plasma, reaction rate constant $\langle \sigma v \rangle$ decreased with increase of fluorocarbon gas flow rate. Moreover, reaction rate constant $\langle \sigma v \rangle$ of $C_5HF_7/O_2/Ar$ plasma was lower than that of $C_5F_8/O_2/Ar$ plasma.

From results of measurement of ion species for C_5F_8 , $C_5HF_7/O_2/Ar$ plasma using Quadruple Mass Spectroscopy

(QMS), For $C_5HF_7/O_2/Ar$ plasma, existence of large mass ion species such as $C_2F_4^+$, $C_3HF_4^+$, $C_4F_4^+$ and $C_4HF_4^+$ ions was verified. For $C_5F_8/O_2/Ar$ plasma, existence of large mass ion species such as $C_2F_4^+$ and $C_4F_4^+$ ions was verified, but density of these ion species of $C_5F_8/O_2/Ar$ plasma was lower than that of $C_5HF_7/O_2/Ar$ plasma. So, from measuring behavior of electron density and reaction rate constant $\langle \sigma v \rangle$, for $C_5F_8/O_2/Ar$ plasma, it is considered that dissociation of C_5F_8 gas molecules progressed and density of high mass ion species was lower because high energy density of $C_5F_8/O_2/Ar$ plasma was higher than that of $C_5HF_7/O_2/Ar$ plasma.

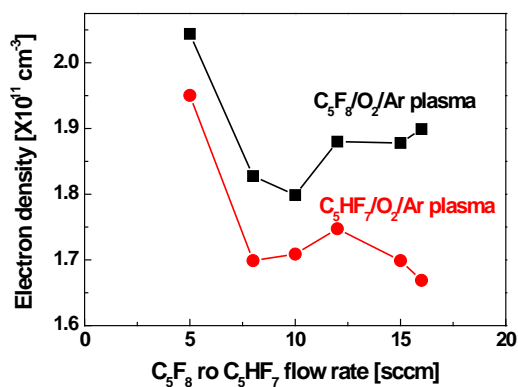


Fig. 1 The dependence of fluorocarbon gas flow rate on electron density for C_5F_8 , $C_5HF_7/O_2/Ar$ plasma.

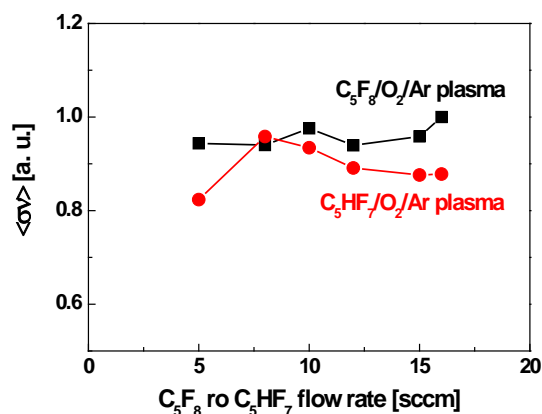


Fig. 2 The dependence of fluorocarbon gas flow rate on reaction rate constant for C_5F_8 , $C_5HF_7/O_2/Ar$ plasma.

I feel that very significant time was able to be spent for the period of two this months in Australia.

In this time, I didn't experiment at CSIRO and the main activity was discussion about my experimental data. In other words, I was not given theme, I had to think the content of researching activity. So, it was precious that I could read a lot of papers about my research and study again.

Furthermore, it seems that living in the apartment for two months in not only the research but also foreign countries, and having lived were the precious lessons for me. Moreover, the friend was able to do in Australia through life, and the culture of various countries such as Australia, U. S. and Korea were able to be studied.

Consequently, this program was able to be spent significantly though it was substantially and greatly different from a short-term dispatch because it participated in the long-term dispatch program, it belonged to the laboratory of the rule university, and it researched, too. Finally, I would like to express my hearty thanks to Prof. Ostrikov, Dr. Kumar, and Nagoya University plasma engineering research center ITP secretariat. I want to tell how to add life in foreign countries telling juniors the experience of this time by all means, and deepens of the exchange with an overseas researcher.