Report on Visit to Sungkyunkwan University by International Training Program

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Plasma process technologies have played a great role on major industries such as display, solar cell, semiconductor and so on, to which it is indispensable in Japan. Since it was widely applied to the manufacturing, plasma technologies have been developed rapidly and extended to application fields. In present, the activities of plasma technologies have been investigated around America, Europe and Japan. Forward, it would be expected to be applied in a lot of advanced fields and it has a big amount of potential. Japan also has invest a lot of money and manpower in developing the advanced plasma technologies and trained many researchers, who is contributing to the science society.

However, if the technological development is limited only domestically, it should be inferior to the flow of globalization. From the viewpoint of overcoming this problem, International Training Program (ITP) gives a good chance for the student and researcher, who are studying the plasma science, to experience and contribute, as dispatching to the excellent institute in the world. Beside the research, as experiencing and understanding the different culture, language and its history, it can be a fruitful chance to learn and acquire various things from the collaboration.

I was dispatched and collaborated with Center for Advanced Plasma Surface Technology (CAPST) in Korea, which is located in Sungkyunkwan University and have been leading the plasma technology development in Korea. Since CASPT consisted of superior professors and students from the universities, which is leading the scientific research in Korea, and was established in 2000, CASPT have been investigating over all of plasma process technologies such as deposition, etching, devices, surface treatments and plasma diagnostics from fundamental research to applications. As a result, there have been many achievements through the development of new technologies and collaboration with corporations and those institutes.

I was dispatched and did the experiments with Dr. Britun, post doctor, in Prof. Han Lab, who is working as a director of CAPST. When arrived first day, we greeted with CAPST members and introduced ourselves. After that, Ph. D student showed and explained the laboratory to us. There were so many apparatuses. Prof. Han lab. almost focuses on the film synthesis by using magnetron sputtering. In order to examine the mechanism of film growth, lab was equipped with various diagnostics tools such as dye laser, Langmuir probe, Fabry-Perot interferometry, optical emission spectroscopy system (OES) and so on. We visited to other laboratories dealing with etching, device manufacturing, the film synthesis by using PECVD. CAPST was already equipped with very useful apparatuses and tools for developing the plasma process technologies and industrial application. Especially, because I collaborated with Dr. Britun in progress of experiments, I had to communicate in English. At this point, the exercise of conversation in English before dispatch as an aim of ITP was very helpful personally. Even though the exercise in private school was just one month, the conversation with native speaker was a great help to me. I think it is not important to make an effort to speak English very well by using right grammar and good pronunciation. The point is to have a confidence to speak English even though using wrong sentences. From that view, it is thought that the conversation experience with native speaker is necessary for students.

If I mention the contents of research, the aim is to examine the species related with carbon such as C atom, C_2 and C_3 generated by magnetron sputtering discharge by using Laser-Induced Fluorescence (LIF) as a diagnostic

technique. Carbon material has a great potential to be applied to so many industries such as automobile, display, semiconductor and secondary battery. Especially, carbon based coatings prepared by plasma processing are described as being amorphous solid carbon composed of small sp^2 bonded graphitic clusters and sp^3 coordinated carbon atoms. Therefore, the high hardness of carbon based films is usually linked with the number of sp^3 like bonds. However, sp^2-dominated hard and conductive carbon based films have recently emerged. These films have an advantage in various industrial applications owing to the hard and conductive properties and have attracted a great deal of interest. CAPST already had a technology to synthesize the conductive carbon films by using magnetron sputtering. Based on this technology, it is expected to apply on polymer substrate at low temperature. Actually, it is difficult to obtain good properties of the films on polymer, because of low temperature process and its own properties of polymer. So, for low temperature synthesis on polymer, it is necessary to investigate the major parameters such as the kinds and densities of sputtered particles, energy, those temperatures and velocities, which have an influence on actual film growth.

In this work, as investigating the internal parameters such the density and velocity of sputtered particles by LIF, it can be expected to enhance and control the film properties. We would expect to understand the mechanism of film growth at low temperature and advance one step for the application of carbon film synthesized on polymer substrates. Moreover, there are few reports relating with the measurements of carbon atoms by LIF. Actually, light atoms such as hydrogen, carbon, oxygen, nitrogen and fluorine are very active species in plasma processing have their first excited levels, optically connected to the ground state, at energies above 6.5 eV. For these species the photo-excitation is only possible with vacuum-ultraviolet (VUV) photons, i.e. with wavelengths shorter than 190 nm. Actually VUV photons are difficult to generate and propagate, although experiments are in progress in this domain. This difficulty can be overcome by the simultaneous absorption of two photons to excite the species on a radiative level (TALIF). From this point, the trial of collaboration has the enough originality itself. And because Hori laboratory has the technology to detect carbon atom in the plasma process by using Vacuum Ultra-Violet Absorption Spectroscopy (VUVAS), the synergy effect can be expected by comparing and considering the results obtained by LIF and VUVAS.

Since I actually had no experience about the LIF technique, I needed to understand LIF technique from the basic theory to applications. First, I ask a favor to Dr. Britun and I received the education two times for 6 hours from him about the theory and experimental results. At the same time, I had a presentation about what I want to do during 2 months to Prof. Han and CAPST members. The schedule could be arranged by Prof. Han and Dr. Britun efficiently.

As a first step to start the experiments, I tried to learn overall and accumulate many experiences from the fundamental preparations such as laser alignment, the choice of dye needed and the configuration of optical parts and experimental skills such as how to choose the excitation wavelength and how to operate without any mistake. As a result, I could accumulate a lot of good experiences from Dr. Britun. However, unfortunately, as it was not enough time to acquire many data due to the problem of maintenance and delivery time needed for ordering new dye and mirrors, it was difficult to acquire good results. For instance, there was some trouble of leak due to the deformation resulted from overheating, because we needed to keep long time to check and measure LIF signal for more than 30 minutes. Fortunately, my experience in master student, when I deposited and analyzed the thin film by using magnetron sputtering, was very helpful for solving the problems. But, there was the limitation to detect carbon species by using dye CAPST possessed because that dye was adequate to detect Ti and Ti^+ in previous works. Nevertheless, we tried to check the fluorescence signal from the excited level in the case of carbon as many as possible. During that time, we ordered new dye proper to detect carbon species to America directly. Because they didn't have in stock, the dye arrived 3 weeks later. As a result, there was not enough time to do experiments by using new dye. So, we focused on what we can do possible by old dye. But, unfortunately, it was failed to detect the fluorescence signal. As an alternative experiment, we tried to measure the density of Ti and Ti^+ by LIF because CASPT already succeeded to measure and analyze those results. In this work, I could learn and

understand fully to measure the plasma parameter by LIF. Two months was very a short period to make a visible result, but it was a very good chance to enhance my research capability and to enlarge a research field in new research environment.

In addition, there was a chance to attend the domestic conference, Korean Vacuum Society, and I could catch the trend of plasma process technology in Korea. The research field using plasma process technology was very similar to that of Japan. I think that's why the major industries supporting each country are very similar, for example, automobile, semiconductor and display. However, three was some gap of research fund and scale between each country. It means, I think, Japan government and corporations are trying to invest a lot of capital and equipment to the field of plasma science rather than Korea. That investment may form the groundwork to develop the plasma process technology and as a result, it could be expect to develop and lead the worldwide advanced high technologies. I could also participate in a big exhibition related with solar cell and semiconductor, which was held in Seoul and is biggest in Korea and could obtain the meaningful information from it. In that exhibition, I could obtain the information that so many corporations including Korea, Japan, Europe and America are focusing on developing solar cell as a next generation energy industry. It was a good experience to have an interest in new research field. If I have a chance to study the research of solar cell, I would like to try to focus on it because I think the solar cell is very attractive and new enough to lead the alternative energy in the future and in these days, it has been receiving the attention in the world including America, Europe and Asia.

As a life in CAPST, we were first supposed to attend the lab. meeting on every Monday morning with all of members. That meeting was presented in only English. We also kept in reporting our research progress every two week. We could attend and understand the recent research in CAPST and also it was possible to ask and discuss about what I wondered. We could feel that CAPST members really gave a support to us in both of research and life in Korea in their heart. First of all, we were accommodated in guest house for foreign researcher located in university for 2 months, which had very ease access to laboratory and was very convenient. Because the accommodation was very close to laboratory, we could save time and be safe even if late night. I would like to appreciate very kind concern to CAPST. Moreover, because there were a few foreign students and researcher in CAPST, I had a good experience to know other country. For example, Ph.D student, who is working in NOKIA in Finland and collaborating with CAPST, was very smart and I could hear the research environment of university and company in Finland. Also, from Chinese student, we could talk about a lot of thing including culture, food and research trend in each country.

As mentioned at the beginning of this report, ITP offers a chance to experience the research as well as the different culture of different country, which we never met with.

Even though I was supposed to be dispatched to Korea, I also had a good time to enjoy with 2 Japanese students for 2 months. I could help them to live and make a relationship fast with CASPT members in laboratory. And also, I could give a tip to feel the Korean culture around university, for example, the folk village, popular performance and famous tourist resorts. In particular, I tried to give a chance to eat and feel various Korean traditional foods, because they had never eaten before and it is difficult to know a various Korean food in detail. In this program, I could make a close relationship with Japanese students and I was happy to let them to know and understand Korea.

What I felt in this program was that this program was very meaningful for students to go and experience in excellent plasma research institute in the world directly and to enhance the research capability through collaboration and some trials and errors. Although ITP was started from this year, it would be excellent program for collaboration if it keeps in collaborating with many countries and accumulating many experiences. Also, if Japan inversely attracts the foreign students, it is a good to understand and communicate each other and it lets them know the research trend in Japan as well as Japanese original culture. Furthermore, in case the dispatch can be extended to 6 months or more than it, it is possible to achieve good and deep results and to discuss in detail.

Plasma technology is one of the fastest growing branches in the scientific technologies and has got a leading position in the industrial applications. There have been investigated

about plasma, but there are a lot of unknown phenomenon because the plasma is very complicated and the sophisticated analysis technology is not enough to clear yet. I hope that the advancement of plasma technology development can be realized through various ways such as the collaboration of ITP with other countries or enough investment to the research.

Finally, I would like to express my sincere appreciation to ITP for giving me beneficial support and kind concern.