（別紙様式５）

変革を駆動する先端物理・数学プログラム（FoPM）

国外連携機関長期研修　報告書

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I stayed at Karlsruhe in Germany, one hour from Frankfurt by train and close to the border with France, for three months. The city was the third-largest city of Baden-Württemberg and the 22nd-largest city in the nation. The city was very compact and convenient that I can find all commodities and foods during the 30 minutes' walk from my house to the university. The host of my internship was Prof. Manfred Kappes in Institute of Physical Chemistry, Karlsruhe Institute of Technology, who is a specialist of gas-phase photoelectron spectroscopy, photodissociation spectroscopy, and ion mobility mass spectrometry of naked metal clusters and owns more than ten unique vacuum apparatus. While their components and functions are described in papers, I expected to get some ideas and insights about the design of such unique machines by watching the details of them with my eyes and using them by myself. I had used several machines such as a high-resolution ion mobility spectrometer and a photoluminescence spectrometer coupled with mass-selected deposition setup.

The most interesting result was wavelength-dependent photoluminescence from an organic dye at low temperature of 5 K in inert gas matrix. The apparatus was composed from an electrospray ionization source, a quadrupole mass filter, a soft-landing ion optics, and a cryostat at 5 K equipped with a mirror. An organic dye was ionized and introduced into the vacuum chamber, mass-selected, and soft-landed on the mirror while spraying Neon gas simultaneously to form the solid of Neon. By spraying the excess amount of Neon gas, the dye ions were deposited as isolated ions rather than solids. By irradiating the light from the outside of the vacuum chamber and collecting the reflected light on the mirror, we can obtain various spectra of isolated ions in Neon matrix such as UV-visible absorption, IR absorption, Raman scattering, and photoluminescence. The advantage of this machine is that ions can be characterized in the isolated state and at low temperature, yielding quite sharp spectra which is quantitatively comparable to the quantum chemical calculation under an isolated environment. Photoluminescence is basically independent from excitation wavelength, but we unexpectedly observed the wavelength-dependent photoluminescence. This finding was very lucky because first experiment was conducted with several wavelength-fixed lasers. To confirm the result, additional experiment was conducted by using a wavelength tunable OPO laser in another room. Although the laser was not used for the photoluminescence, the collaborator quickly coupled the laser light with the apparatus through the optical fiber. I was impressed by the extremely high resolution of photoluminescence spectroscopy at 5 K and the flexibility of the machine because both points were indispensable for that finding.

I also conducted the spectroscopy of ligand-protected metal clusters brought from Japan, which is my research interest, and obtained several results. However, the spectra were broader than those of dyes or small molecules due to the large flexibility of clusters, indicating that the resolution was limited by not the apparatus but the molecule itself. A vacuum and low temperature environment is simplest and most ideal for precise spectroscopy, but real molecules are too complicated. This is very sad news for me as a physical chemist but overcoming this difficulty would be a breakthrough not only for cluster chemistry but also other fields with complex systems such as biological chemistry or nanoscience.

Besides the experience of research, the life in Germany was quite interesting for me because this is my first visit in Europe and my first long-term stay in a foreign country. I was confused everywhere at first regarding the different culture about food, supermarket, restaurant, public transportation, and so on, but gradually adapted to it. I was surprised that just after arriving at Germany the train was delayed for 30 minutes as it does not happen in Japan, but finally I felt that Japanese train are too punctual and Japanese people are too strict. I could not experience this kind of culture shocks in Japan. The biggest difference between Germany and Japan is probably the working style. In Japan, people including me try to do everything by myself and take a long time to learn how to do it, and finally become hard workers. However, German people are specialized to their own work and the division of labor is significantly progressing, resulting in the short working time compared to Japan. This kind of specialization seems the national character of Germany. Both styles have their own advantages, and the combination of good points would be more productive than ever.

In summary, this internship was a very exciting, valuable, and unforgettable experience for me. I would like to appreciate my supervisor Prof. Tatsuya Tsukuda introducing Prof. Kappes, secondary supervisor Prof. Kazumasa Takeuchi in FoPM program discussing unfamiliar research topics actively, host supervisor Prof. Manfred Kappes accepting my internship, all collaborators, especially Dr. Sreekanta Debnath, Dr. Erik Schneider, Dr. Hennrich Frank, helping experiments and discussing results, and FoPM program providing financial assistance for the internship.

Picture of currywurst, the most favorite food in Germany, in the cafeteria of the university, an apparatus used in the internship, an overview of Karlsruhe, and a Christmas market in München.