

MERIT Overseas Dispatch

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Place: Johnson Group (Department of Chemistry, Massachusetts Institute of Technology)

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Research Project: MOCs as Reversible Cross-Linker in Polymer Network

Research Background and Contents:

To realize a sustainable society, extending the lifetime of polymer materials, such as plastics and gels, is a crucial challenge. Mechanically tough polymer materials are likely to have long lifetimes because they absorb more energy before being damaged. Johnson Group has discovered that "weak bonds" incorporated into polymer networks paradoxically make materials tough by sacrificially breaking upon stress. However, since those "weak bonds" are covalent, the original network structures cannot be rebuilt once the bonds break. Finally, the materials gradually degrade. In new projects, we use metal–organic cages (MOCs), which consist of metal ions and organic ligands, as "weak bonds" in polymer networks. MOCs formed by coordination of organic ligands to metal ions are able to reversibly associate and dissociate. Therefore, it is expected that the MOCs, once dissociated by stress, would reassociate and rebuild the polymer network structures, leading to the recovery of the original mechanical properties. In addition, we prepare a pair of ligands covalently connected by a polymer chain that can be encapsulated in a MOC. In this case, even if the MOCs dissociate, cross-linking structures of the polymer network would be maintained, potentially providing materials with better mechanical properties.

During my stay, I aimed at preparing samples for single-molecule force spectroscopy (SMFS), which observes energy absorption behaviors of a single polymer chain upon stress. First of all, I synthesized organic ligands connectable to a polymer chain in order to incorporate MOCs into polymer networks. Next, by living radical polymerization, I prepared polymer chains with a functional group necessary for SMFS measurements. Finally, I connected the polymer chain to the ligands and confirmed the formation of the MOCs after adding metal ions by nuclear magnetic resonance (NMR) spectroscopy. Unfortunately, it was unclear whether the ligands in the polymer chains were included in the MOCs. We plan to optimize the ratio of the ligands in the polymer chain and conditions for MOC formation.

Research Life:

Through the research activities in Johnson Group, two things particularly have left

impression on my mind. First, excellent self-management skills are required. They do not set core time, and everyone can come and go as they pleased. At first glance, they enjoy freedom, but no one scolds you for being late to meetings or for making little progress on your project. In other words, those who lack self-

management skills seem to fall behind. Second, discussions are always positive and constructive. They hold meetings in a relaxed atmosphere, sometimes with pizza in hand, yet actively discuss. Additionally, there are opportunities such as social activities like lab trips and drinking parties, as well as DEI (Diversity, Equity & Inclusion) events, where they have a debate by bringing social issues into academia. The time spent in the lab is not dedicated only to research but well balanced with each personal life.

Daily Life:

The climate in Cambridge, where the temperature was 5 °C lower than in Tokyo, was quite comfortable, although there were a few days when the temperature reached 35 °C. That area is very safe, so I had no issues for going home late from the lab or drinking parties, except for one shooting near the campus. Since many students were away for summer

internships, I was able to rent a fully furnished room in a dormitory, while the rent was 200,000 yen per month. Due to the weak yen, prices were about two to three times higher than in Japan. When you order one main dish at a restaurant, it costs around 2,500 yen. Therefore, I cooked as much as possible. I was never bored with a wide variety of bread, pasta, and sauces. I also enjoyed my weekends, as lab members invited me to home parties and parades. The most memorable experience was the fireworks on the 4th of July, Independence Day. There was a bunch of visitors along the Charles River next to the campus.

Acknowledgements:

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Boston Pride Parade for LGBTQ+



Fireworks on Independence Day