

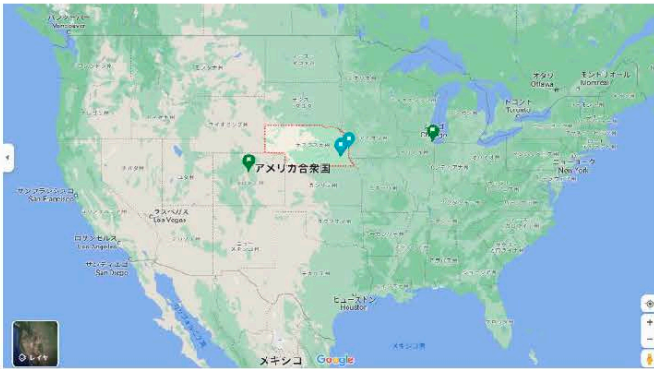
**Report on the short-term overseas study program  
for KU Engineering students  
Graduate School of Engineering, Kyoto University**

Name:	S Y	Date:	2022/11/12
Department	Engineering	Grade:	M1
Undergraduate School:	Materials Science		

## 1. Destination and My Stay

University of Nebraska - Lincoln(UNL), College of Arts and Sciences, Physics and Astronomy, Jorgensen Hall(Fig. 1)

Period of my travel: 2022/9/7-2022/11/3



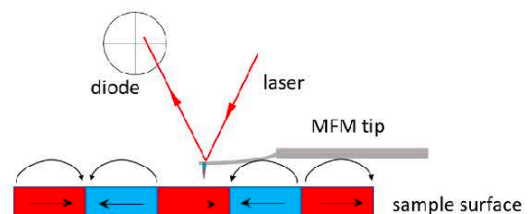
**Fig. 1:** Location of Nebraska State(Google Map) and picture of Jorgensen Hall at UNL (<https://facilities.unl.edu/node/75>)

Football is their pride and dominating news of the next day of a game day. Football is so concerned by some people that the football stadium on campus has been the third populated place in Nebraska. The state is in the middle of Corn Belt. Huge farms of corn, soybean and livestock cover the large portion of the really flat land. The weather fluctuates a lot and almost unpredictable even for local people without a weather forecast. There were few entertainment that you can enjoy at typical big cities like Osaka or L.A.. Instead people enjoy nature and things inside their house. People are more relaxed and easygoing compared with those in big cities. This is more like a human nature of those who are living in rural, which is also a tendency of Japan. One thing that is related to this and I was seriously surprised was that my host family didn't charge me any rent for my 2 months stay in their huge basement with a kitchen and a bathroom!

## 2. Research Activities

### A. Magneti Force Microscopy(MFM)

I was assigned MFM measurements tasks and worked on several samples of thin film CoPt. The background of my research in UNL was based on the work done by a Singapore group [L. Liu et al., *Nat Commun*13, 3539 (2022)]. They found that CoPt thin layer realize field free  $M$  switching with a current pulse, which is a unprecedented phenomenon. This phenomena can be potentially applied to low energy spintronics technologies such as device memory. At the end of the paper they discuss the Co concentration dependance about the [111]

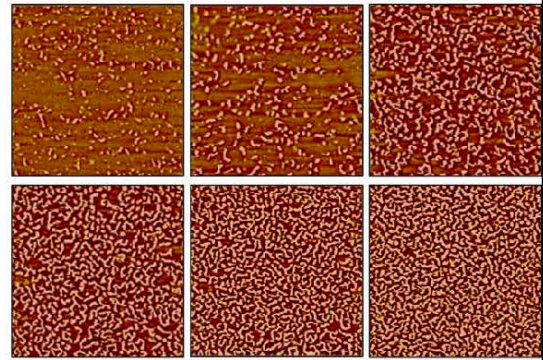


**Fig. 2:** Schematized picture of the principle of MFM. Red and blue region represent differently polarized magnetic domain.

direction. They found that Co concentration have something to do with the spin-orbit torque, which is thought to be essential to  $M$  flip. In order to validate their theory they spattered thin films with different Co concentration gradient. Moreover, for further research they tried to visualize skyrmions on the sample surface. Here, my task was to see at which field the samples start to form skyrmions and to roughly measure their sizes.

MFM is a sophisticated measurement technique to characterize the magnetic state of a sample surface by measuring changes of magnetic force between a probe tip and a sample. Mostly you can measure domains of magnetic materials. On Fig. 2 I showed a schematized picture of the principle of MFM measurements. A laser is pointed towards the tip's cantilever, which is magnetic, and they are aligned so that the diode can detect the photons. When there are magnetic interactions between a sample and the cantilever, it will be bent and the point where the laser is focused on the diode deviate from the original point. This deviation will be detected as a voltage change and you can visualize the sample surface by analyzing the voltage changes.

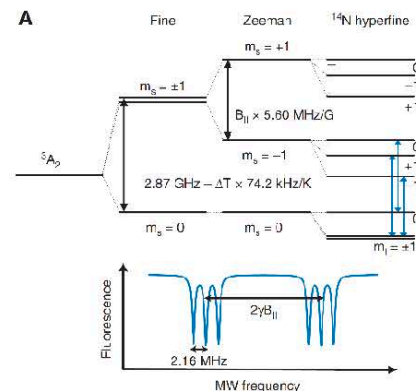
On Fig. 3, I shortly shows the measurement result. You can see the clear domains and their growth.



**Fig. 3:** MFM results on CoPt thin film of 20nm. The external magnetic field was 500, 300, 200, 100, 0, -100 Oe from the top left to the bottom right

B. Nitrogen Vacancy Quantum Diamond Microscopy(QDM)

I was also collaborated with a team in the college of Engineering. Their project was about QDM using NV diamond. NV diamond is a diamond which has a nitrogen defects and vacancy defects. A Hamiltonian of NV bonds orbitals sensitively couple with magnetic field, electric field, pressure and temperature. The change in the Hamiltonian is equivalent with the deformation of electric state of NV, which can be detected by the absorption of green light. This QDM is useful to image, for example, shape of a nanostructure or small magnetic field down to few mT. Using this a member of the team is going to try to visualize the dynamics of skyrmions on the CoPt thin films. Their final goal is to characterize the chirality and the type of them. Unfortunately, I was not able to try NV measurements, however, my MFM research was a major contribution on their research and it helped them to make a solid plan on a NV measurement.



**Fig. 4:** Electric state of NV bonds.

C. Accomplishments

I was able to learn basic techniques of MFM and got some idea about NV QDM. I believe that I have got used to use the MFM equipment to some extent and I can use it smoothly. Also I got some ideas of how to communicate with people in English. The touch of the language is very different from that of Japanese and at first I had a little difficulty in communicating smoothly and naturally. However, now I am able to exchange

ideas or what I noticed with people without misunderstandings. Of course this is acquired thorough many miscommunications. I think that I accomplished one of the purpose of this program.

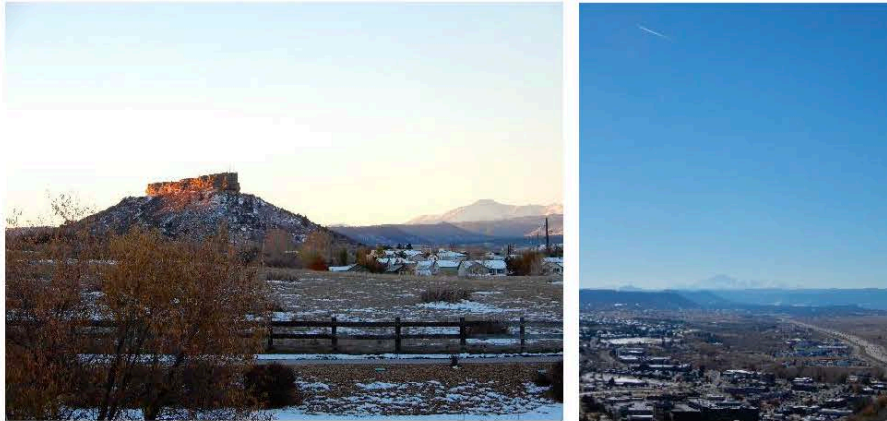
What is more, I got a relationship with researchers overseas. The people in College of Arts and Sciences and College of Engineering are now my collaborators. In a broad sense, researchers in the Singapore group are also some of them. I am involved in their research and I will join meetings with these three parties and will keep on doing discussion with them in the future.

### 3. Other Activities

#### A. Home stay and church

I fortunately found a kind and nice Christian host Family close to UNL campus. It was a calm and peaceful place. I personal emailed local church and they were kind enough to find me a host family. One awkward experieence was that I mistakenly joined abortion protest activity of Life Chain, which is seriously debated in the US

At the end of the stay I was able to travel to Colorado with friends in church. I climbed Rocky Mt. to the height of 14,000 ft.



**Fig. 5:** Castle Rock and Rocky Mt.