

## **MERIT Long-Term Oversea Dispatch Report**

**MERIT class 12<sup>th</sup> , School of Chemistry and Biotechnology, Industrial Institute of Science**

**1<sup>st</sup> grade of Master Rena Tajima**

### **【SUMMARY】**

Ten weeks research internship has been conducted at AK Biesalski in Technical University of Darmstadt in the period of 06.01.2023-15.03.2023 supported by IIS-TUDarmstadt Exchange Research Program. This Program is funded by Continental AG Japan. The research title is “ The Effect of Dry-Moist Cycle of Humidity on Paper Aging and Actuation Properties of Papers.”

### **【BACKGROUND】**

Test paper coated with poly(dimethyl acrylamide-co-MABP) shows actuation properties after undergoing the dry-moist cycle in the humidity chamber. The paper materials which are basically made of cellulose are eco-friendly and lightweight, and therefore they are expected to be applied in various fields of industries e.g. robotics. This internship was conducted to elucidate the effect of paper aging caused by dry-moist cycles of humidity on the actuation properties of paper sheets.

### **【BRIEF SCHEDULES OF THE INTERSHIP】**

During the first and second weeks, the test papers were produced from already-made papers based on the ISO standard. Poly(dimethyl acrylamide-co-MABP) was also synthesized according to the procedures in the previous paper. In the third week, the test papers were coated with the polymer by impregnation into the polymer solutions which are made of either water or isopropanol, followed by drying, UV photo-crosslinking, and extraction of the unreacted polymer. The mechanical properties of coated paper samples that underwent the humidity cycle were measured with a tensile tester in the fourth week. From the fifth week, paper hygroexpansion measurements and paper actuation measurements were conducted except in the sixth week when I got positive on a covid antigen test, and the seventh week when I joined the conference held in Freiberg for 2 days. The final presentation to professor Markus was held on the last day of my stay.

### **【OUTCOMES】**

After the paper samples were impregnated in either Poly(dimethyl acrylamide-co-MABP) or Carboxymethyl cellulose (CMC) solution, the former polymer has been crosslinked to the cellulose surface by UV radiation while the latter polymer just stayed on the surface of the fiber. We conducted 1. Hygroexpansion measurements, 2. Actuation measurements, and 3. Mechanical test. One dry-moist cycle of humidity consists of three phases; 10% relative humidity step (RHS), 90% RHS, and 10% RHS.

Hygroexpansion measurements: In this experiment, all the samples underwent the dry-moist cycle twice. The difference between the surface area in RHS 90% and 10% gets bigger by increasing the amount of coated polymer. In addition to this, it is revealed that the crosslinks also affect the shrinkage of the paper samples by comparison of the paper sheets with different coatings.

Actuation measurements: In this experiment, the paper samples underwent the humidity cycle four times. The results obtained in this experiment (without crosslinks) and the data in the previous study (with crosslinks) were compared. The paper samples are less likely to get back to their original position according to the increase in cycle step number in both experiments while the paper samples without crosslinks show an increase in the distance between the borderline to the tip of the samples.

Mechanical tests: In this experiment, the paper samples underwent 1, 3, 6, and 12 humidity cycles respectively. The tensile properties were measured in both wet and dry states. Unfortunately, I couldn't complete the tests with all conditions especially the samples without crosslinks. As for the samples with crosslinks, there was a clear increase in Young's modulus of the reference paper sheet on wet state tensile test due to the phenomena called hornification that stiffens the fiber during the humidity cycles, and thus the elasticity increases. However, the sample coated with polymers has less effect of hornification due to the fact that polymer crosslinks prevented the fiber structures from being changed by hornification.

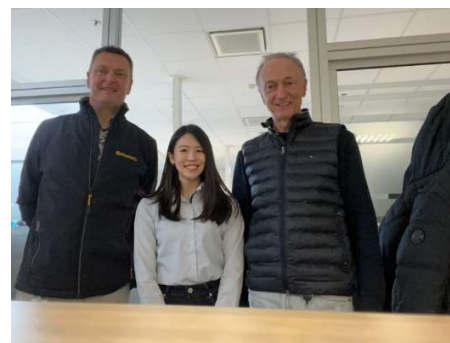
### 【PERSONAL FINDINGS】

During the internship, I could connect with many local and international students. The most precious thing that I learned from my stay is the significance of networking with people. Ph.D. candidates there usually look for collaboration with their colleagues because they don't have a supervisor with whom they can discuss their matters daily. Therefore, communication in the lab and in official meetings such as conferences are considered to be very important. I practiced networking a lot by getting involved in student collaboration helped by my supervisor.

Lastly, all the expense regarding this internship is covered by the fund raised by Continental AG, and this internship has been supported by those concerned with the University of Tokyo including my supervisor Prof. Naoko Yoshie. I sincerely appreciate their kindness in giving me such an awesome opportunity.



AK Biesalski



A day visit to Continental AG Frankfurt