# Doctoral Dissertation Evaluation Review

Degree requested Doctor of Life Science Applicant's name PING RAO

Examiner :
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Title of Doctoral Dissertation

Fast Underwater Adhesion of Hydrogels by Multi-Scale Design
（マルチスケール設計によるハイドロゲルの高速水中接着）

Results of Evaluation of the Doctoral Dissertation (Report)

Due to the water-containing nature of hydrogels, the major potential applications of hydrogels are in wet environments, such as artificial organs, tissue engineering, bio-medical devices in the human body, and underwater soft robotics. In many such applications, permanent bonding or reversible attachment of hydrogels to other surfaces, synthetic or natural, hard or soft, is required. However, hydrogels usually show poor adhesion to other surfaces in their fully swollen state. Recently, prominent progress has been achieved on the irreversible robust bonding of hydrogels to diverse synthetic and biological surfaces, which shows that chemical bonding or physical interlocking of the interface and bulk energy dissipation are critical for the robust bonding of the hydrogels. On the other hand, the research for in situ underwater adhesion of hydrogels is still at its born. The state-of-the-art technology suffers from shortcomings including long contact forming time and very weak adhesion strength. A general strategy to develop hydrogels with fast, strong, and reversible adhesion underwater, is still lacking.

This study focuses on developing tough hydrogels with fast, strong and reversible underwater adhesion based on a multi-scale design. Inspired from the cling-fish, the author combined the surface engineering to improve contact efficiency, and the self-healing materials with dynamic bonds to form reversible bridges at the interface as well as dissipate a large amount of energy in the bulk during debonding process. The author revealed the effect of surface engineering structure on underwater contact formation by observing the underwater evolution of contact area using a home-made set up. The results illustrated that connective grooves accelerates the water drainage and small contact feature gives a better contact. Furthermore, the underwater probe tack test showed that the small patterned hydrogels with dynamic bonds delay the crack propagation and dissipate more energy. Finally, the author revealed the trade-off relationship between strong adhesion and repeatability in a limited time. Small patterned surface structure achieves better contact to give a strong adhesion while it needs a long time to recover due to elevated deformation at debonding. To obtain fast, strong and reversible underwater adhesion, proper pattern size of hydrogels should be designed.

In conclusion, the author has successfully developed a strategy to develop tough hydrogels with fast, strong and reversible underwater adhesion, and the strategy can also be generalized to other system with dynamic bonds such as hydrogen bonds. These works will help to design underwater adhesives used in some applications requiring fast and reversible adhesion in wet environments or underwater such as reusable sheets for wound dressing, temporary adhesives for tissue repairing, and anti-slippery gloves for wall-climbing robotics.

Therefore, we acknowledge that the author is qualified to be granted a Doctorate of Life Science from Hokkaido University.