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<thead>
<tr>
<th>項目</th>
<th>内容</th>
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<tbody>
<tr>
<td>Title</td>
<td>研究による摩擦性質の検討: ゾオトリオン性水凝膠の摩擦性質の評価: 大規模な実験データの分析</td>
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<td>Author(s)</td>
<td>AHMED, Jamil</td>
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<tr>
<td>Issue Date</td>
<td>2014-09-25</td>
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<tr>
<td>Doc URL</td>
<td><a href="http://hdl.handle.net/2115/57274">http://hdl.handle.net/2115/57274</a></td>
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<tr>
<td>Type</td>
<td>theses (doctoral - abstract and summary of review)</td>
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</tbody>
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**Additional Information**

他にも本項目に関わるファイルがHUSCAPにあります。上記URLで確認してください。

**File Information**

- Jamil_Ahmed_review.pdf (審査の要旨)
Study on frictional properties of zwitterionic hydrogels

(両性イオン性ゲルの表面摩擦に関する研究)

Results of Evaluation of the Doctoral Dissertation (Report)

Zwitterionic polymers are polyelectrolytes that contain cations and anions in the same repeating unit. Recently, the zwitterionic polymers have been found to have excellent anti-biofouling properties and non-toxicity, which made them suitable for many biomedical applications. Thus, these polymers have drawn a great attention of many scientists. Until now, studies have been focused on zwitterionic polymers and there is very few studies on zwitterionic hydrogels. Recently a zwitterion based tough double network (DN) hydrogel has been developed by using poly(N-(carboxymethyl)-N,N-dimethyl-2-(methacryloyloxy) ethanaminium, inner salt) (PCDME). The DN hydrogel using the zwitterionic polymer as the second network exhibits excellent anti-biofouling properties in addition to high mechanical strength and toughness. This promises a great potential of the zwitterion-based hydrogels as good candidate for bio-application, for example, as coating materials of low-friction biomedical devices and implants. Understanding the surface frictional properties of the zwitterion hydrogels is indispensable for these potential applications. It has been revealed that zwitterionic PCDME hydrogel remains stable of its swelling and mechanical properties over a wide range of pH and ionic strength, which makes it suitable for frictional study under different conditions.

In this thesis, the surface sliding friction of zwitterionic hydrogel PCDME was systematically studied. The effect of macroscopic contact between the gel and substrate is explored. The frictional tests were carried out in aqueous solution using a rheometer with parallel plate geometry and the interfacial contact during the measurement was monitored by a laboratory-made optical system, which gives information on the evolution of gel contact to the glass during sliding motion. The frictional stress on glass was found to be high in water and it showed a strong dependence on interfacial contact. The real-time contact images showed that pre-existing water layer at the interface facilitates forced wetting and reduces frictional contact area, which in turn reduces the friction. Again, a very weak dependence on pressure was found as long as the two sliding surfaces were in complete contact. It was found that at full contact the friction is mainly due to the elastic stretching of the adsorbed polymer chain. With the obtained knowledge of the effect of interfacial contact, the influence of surface chemistry of both surfaces was explored. Hydrogels with different swelling degree were prepared by modifying the crosslinking density and were swelled in aqueous solution of various pH and ionic strength. The results performed in solutions with
varied ionic strength revealed that the high friction on glass substrates has an electrostatic origin. The 
electrostatic potential measurement showed that the PCDME gels have an isoelectric point at pH 8.5. Since 
the glass substrates carrying negative charges in pure water, the gel and the glass have electrostatic 
attraction in water. Study on the effect of pH has shown that below pH 8.5, attraction between the 
positively charged gels and negatively charged glass gives high friction, while above pH 8.5, the electrical 
double layer repulsion between two negatively charged surfaces gives low friction. A series of frictional 
tests carried out with hydrogels of different swelling degrees in water at pH 6.8 showed that the friction is 
related to the swelling degree through the surface polymer chain density of the hydrogels. However, 
through the modification of the negatively charged glass substrate with hydrophobic silane binding agent 
at various extents, calculation of charge density on their surfaces and friction study of the hydrogel against 
them, it was found that the frictional stress is linearly related to the charge density on the glass surface. 

In conclusion, the author has found that although the PCDME gels behave like neutral gels in the 
bulk properties, their surface properties sensitively change with pH and ionic strength of the medium. The 
friction of the gels is governed by the electrostatic interaction. These new findings on the sliding friction of 
zwitterionic hydrogels will be helpful for understanding and finding new approaches for designing 
low-friction biomedical devices and implants. Therefore, we acknowledge that the author is qualified to be 
granted the Doctorate of Life Science from Hokkaido University.