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Author(s)	八島，慎太郎
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学 位 論 文 内 容 の 要 旨

博士の専攻分野の名称　博士　(生命科学)　氏　名　　八島 慎太郎

学 位 論 文 題 名

Friction and Lubrication of Hydrogels with Surface Geometric Patterns
(表面ジオメトリックパターンを有するハイドロゲルの摩擦と潤滑)

Biological systems show fascinating tribological behaviors, as can be seen from the extremely low friction between animal cartilages, and between eye and eyelid, etc. It is believed that the soft and wet nature of soft bio-tissues is responsible for these low friction behaviors but the true mechanism is hardly known. Hydrogels are a class of soft and wet materials, similar to the bio-tissues. Recently, due to the invention of tough hydrogels, hydrogels are drawing great attention as model substances or substitutes of bio-tissues. Thus, studying the hydrogel friction becomes an attractive research topic, devoting to revealing the secret of biological friction and to developing low friction biomaterials. In the last decade, friction of various kinds of hydrogels has been investigated, and very rich and complex frictional behaviors are observed. The previous studies have been mostly focusing on the effect of interfacial interaction between the sliding surfaces. Like any friction events, surface geometry is one of the important factors governing the friction of living tissues. For example, the surface roughness is reported to play an important role in the friction of animal articular joint in synovial liquid. Few are known on how does the surface geometry of the hydrogels influence the friction and lubrication of hydrogels in liquid.

This thesis focuses on the friction of hydrogels with topologically patterned surface in water. This dissertation consists of 5 chapters. In Chapter 1, friction of hydrogels with random surface roughness against smooth glass is studied. In contrast to the gels with flat surface, the gels with rough surface of 1-10μm order showed well reproducible frictional behavior and their frictional stress was larger than that of flat surface gel. These results are different with the dry friction, in which the surface roughness reduces the contact area to the substrate and therefore reduces the friction. The opposite phenomenon in liquid suggests that rough surface of gels enhances the contact of gel with its counter surface, which is confirmed by the observation of gel/glass interface. It is revealed that rough surface gel forms firm contact to the counter surface by their apexes due to the high local pressure and the short time of liquid squeezing.

Chapter 2 presents with friction of hydrogels with well-defined concave shapes and convex shapes. Hydrogels surface with concave shapes is expected to keep the lubricant, and decrease the contact area. As a result, concave gels show lower friction than that of flat gel. This effect is strongly depending on the presence of water. When no water is entrapping at the interface as a lubricant, concave gels show almost the same friction with that of flat gel. Therefore, it is confirmed that concave pattern plays a role in friction reduction by keeping the water in the concave holes. On the other hand, convex gel increases the friction though it reduces the contact area with substrate. This phenomenon is related to the enhanced contact area in comparison with the flat surface, and it is the same effect as rough surface gels observed in Chapter 1. When the normal force is applied, the apexes of convex pattern can easily form contact with glass substrate. It is confirmed that convex gel could make contact even in a very viscous solution ($[\eta]$=10 Pa.s) by the observation of gel/glass interface and frictional measurement.

In Chapter 3, the interface of hydrogel/glass in viscous polymer solution is studied, and characteristic contact pattern is observed for the first time. The observed patterns, in circular symmetry by the rotational motion of the disc-shape gels, can be classified into a kind of non-equilibrium patterns. From the viscosity dependence of the polymer solution, it is predicted that this phenomenon is related to the shear thinning of polymer solution as a lubricant.

In Chapter 4, dry friction between soft silicone rubber and glass with spherical asperities is reported. By using silicone rubber, instead of hydrogels, the soft contact area is evaluated quantitatively by direct interfacial using optics. The relationship between frictional forces and real contact area is explored.

In Chapter 5, summary of the work is given. This dissertation is the first systematic work devoting to the gels friction with well-defined surface geometry, and the results will give insight to understand the topological behaviors of living tissue.