Bioinspired adaptive lubrication

Feng Zhou

State Key Laboratory of Solid Lubrication, Lanzhou Institute of Chemical Physics, Chinese Academy of Sciences, Lanzhou, 730000, China
Corresponding author: zhouf@licp.cas.cn

Inspired by the excellent surface hydration lubrication mechanism, typical layered biochemical feature and the adaptive load-bearing/stress dissipation route of natural articular cartilage, a series of novel layered cartilage lubrication materials have been designed by soft/hard combination strategy. These novel materials exhibit high load-bearing, low friction and excellent wear-resistance properties, as well as remarkable lubrication performance of cartilage. Those novel design, inspired by nature would provide new route for the development of high-performance water-based lubrication materials.

Keywords: bioinspired, adaptive design, soft matters,warer lubrication, load-bearing/wear-resistance

1. Introduction

Natural articular cartilage is a highly efficacious water-based lubrication system featured as high load-bearing, extremely low friction and good wear-resistance properties. Over the past decades, the use of artificial soft matter materials (polymer brush and hydrogels) has been focused to imitate such considerable tribological performance. Although different lubrication mechanisms are suggested, such as hydration lubrication mechanism [1] and adsorption-repulsion model [2] when considering polymer brushes and hydrogels-based systems, it is becoming increasingly apparent that the tribological performance of cartilage cannot be attributed to a single surface lubrication mechanism alone but on the synergistic action of multiple factors including extreme hydration, unique biochemical structure and special stress dissipation route [3]. Common results to support above argument are that polymer brushes-grafted surface exhibits poor lubrication under cartilage-liked boundary condition (non-smooth but micron roughness) and pure hydrogels system show poor load-bearing capacity under high contact pressure (>2 MPa). As a result, by synergistically combining surface hydration mechanism and stress dissipasion-dominated design, novel cartilage-inspired adaptive lubrication materials are developed.

2. Methods

2.1. Concept for designing adaptive lubrication system

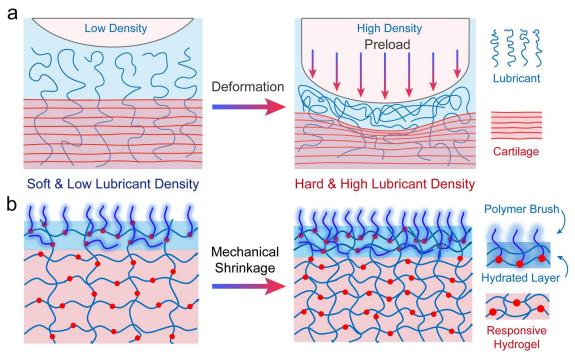

Figure 1: (a) Adaptive mechanically controlled lubrication mechanism found at natural articular joints interface under dynamic loading/unloading process and (b) bioinspired adaptive lubrication system.

2.2. Results

One kind of novel archetype of cartilage-mimicking bilayer material by robustly entangling thick hydrophilic polyelectrolyte brushes into the subsurface of a stiff hydrogel sub-strate is developed. This kind of cartilage-inspired lubrication material is capable of attaining low friction coefficients (order 0.01) under heavily loaded conditions (order 10 MPa contact pressure) in water environment, a performance incredibly close to that of natural articular cartilage. maintain low friction even when subjected tok reciprocating cycles under high contact pressure, with almost no wear observed on the sliding track.

3. Discussion

Natural articular cartilage has successfully combined surface hydration lubrication and adaptive load-bearing/stress dissipation to achieve extraordinary lubrication even at relatively high contact pressure. Inspired by adaptive lubrication mechanism of cartilage, soft/hard combination strategy is used to develop a series of cartilage materials, for which are capable of attaining low friction coeffcients upon encountering tens of thousands reciprocating cycles under high contact pressure (1~10 MPa), with almost no wear observed on the sliding track. The essential mechanism is that the topmost soft layer provides effective aqueous lubrication, whereas the stiffer substrate layer provides the load-bearing and stress-dissipation capacities. The optimal matching of the mechanical modulus of the lubricating layer and the load-bearing layer is the key to realize the excellent wear-resistance performance of our system.

4. References

[1] Klein, J. “Hydration lubrication,” Friction, 1, 1, 2013, 1-23.
[2] Gong J P. “Friction and lubrication of hydrogels-its richness and complexity,” Soft Matter, 2, 7, 2006, 544-552.
[3] Israelachvili, J. N. et al., “Adaptive mechanically controlled lubrication mechanism found in articular joints,” Proc. Natl. Acad. Sci, 108, 2011, 5255-5259.