Cartilage-inspired lubrication with polymer brushes and gels

Nicholas D. Spencer

Laboratory for Surface Science and Technology, Department of Materials, ETH Zürich, Switzerland

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nspencer@ethz.ch

Cartilage is an extraordinary material that allows our joints to move with low friction and wear, often for many decades. Imitating cartilage with polymer brushes and gels has a number of purposes: It can help us understand more about the lubrication mechanism of cartilage itself; it is a necessary step for the development of improved replacement materials for cartilage that is damaged; and finally, the soft, highly lubricious materials developed can have many potential applications in industry and medicine.

Keywords: cartilage, polymer brush, hydrogel, soft tribology

1. Introduction

Cartilage is unique, both in terms of its impressive lubricious properties and the fact that it continues to function, without a blood supply, for many decades, providing very low friction coefficients. In the simplest terms, cartilage consists of a hydrogel material with a stiffness gradient that interfaces to bone, attached, at the outer edge, to loose polysaccharide chains, which are thought to provide a lubricating function.

2. Polymer Brushes and Gels

Polymer brushes, which bear a resemblance to the loose chains on a cartilage surface, are well known for their lubricious properties, but when coating hard-hard contacts, minor disturbances in tribological conditions or the inclusion of foreign bodies, can rapidly lead to catastrophic failure, as asperities on one hard countersurface encounter the opposing brush. This problem is significantly reduced when the underlying substrate is soft, as in the cartilage case. When imitating cartilage, elastomers can provide this soft base layer, but an even more effective substrate for brushes in tribological applications is a gel. These can be readily tailored to ensure compatibility with the brush, and provide a number of cushioning functions, including elastic, viscoelastic, and porelastic, depending on the loading conditions and gel architecture.

3. Approaches to Imitating Cartilage

In our laboratory, we have explored a variety of systems for imitating cartilage, some of which have actually reached comparable friction coefficients to those observed in cartilage, as well as toughness values and wear resistance that render them of interest for medical and industrial applications. The general approach is shown in Figure 1, and involves the use of a tough, preferably double-network gel, upon which is a layer of brushy loose chains, which either appear spontaneously during synthesis of the gel [1,2], or are deliberately grafted to the gel in a separate step [3,4].

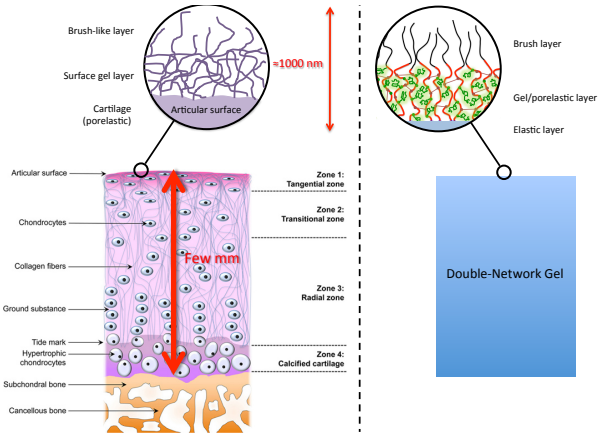

Figure 1: Imitating Cartilage with a Combination of Polymer Brushes and Gels

4. References

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