NANOMECHANICAL AND TRIBOLOGICAL PROPERTIES OF MUCIN LAYERS AS COATING FOR BIOMATERIALS

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Introduction

Mucin is high molecular weight glycoprotein that comprises slimy mucus layers that are known to protect underlying internal organ tissues. Due to its biological origin, mucin layers have been considered as potent coating for biomaterials, displaying effective anti-biofouling properties [Bushnak, 2010] and favourable immune responses [Sandberg, 2009a]. Another unique, but less studied properties of mucin layers is its lubricity [Lee, 2005], which can benefit various biomedical devices and implants. In this work, we have investigated the surface adsorption and nanomechanical/tribological properties of mucin coating films on various surfaces over a broad range of length scale.

Methods

Commercially available bovine submaxillary mucin (BSM, Sigma-Aldrich, M3895-1G, type I-S, St. Louis, MO) was purified according to anion exchange chromatographic method [Sandberg, 2009b], and used as coating material. Formation of BSM films onto surfaces were achieved via spontaneous adsorption from aqueous BSM solutions, and the adsorption properties were characterized either by OWLS or QCM-D, or the combination of both. Surface force apparatus (SFA) was used to understand the basic surface force profiles between opposing BSM films formed on atomically smooth surfaces, mica. Atomic force microscopy (AFM) was used to investigate nanoscale wear properties on both hydrophilic (SiO_2) and hydrophobic (methylated SiO_2) surfaces. Pin-on-disk tribometry was also employed to characterize the lubricating properties on macroscale contacts. PDMS was used as tribopair for tribometry, in order to emulate the soft contacts involving biological organ tissues.

Results

Formation of BSM layer was readily achieved on hydrophobic surfaces (methylated SiO_2 and PDMS surfaces). Formation of BSM layer onto hydrophilic surfaces showed noticeable differences between mica and SiO_2 surfaces, with the former revealing more facile adsorption. In all cases, adsorption behaviour showed strong dependence on solvent parameters, e.g. pH and concentration of BSM. SFA studies showed purely repulsive interactions between BSM-coated mica surfaces at neutral pH condition, but much reduced repulsion by rinsing with acidic solution. AFM nanowear studies showed that BSM films on methylated SiO_2 were more resistant to scratching at acidic than neutral pH condition. Meanwhile, BSM films on SiO_2 were easily removed and did not show much pH dependence. Pin-on-disk tribometry showed that BSM displays superior lubricity at neutral pH than at acidic pH at soft sliding contacts between two PDMS surfaces.

Discussion

Nanomechanical and tribological studies by SFA, AFM, and tribometry in this work collectively show that BSM readily formed repulsive and slippery monolayer films on hydrophobic surfaces. The BSM films were more repulsive and slippery at neutral pH, but denser and more wear-resistant at acidic pH condition. This is thought to arise from changing the conformation of BSM from highly hydrated and stretched to collapsed and rigid state by changing the solution from neutral to acidic pH. Formation of BSM films and nanomechanical properties on hydrophilic surfaces were different on mica (favourable) and SiO_2 (unfavourable) surfaces, which yet to be explained – specific interactions are likely to be involved in the former case.

References

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