Friction and wear properties of mucin films as studied with atomic force microscopy (AFM)

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Abstract

Secreted mucus gels are known to protect underlying epithelial tissue surfaces from invasive microbes and physical insults by forming a lubricating layer. Interestingly, lubricity is observed from the films generated from mucins, the major macromolecular constituent of the mucus gels, at much lower concentration to form mucus gels and even at the interfaces comprised of engineering materials in aqueous environment. The lubricity of mucins is ascribed mainly to that the central part of mucinous polypeptide is heavily glycosylated with post-translational O-linked glycosidic modification, which enables the entrainment and retention of water, base lubricant, at the sliding interface. Further, upon interaction with hydrophobic surfaces in aqueous environment, unglycosylated N- and C-terminal groups of mucins act as anchoring groups that a highly hydrated and lubricious mucin layer can be spontaneously formed on hydrophobic surfaces.

In this study, tribological properties of bovine submaxillary mucin (BSM) and porcine gastric mucin (PGM) films generated on surfaces have been investigated with atomic force microscopy (AFM). Friction and wear properties of the two mucin films were studied in variation of substrate hydrophilicity, solution pH, impurities, as well as the interaction with mucoadhesive polymers. A general trend is that the lubricity of mucin films tends to improve with increasing mucin purity [1,2]. Both lubrication and anti-wear properties of mucin films are significantly superior at hydrophobic substrates and low pH condition [3]. Mucoadhesive polymers, such as chitosan and poly(acrylic acid) (PAA), often act as crosslinker between mucin molecules and stabilize the films against tribostress [4]. A particularly interesting observation is that lubricating effect of mucin layers is significantly different according to the contact length scale; while mucins tend to lower the friction forces at macroscale contacts, they rather increased the friction force at nanoscale contact [2,4]. This is explained by the relative contact size of mucin molecules and sliders, e.g. macroscale pins in tribometer vs. AFM probes. Further insights on the lubrication mechanisms of mucin films or solutions are discussed in close correlation with the conformation of mucin molecules in bulk solution and at the surface, as characterized by circular dichroism (CD) spectroscopy, dynamic light scattering (DLS), and optical waveguide lightmode spectroscopy (OWLS).

References

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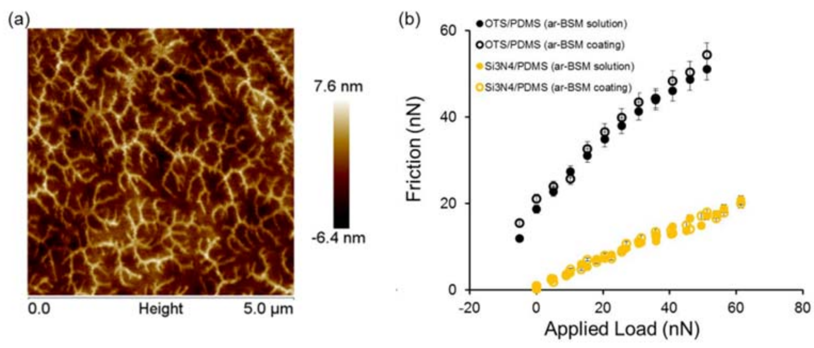

Figure 1. (a) A representative AFM image of BSM molecules adsorbed on PDMS surface (1mg/mL in PBS, imaged in ambient) (b) A representative friction vs. load plots from the sliding of AFM probes (OTS-coated (black) or bare Si_3N_4 (yellow)) against BSM layers in BSM solution (filled) or buffer (empty).