Correlation between the adsorption and the nanotribological performance of fatty acid and amine based organic friction modifiers on steel surfaces

Rosa M. Espinosa-Marzal

University of Illinois at Urbana-Champaign

Friction modifier additives are added to automobile engine oils and transmission fluids to improve fuel efficiency by reducing friction, particularly when boundary lubrication conditions are prevalent. Organic friction modifiers (OFMs) encompass low molecular weight amphiphilic molecules, i.e. surfactants, that form protective layers on metal (oxide) surfaces, via chemi- and/or physisorption, driven by the affinity of the polar functional group to the surface. Surface-adsorption of amphiphilic molecules is a vital mechanism of boundary lubrication on stainless steel surfaces. In this work, the self-assembly of several fatty-acid and fatty amine based organic friction modifiers in alkane solvents and their adsorption onto stainless steel surfaces was investigated using Dynamic Light Scattering and Quartz Crystal Balance with Dissipation, respectively. These properties were related to the friction force between a sharp tip and the steel surface measured by Lateral Force Microscopy. The molecular structures of the organic friction modifiers were chosen in order to study the effects of unsaturation and number of alkyl chains as well as the composition of the polar head groups on their assembly in solution, adsorption and nanotribological behavior. A correlation between the adsorption rate constant and the coefficient of friction of the organic friction modifiers was revealed in these studies, with the coefficient of friction decreasing with an increase in the adsorption rate. We thus propose that a fast adsorption rate is a relevant characteristic for optimal tribological performance of the investigated OFMs. During boundary lubrication, i.e. at high loads and low sliding velocities, the adsorbed molecules help to reduce friction by preventing asperity-asperity contacts of the underlying substrates. Such molecules can be worn out, as most of them are only physically adsorbed to the surface, thereby leading to an increase in friction. However, if adsorption is fast (i.e. if the rate constant is large), the boundary film can rapidly "re-heal", implying that new molecules will rapidly re-adsorb and occupy the space of the worn-out molecules, thereby maintaining a low CoF. The different molecular and supramolecular structures lead to specific behaviors that are discussed, as well.

Keywords: nanoscale friction, organic friction modifiers, adsorption, AFM.

*Corresponding author: rosae@illinois.edu