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# Frictional Properties of Hydrogenated and Deuterated Alkanethiols

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A better understanding of friction at the atomic scale has become more important recently because of its influence over the behavior of micro, and nano-mechanical parts in contact. Self-Assembled Monolayers (SAMs) are an array of saturated hydrocarbon chain molecules that because they are chemically inert they have been used already as lubricants to reduce friction and wear between silicon micromachines' parts. It was not until the introduction of instruments such as the Atomic Force Microscope (AFM) that studies of friction at the atomic scale became possible [1,2]. In this project we compare the friction force between a silicon nitride ($Si_3N_4$) tip and hydrogenated and deuterated alkanethiol SAMs by making use of an AFM to study how friction is affected by changing the atomic and molecular vibration modes of the SAMs via deuteration.

The samples we discus here were stamped hydrogenated (H) and deuterated (D) SAMs on a gold substrate of thickness that ranged from 1000Å to 2000Å; the gold substrates were made by electron beam vapor deposition (EB-VD). Micro contact printing was used to transfer the SAMs to the substrates with a micro-fabricated poly (dimethylsiloxane) (PDMS) stamp. A Digital Instruments Multi Mode Scanning Probe Microscope with a Nanoscope IV controller (DI MM-NS IV) in the AFM and LFM lateral force contact modes was used with a 'J' piezo-electric scanner tube for scan sizes between 10microns up to 80microns. Microfabricated $Si_3N_4$ tips on a triangular cantilever from Digital Instruments were used for all the scannings; a $SrTiO_3$ sample was also used to characterize the tips and avoid those that were not sharp or had double-tip terminations.

AFM Friction images of H-SAMs on the gold substrate showed well-defined areas between the thiols monolayer and the bare gold, (Fig. 1). AFM was then done to a set of samples with a cross-stamped pattern that was stamped first with D-SAMs and then followed by H-SAMs at perpendicular orientation, (Fig. 2). Roughness Statistical analysis of these images gave an average friction force for the deuterated thiols 14.63% lower than that of the hydrogenated ones. In another set of samples with the cross-stamped pattern half the samples were stamped with D-SAMs first followed with H-SAMs, the other half were stamped in the reversed order. We observed that regardless of the thiols solution the SAMs that were stamped first possessed lower friction than the one stamped secondly. Figure 3 shows the friction obtained from a sample that was stamped first with H-SAMs and then with D-SAMs. This indicates that kinetic processes during the stamping have a serious effect on friction, which had not been previously reported. Interestingly, the ratios between friction from Deuterated and Hydrogenated areas was somehow constant as can be seen in figure 4, where friction ratios from two samples are shown and did depend on the order of stamping. Despite the first-order effect of friction being lower on the species stamped first, the friction force ratio between the second (higher friction) and first (lower friction) species was larger when H was stamped first.

This suggests that D-thiols may have intrinsically higher friction than H-thiols. Further research is required to verify these results.

References

[1] I. L. Singer, J. Vac. Sci. Techn. A 12(5), Sep/Oct 1994, 2605-2616.
[2] Schwarz Udo, and Holscher Hendrik, Modern Tribology Handbook, Bhushan, 2001 Vol 1 Chap18.
[3] This project was granted a Research Scholarship by the Microscopy Society of America. I thank the Engineering Physics Nanomechanics group at UW-Madison; and Profs. Robert W. Carpick and Nickholas L. Abbott.

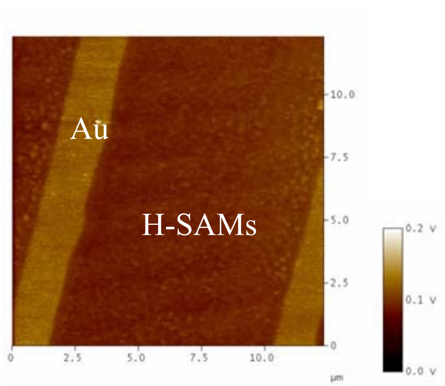


Fig. 1, AFM Friction image of Hydrogenated alkanethiols over the gold substrate.

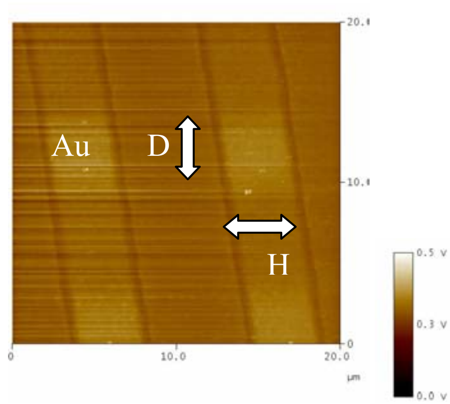


Fig. 2, Sample orthogonaly stamped first with D-SAMs and then with H-SAMs.

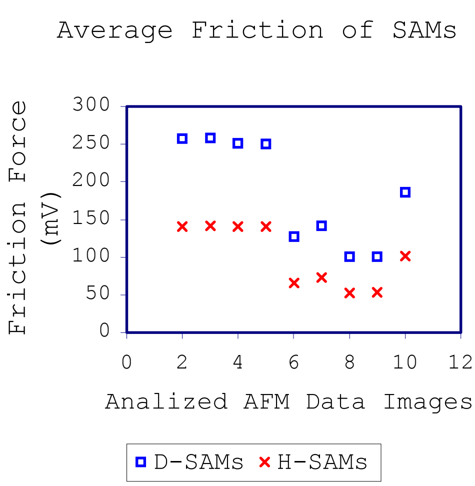


Fig. 3, Friction force obtained from different areas in a sample that was stamped first with H-SAMs and followed by D-SAMs.

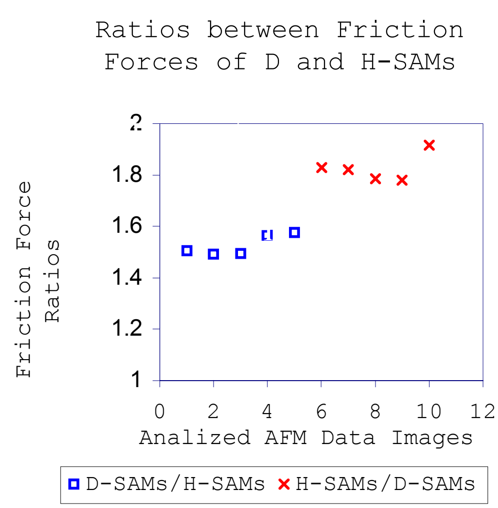


Fig. 4, Ratios between friction of H-SAMs and D-SAMs, the second and first species, suggesting D-thiol may have an intrinsically higher friction response.



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