Analysis of Water Sorption into Lubricious Solid Lubricant Films

Rachel S. Colbert[1], Nicolas Argibay[1], Michael T. Dugger[1], and W. Gregory Sawyer[2]

[1]Sandia National Laboratories
Albuquerque, NM 87123

[2]Department of Mechanical and Aerospace Engineering
University of Florida, Gainesville, Florida 32611

Introduction

The role of water in the tribological behavior of solid lubricants is a not well-understood interaction with no clear correlation between friction and wear. Previous studies demonstrated the ability to measure water adsorption on powders using a microbalance, but there are limited studies on the soprtion kinetics of solid lubricant films.

Quartz Crystal Microbalance Theory

A quartz crystal microbalance (QCM) measures the change in frequency based on an associated change in mass per unit area.

Image of a quartz crystal resonator holder

Sauerbrey Equation

The Sauerbrey equation correlates the change in oscillation frequency of the quartz crystal with a change in mass.

$$\frac{\Delta m}{A} = \frac{\Delta f}{2f_0^2}\sqrt{\mu_q \rho_q}$$

Δm = change in mass (μg)
A = piezoelectrically active crystal area (cm^2)
Δf = change in frequency (Hz)
f_0 = initial frequency (Hz)
μ_q = shear modulus of quartz
ρ_q = density of quartz

The Sauerbrey equation is valid for:

$$\frac{\Delta f}{f_0} < 0.02$$

In the present work:

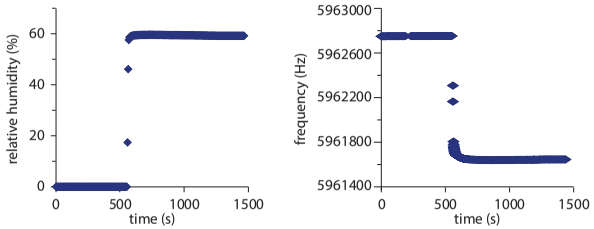
$$\frac{\Delta f}{f_0} \approx 3\text{x}10^{-8}$$

Experimental Setup

The coatings studied during these experiments were:

Coating	Deposition Technique	Crystal R_a	Thickness
MoS_2	magnetron sputter	350 nm	0.11 μm
MoS_2	magnetron sputter	8 nm	0.99 μm
MoS_2	impingement coating	8 nm	0.25 μm
$MoS_2/Sb_2O_3/Au$	magnetron sputter	350 nm	1.39 μm

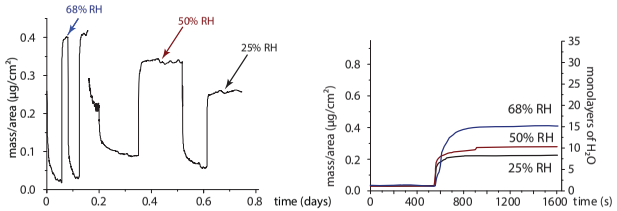
Step changes in relative humidity were desired to observe the diffusion rates of water into the films.



Relative humidity step changes and associated quartz crystal frequency changes

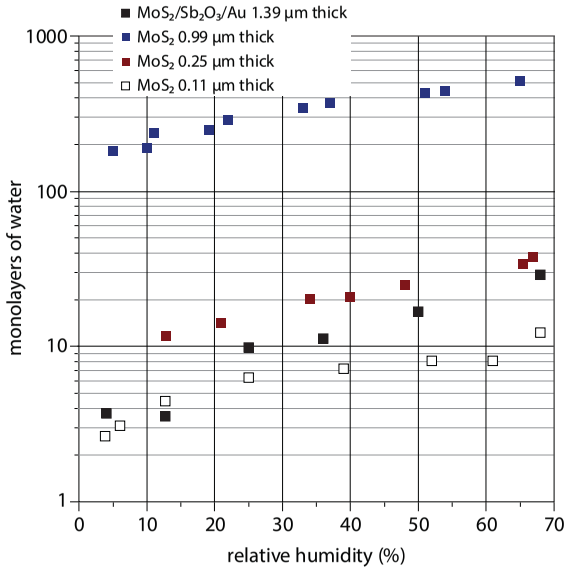
Experimental Results

The reversible water sorption on MoS_2 films was studied at room temperature.



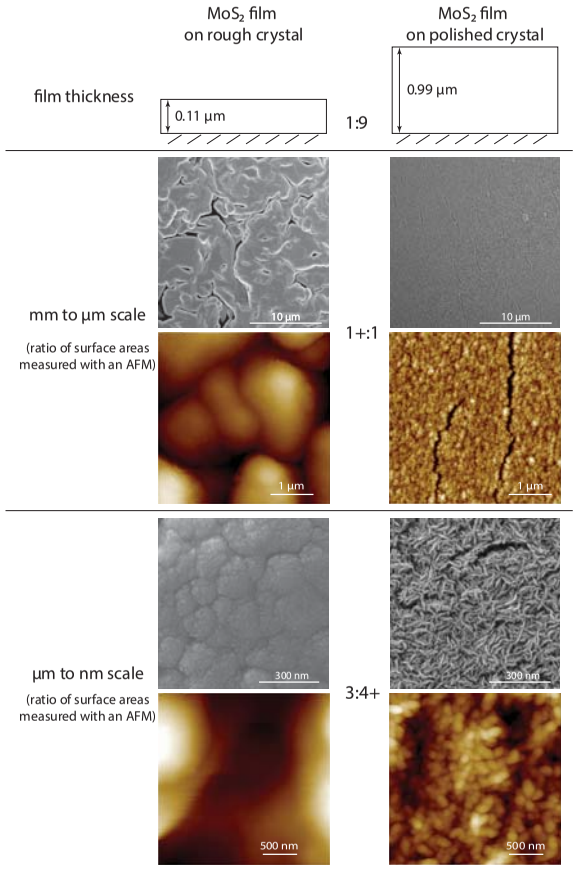
Step change in relative humidity experiments on a pure MoS_2 coated crystal

The quantity of water sorbed for each film at various relative humidities was repeatable. A trend of increasing quantity of water uptake with increasing film thickness was found for the pure MoS_2 films.



Water sorption isotherms for films studied

Film surface area and thickness effects on the water uptake were compared for the 0.11 μm and 0.99 μm MoS_2 films.



Differential ratio for various length scales between the coated 0.11 μm rough and 0.99 μm polished crystals

Conclusions

Despite the small differences in the film topography, the 4-fold increase in water uptake appears to be primarily due to the film thickness. This leads to the understanding that water is diffusing throughout the film and is not strictly a top surface adsorption phenomenon.

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