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Tribological characterization of gradient monolayer films from trichlorosilanes on silicon

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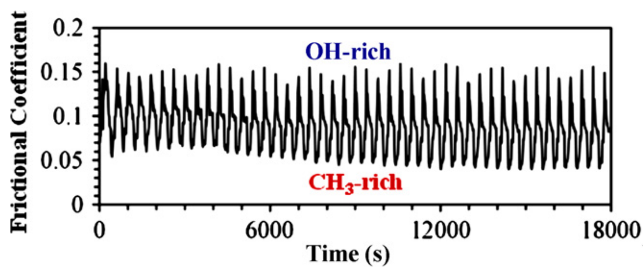
HIGHLIGHTS

- ► We report the assembly of 1- and 2-component gradient monolayer films on silicon.
- ► Ellipsometry, contact angles, and tribometry verify gradient formation.
- ► 1-Component gradients exhibit a broad range of frictional coefficient.
- ► 2-Component gradients show good stability and a threefold change in friction.

GRAPHICAL ABSTRACT



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ABSTRACT

We report a simple and effective approach to assemble single- and dual-component gradient monolayer films of silane precursors onto a silicon substrate under ambient conditions. Characterization of these gradient films with water contact angles and ellipsometric thicknesses has been performed to confirm gradient formation with a high degree of repeatability. Tribological testing of these gradient films was also performed to determine the role that surface energy and dispersive forces within the monolayer have on the frictional performance of the resulting films. Our results show that the tribological properties of single-component gradient monolayer films prepared from octadecyl trichlorosilane on silicon are dependent upon the surface coverage and surface energy of the gradient monolayer. We also demonstrate that the coverage of a hydrocarbon monolayer is a critical aspect of the frictional response of the film by relating the tribological performance of gradient monolayers to that of pure monolayers with known thicknesses. Sparse monolayer regions are more prone to frictional failure by exposing more of the underlying substrate and further enabling the probe tip to impart the normal load to fewer adsorbed molecules to greatly increase the pressure per adsorbate. Two-component monolayers with methyl and hydroxyl termini offer much greater stabilities to prolonged cycling due to stronger intermolecular interactions that prevent probe–substrate interactions.

1. Introduction

The ability to control the surface energy of a substrate with a high degree of positional precision, such as creating gradients of surface energy [1], is an essential requirement for many applications, including directed droplet motion [2], biological detection and selective attachment [3–6], microfluidics [6], and chemical sensing [7]. Techniques that can produce consistent gradients of one or two component monolayers using alkanethiol [3,7] or n-alkyl trichlorosilane [6,8] precursors on gold or silicon surfaces, respectively, include diffusion through chromatographic media [7], ink jet printing [9], gradual immersion [4], laminar flow [5,10], controlled vaporization [2,11,12], controlled oxidation [13], contact printing [6,8], and photodegradation [14]. A potential disadvantage of forming gradient mixed monolayers with two or more different thiols is the tendency for phase separation of the identical chains

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