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Nanoscale Polymer Patterns for Tribology

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Tribologically relevant geometrical and chemical design cues of single- and multi-asperity contact asperities are lacking. We fabricated well-defined sub-micron scale mushroom-shaped, hierarchical, and cylindrical pillar patterns to study the individual and cumulative role of physico-chemical parameters on tribology at nanoscale, using an AFM borosilicate ball tip. The experiments demonstrated the individual role of the geometrical and chemical cues with effective lateral stiffness at the contact being the single most important factor determining frictional sliding. A master curve in graph of adhesion vs. friction clarified the effect of physico-chemical parameters on the correlation between nanoscale adhesion and friction.

Keywords: nanotribology, polymer patterns, frictional sliding, adhesion, AFM

1. Introduction

Microsystems have single-and multi-asperity contacts depending on the surface form, topography, and effective normal load. Configuring single- and multi-asperity asperity experiments mimicking those conditions was difficult. Furthermore, data from various single- and multi-asperity experiments was difficult to correlate due to the wide variety of experimental conditions. Hence, a comprehensive view of micro/nano tribological interactions was difficult to achieve. We used polymer patterns of varying geometrical and chemical cues to simulate single and multi-asperity conditions and give insights into role of geometrical and chemical cues in determining nanoscale adhesion and friction.

2. Methods

2.1. Pattern fabrication

We used Capillary force lithography along with nanodrawing procedure to generate mushroom-shaped, hierarchical and cylindrical pillar patterns (Table 1).

Table 1: Geometrical parameters of patterns fabricated in PMMA and PS.

Patterns		Radius (nm)	Height (nm)	Pitch (nm)
Cylindrical	Flat	250	220	500-1000
	Round	250	160	
Mushroom-shaped	Flat	250	550	
	Round	100		
Hierarchical	Nano	100	160	500
	Micro	3000	4000	3000

2.2. Tribological characterization

We used atomic force microscopy to estimate adhesion (pull-off) force and friction force between the patterns and a borosilicate ball of 10μm diameter.

3. Results

The adhesion and friction of patterned surfaces was significantly smaller to that of flat surfaces. Flat top patterns showed higher adhesion and friction than round-top patterns. Similarly, hierarchical patterns showed smaller adhesion and friction compared to corresponding single-scale patterns. Interestingly, in contrast to previous studies, cylindrical and mushroom-shaped patterns of equal projected area showed similar adhesion properties but very different frictional properties (Figure 1).

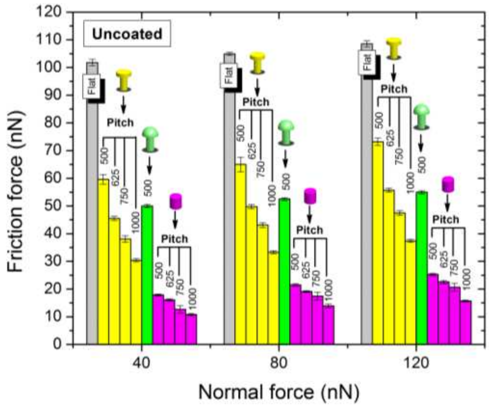

Figure 1: Friction force measured on mushroom-shaped and cylindrical pillar patterns made in PS with equal pillar projected area and varying pitch.

4. Discussion

We obtained general characteristics of frictional sliding of all the patterns using adhesion *versus* friction graph that showed master curves spanning two orders of magnitude of adhesion. The master curves exhibited a power law relation whose power strongly depended on the effective lateral stiffness of the contact. For example, the mushroom shaped pattern with significantly smaller lateral stiffness showed larger friction characteristics compared to cylindrical patterns and thus lie on a master curve with a higher slope.

5. References

[1] Pendyala, P. et al., "Individual role of physico-chemical characteristics of nanopatterns on tribological surfaces," ACS Appl. Mater. Interfaces, 8, 44, 2016, 30590-30600.

[2] Pendyala, P. et al., "Effect of capillary forces on the correlation between nanoscale adhesion and friction," Tribol. Int., 114, 2017, 436-444.