Micro-Structured Polymer Film Mimicking the Trembling Aspen Leaf

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Abstract
Surface micro-patterns are fabricated on a silicone polymer film tailored to mimic the surface properties of the Trembling Aspen leaf via a two-stage pattern transfer process. A self-assembled monolayer of releasing molecules was found to be essential for the pattern transfer. This process is easily scalable and able to achieve a clear and accurate pattern transfer mimicking complete leaves. The properties of the leaf are observed, and contrasted to those of the synthetic variant. Micro-structured polymer films mimicking the synthetic leaf were found to possess enhanced hydrophobic properties compared to un-patterned smooth films. The friction properties of the smooth and micro-patterned surface were investigated at varied preloads. Micro-patterning reduced the friction force and delivered an almost constant coefficient of friction over the range of preloads examined. The difference in the friction behaviour of the smooth and patterned sides of the micro-structure film or artificial leaf results in a unique and appealing tactile experience when one touches and feels the film.

INTRODUCTION

Biomimetic surface engineering can be interpreted as the adaptation of biological surface features and design derivatives from nature to impart specific surface properties. Successful imitations of natural surfaces incorporate many different unique phenomena observed within natural environments, and transfer these properties to various engineering applications [1-5]. In adding a pattern or controlling the chemical properties of a surface, many different beneficial properties are able to be tailored and controlled including the wetting state induced, the tribological properties that influence the feeling of the material, and the interaction of materials with the environment.

Plants like the Lotus flower and the Trembling Aspen (Populus tremuloides) use a hydrophobic surface to promote a self-cleaning mechanism known as the “lotus effect.” This phenomenon results from the application of superhydrophobic surface properties to bead up water droplets, which then roll off while collecting contaminants from the surface and ultimately increasing the photosynthesis efficiency of the plant [1-10]. The surface of superhydrophobic leaves consists of micro-scale papillae, or bumps, covered with nano-scale wax crystals. This architecture along with the ability of the leaves to tilt or vibrate creates a self-cleaning surface which allows a water drop to roll on the surface and remove contaminants due to the reduced area of contact at the interface. Likewise, insects like the Stenocara Beetle have a patterned back that induces a superhydrophobic effect and moves water droplets to its mouth, allowing it to survive on water collected from fog or moist air in dry and arid conditions [11]. The Trembling Aspen is a medium sized deciduous tree that can grow up to 25 meters in height, and are typically found in moist areas throughout North America. To take advantage of the specific hydrophobic properties of the leaf biology, the species has evolved to possess a long stem relative to other tree species which serves to promote a slight vibration of the leaf even in low wind conditions resulting in the descriptive trembling title. This provides the incline and kinetic energy that promotes the rolling action of the water droplets. The leaves of the Trembling Aspen also possess a protective coating of lipophilic structures deposited on the outer structures of the leaf. There are also several lipid layers that form a wax consisting primarily of aliphatic compounds such as alkanes, aldehydes, ketones, primary and secondary alcohols and esters. The resulting wax crystals on the surface of the leaf assist with both light reflection and the sought after non-wetting properties.

This body of work aims to directly copy the surface topography of a hydrophobic leaf through synthesizing a replica that is physically identical to the biological sample in terms of physical structure. The polymer Sylgard 184 was selected as the synthetic material of choice for its ability to flow easily and replicate complex patterns with a high precision through soft-lithographic processing. Furthermore, from an application standpoint, “the high hydrophobicity, contamination resistance, and long-term
endurance make PDMS a very useful polymer for insulation, anticorrosion, and antifouling coatings [12]. Currently, polyesters are the most common material for synthesizing artificial plants, where heated moulding techniques generate the plant-like appearance. Alternatively, Erb et al. used sandblasted nano-crystalline nickel plates as negative templates to reproduce the nano-scale roughness observable on the Trembling Aspen leaf with several polymers as an easy and inexpensive reproduction technique. The hydrophobic properties of the roughened surfaces were examined, and the influence of heat on the hydrophobic ability of the Trembling Aspen leaf in nature was also discussed [13-14].

In this article, we apply a two-step pattern transfer process to transfer the natural pattern of a Trembling Aspen leaf to a polydimethylsiloxane (PDMS) synthetic variant. Using a gas-phase application process for a self-assembled monolayer (SAM) of 2H-perfluorodecyltrichlorosilane (FDTS), a releasing layer was added to the surface of PDMS to facilitate the successful pattern transfer. The hydrophobic properties of micro-structured systems are well characterized as a combination of both chemical and physical surface properties [15-19]. In employing a replica moulding technique to mimic the natural pattern of a Trembling Aspen leaf, the addition of surface roughness enhances the wetting state of the synthetic material and for control of interfacial properties. The ability to replicate the surface patterns and properties of the Trembling Aspen to scale in a very repeatable process allows for synthetic leaves to be generated with a relatively low cost. In applying soft-lithographic techniques, the moulds built through the process are able to be recycled for repeated use, leading to an easily scalable process. The wetting properties of the synthetic leaf are contrasted against the natural sample through sessile contact angle testing, and used to systematically develop the mechanisms of the pattern transfer. The friction properties of the compliant surface are studied as a function of the preloading force, showing a clear trend of increasingly large surface area as the contact mechanics transferred from laid to conformal states.

MATERIALS AND METHODS

The PDMS is from a Sylgard 184 kit containing both the polymer resin and curing agent. The polymer kit was purchased from Dow Corning and used as received. Sylgard 184 was chosen due to its standard use as a research material with characteristic high hydrophobic surface properties, high fracture toughness over a wide temperature range, and low surface and bulk conductivity. The PDMS is used in a 10:1 mixing ratio of resin to curing agent, and is mixed via a vortex mixer and then degassed to remove any trapped air before curing for 60 minutes at 90°C. The surface active releasing agent FDTS was purchased from Gelest, PA. A molecular thin layer of the FDTS is applied to the PDMS post-surface activation to form a layer approximately 1-2nm thick on the cured PDMS surface.

Typical synthetic PDMS leaves were approximately 2mm thick with one face patterned. All testing occurred across several samples, where the wetting properties were characterized by measuring the water contact angle. Sessile contact angle testing was used to capture the silhouette of a static water droplet, where image processing software applied an elliptical best-fit model to determine the contact angle. Friction tests were performed on a unique micro-indentation and friction system that includes an inverted optical microscope (Carl Zeiss Axio Observer; Z1m) to capture images of the contact area during testing [3]. Individual tests involved an elastomer PDMS hemispherical probe (0.6mm diameter ± 0.01mm) mounted on a load cell (Transducer Techniques; TMO-2), attached to a compact nano-positioner (PI P-611; ZXS) with a resolution of 0.2nm. The motion was controlled by a nano-positioner and a displacement controller (PI E-625; PZT). The instrument is controlled through a custom developed LabVIEW (version 8.5, National Instruments) interface. The preloading force was varied over the range of trials to measure the effect of the patterned substrate compliance on the resulting friction enhancement while the area of contact was observed to determine the contact mechanism. Data was collected for two separate trials on the patterned surface at each defined preloading force, and contrasted to a smooth surface under similar experimental conditions. Tests varied the preloading force from 1.96 to 29.4mN. The value of the friction force was determined by locating the maximum value of FX from the friction trend, and then using all values that fall within 80% of this value to generate a data set. The average of these values is then used. The coefficient of friction is then determined by dividing this average friction force FX by the preloading force FZ.

RESULTS AND DISCUSSION

Surface properties of the Trembling Aspen leaf

The Trembling Aspen leaf samples are used as the initial moulds for the pattern transfer. (Figure 1) displays a Trembling Aspen leaf taken from a tree on the University of Waterloo campus in summer along with a magnified optical image that showcases the surface micro-structures. The surface pattern consists of a dense array of similar sized micro-papillae that are hemispherical in shape.

The hydrophobicity of the Trembling Aspen leaf is derived from a hierarchical system starting with the micro-papillae on the surface, where the micron sized asperities are coated with a hydrophobic waxy layer that is further crystallized to create a nano-structure [13]. In order to better understand the developed pattern transfer process and to compare the synthesized leaf versus the Trembling Aspen leaf samples, the contact angle has been characterized at the different stages of the process. (Figure 2) displays a typical water contact angle on the waxy natural surface.
patterned surface of the leaf sample. In order to achieve a proper statistical analysis of the data, thorough and structured collection is important to ensure repeatability of the data. The Trembling Aspen leaf has an average contact angle of 135.7°, which was determined from three separate and distinct points on the surface on three different samples. This type of sampling was utilized in order to determine the sources of variability for the biological sample. Table 1 lists the data collected to find out if significant variability exists among the different leaf samples, or on different locations on the surface of the leaf. F-observed values were determined from the mean square of the variance sources over the total mean square and can be compared against critical values specific to the population size. The relevant critical value for both cases is the same, \( F_{0.05, 2, 8} = 2.614 \), equalling a critical value of 4.46, which reflects the null hypothesis being tested under a 95% confidence interval. The F-critical being greater that the observed values indicate that neither of the two sources of variability reject the null hypothesis. Therefore, there is no significant variability from sample to sample or between different spots on each sample. However, it is worth noting that there is a greater contribution of variance within the leaf samples than between the same samples indicating that the variance observed may be a result of varying instrumental and procedural error rather than between different leaf samples.

From observing the interaction of water droplets on the surface, we noticed a relatively high adhesion properties of the Trembling Aspen. Droplets less than 15µL were able to be held at 180° angles without the droplet falling off. This phenomenon indicates a Wenzel wetting interaction [10]. The Wenzel wetting mechanism accounts for the presence of roughness on the surface of a sample, and offers a modified contact angle based on the roughness factor described by the real area of contact at the solid-liquid interface versus the projected area of contact. The relative high adhesion of the surface is a result of water being able to completely wet the patterned surface and penetrates in between the surface structures versus sitting on top of them. Furthermore, high-adhesion properties have been linked within several reports to be a function of the skewness and kurtosis of a surface, where a skewness towards peaks versus valleys will lower the adhesive characteristics of the surface [10,20,21]. Therefore the rounded nature of the surface structures present on the Trembling Aspen may trend towards relatively greater adhesive properties.

**Pattern Transfer to Polymer Films**

To replicate the surface structure of the Trembling Aspen leaf, we adapted a recently-developed two-step soft-lithography pattern transfer technique [1]. (Figure 3) illustrates the general steps of the two-stage pattern replication technique. A fresh sample is taken from a tree and brought back to the lab to serve as the initial patterned substrate. The leaf sample was prepared by attaching it to a glass slide and taping all edges down to prevent any PDMS from leaking underneath the sample or curling of the edges during the thermal curing process. The first step of the pattern transfer is to make a negative PDMS stamp (Figure 3 a-c). The second step of the pattern transfer is to use the PDMS stamp to make the synthetic leaf mimicking the surface structures of the initial natural patterns of the Aspen leaf (Figure 3 d-f).

To make the PDMS stamp, silicone resin mixed in a 10:1 ratio of resin to curing agent, was vortex mixed, degassed, and then applied to the leaf sample after which it was left to cure for one hour at 90°C as in Figure 3-b. During this step, it was found that the leaf sample decomposed at this temperature; the leaf colour changed to a dull green from the initially vibrant green due to the rapid degradation of chlorophyll, which is the plant pigment responsible for giving plants its green colour [22]. The heat also causes water to evaporate from the leaf leading to a slight decrease in size and shriveling. However, this made for easier peeling as the internal structure of the micro-papillae shrank, and no longer filled the holes of the PDMS structure formed over the early stages of the curing process. Room-temperature curing was trialed with these samples to attempt to navigate this issue with both fresh and dried leaf samples. However, it was very difficult to peel the PDMS after leaving it for the recommended 24 room-temperature curing period [23] as the leaf readily adhered to the PDMS due to a slight dissolving of the natural waxy coating layer, resulting in an impossible delaminating due to the tearing of the leaf sample. From visual analysis following the pattern transfer, it was found that the negative stamp actually copied the initial size of the micro-papillae before any size decrease. In fact, the decomposition of the initial sample is a convenient result of the curing procedure, as the size decrease of the initial mould lead to easier delamination.

(Figure 3-c) shows the surface treatment of the PDMS negative stamp with the gas-phase application of a monolayer of FDTS, which in this procedure served to act as a releasing agent between the two PDMS layers. The procedure involved the initial exposure of the negative stamp to a ultra-violet ozone (UVO) plasma treatment for two hours. This treatment modifies the surface of the PDMS via chain-scission and silica migration, thereby increasing the density of SiO₂, density at the surface and generating an abundance of hydroxyl functional groups to serve as bridging molecules for the chlorinated silica head-group of FDTS [1,12,24]. The effectiveness of the UVO treatment was confirmed through testing the wetting state of the PDMS, where

![Figure 2 Images of a 10µL water droplet on the surface of the Trembling Aspen leaf.](image-url)

**Table 1:** The ANOVA table of the Trembling Aspen leaves sampled (3 samples at 3 separate points on the surface) showing the F-observed values for the null hypothesis of observing if the variances are zero.

<table>
<thead>
<tr>
<th>ANOVA</th>
<th>Sum of Squares</th>
<th>Degrees of Freedom</th>
<th>Mean Square</th>
<th>F_obs</th>
</tr>
</thead>
<tbody>
<tr>
<td>Between Samples</td>
<td>107.43</td>
<td>2</td>
<td>53.71</td>
<td>1.386</td>
</tr>
<tr>
<td>Within Samples</td>
<td>202.64</td>
<td>2</td>
<td>101.32</td>
<td>2.614</td>
</tr>
<tr>
<td>Total</td>
<td>310.07</td>
<td>8</td>
<td>38.76</td>
<td></td>
</tr>
</tbody>
</table>
the contact angle of the surface reflected that of a completely wetting state (contact angle < 5°) when exposed to the UVO plasma for two hours.

With the addition of a monolayer of FDTS to the surface of the PDMS negative mould, the second stage of the transfer process is facilitated. Through sessile contact angle testing, the surface energy of the patterned PDMS was not observed to change by much as the surface maintains a constant wetting state. Thus, the role of the FDTS layer is to prevent the migration of the PDMS components between the two layers. Without the FDTS layer, the PDMS chains may interpenetrate and crosslink between the two samples under curing conditions, removing the interface at which to separate the samples. The possibility of skipping the surface treatment step was trialed, but it was determined that it was not possible to practically delaminate two PDMS samples from one another without tearing one, or both, of the samples as they fuse during the second curing stage in (Figure 3-d).

Once the surface has been treated, (Figure 3-d) shows the application of a second layer of PDMS in a 10:1 ratio of resin to curing agent following the exact procedure as (Figure 3-b) stated above. The new synthetic leaf sample was then peeled from the negative mould in (Figure 3-e). Figure 4 shows the result of a complete leaf able to be copied to scale using a Canadian loonie as a reference for size. Figure 5 represents the surface pattern of the synthetic leaf sample as viewed through an optical microscope at varied magnifications. It can be seen that the initial size, shape, and density of the micro-papillae are preserved throughout the dual pattern transfer procedure to the synthetic leaf sample.

Following the final peeling of the synthetic leaf sample from the negative stamp, close analysis of the surface shows that the PDMS negative stamp was not damaged from the procedure, and was able to be used repeatedly to generate several identical samples without a loss of the releasing layer that allowed for the two PDMS samples to delaminate. This is a major benefit of the use of the PDMS stamp, where the flexible mould is able to be used repeatedly to mass produce samples without the major loss of materials from a destructive process. Additionally, even though the decomposition of the initial leaf sample results in a destructive procedure involving the samples used as initial moulds, the sample is able to be preserved in the synthetic variant, where simply repeating the surface treatment allows for a multiple use secondary master moulds.

**Surface properties of the micro-structured film**

The water contact angle of the synthetic leaf was measured with the same procedure as the natural Aspen leaf. Figure 6 shows a typical measurement. The average water contact angle of the synthetic leaf was determined to be 115.8°, which is less than that of the Aspen leaf. Hence, even with similar micro-structures in size, shape, and density, the synthetic leaf is less hydrophobic than the initial Aspen template. This may be a result of the different surface chemistry of the PDMS and the waxy layer of the Leaf. We also suspect that some nano-structures of the Leaf might not have been transferred to the PDMS film because of the subtle shrinking and heat decomposition of the waxy layer during in the pattern-transfer process [13]. It is informative to compare micro-patterned PDMS with smooth PDMS film. Our previous studies showed that smooth PDMS (Sylgard 184) made through the same procedure has a water contact angle of 105° [25]. Thus, the micro-patterns transferred from the Aspen leaf have enhanced the hydrophobicity of PDMS. It is also worthwhile to mention that the Sylgard 184 will remain functional within a temperature range of -45 to 200°C, including thermal cycling within temperature conditions reaching as low as -55°C [23].

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**Figure 3** Schematic diagram of the Trembling Aspen synthetic leaf fabrication. Images (a) through (c) display the initial moulding of a negative stamp capturing the specifics of the leaf sample and the subsequent surface treatment with the FDTS releasing agent, while images (d) through (f) display the second pattern transfer to fabricate the synthetic leaf sample out of PDMS (Adapted from [1]).

**Figure 4** A full size sample synthetic leaf after peeling is complete.

**Figure 5** Images of the synthetic leaf sample as a copy of the original Trembling Aspen leaf mould at (a) 50 times, (b) 125 times, (c) 500 times, and (d) 1250 times magnification following the successful delamination of PDMS from PDMS following the surface treatment. Reference scale bar again shows that the final micro-papillae are approximately 20µm in diameter on average.

**Figure 6** Typical measurement of water contact angle on the synthetic leaf sample.
contrast, the Trembling Aspen leaf degrades at any temperature greater than 50°C for an extended period (as shown with the complete decomposition during the fabrication), and freezes in sub-zero temperatures. Thus, having almost the identical surface structures at the macro and micro scales, the synthetic leaf may be able to serve a model leaf for varied applications, for example, in the testing and development of pesticides and decorating products.

In addition to the hydrophobicity property, we noticed that the synthetic leaf has an appealing tactile experience when one touches and feels the artificial leaf with fingers. To characterize the tactile properties, we measured the friction properties of the micro-patterned film in comparison to a smooth control. Friction scans were performed with a PDMS probe scanning the surface at a speed of 5µm/s for 1000µm. Each defined preload force involved a single trial on two separate patterned surfaces, and one trial on a smooth PDMS surface for contrast. Within this study, the friction is measured at multiple preloading forces in order to gauge the effect of adding the pattern to the PDMS film surface, where the mode of contact changes from a laid state to almost conformal state over the range of loading forces trialed. (Table 2) lists a comparison of the friction properties for both smooth and patterned PDMS samples as the preload increased from the low end (1.96mN) to the high end (29.4mN).

Figure 7 displays the friction traces of these sample surfaces at a low and high end of preloading forces to give a direct comparison between the patterned and smooth PDMS samples. In (Figure 7-a), where a low preload of 0.2 gram (or 1.96 mN) was applied, the most striking observation is the large decrease in friction force observed for the patterned surface. This is expected as the laid contact mechanism indicates a dramatic decrease in real area of contact, which is confirmed from the optical image of contact area. For the low preload tests, the difference in friction force from smooth to patterned PDMS was measured to be 3 gram (or 9.53 mN), or 4.86 times the initial loading force. Additionally, the smooth surface shows a very large value of static friction resulting from the stiction at the onset of the initial contact, which is much more pronounced at lower preloading values. This can be explained by the surface interaction mechanism studied by Bowden and Tabor and the subsequently proposed model of friction by Homola and Israelachvili $F_z = \mu F + z^+$ A [26], where lower preloading forces indicate a shift of $F_z$ to zero and a greater influence of the contact area and interfacial interactions on the friction force. From (Figure 7-a), the addition of a pattern eliminated the stiction spike at the onset of lateral motion. This phenomenon is a result of the patterned surface continually recreating the area of contact with each aspereity in a series of small stick-slip type motions which is reflected in the erratic and constantly changing $F_x$ for the patterned surface, while the overall value of the $F_x$ remains relatively constant [27]. For the smooth sample, the elastic nature of the PDMS surface generates several stick-slip events, where the peak values of $F_x$ reach a similar maximum and occur on a regular interval.

In (Figure 7-b), a high preload 3 gram (or 29.4mN) was applied. At this greater preload, the difference in $F_x$ between the smooth and patterned samples is only 12% of the preload value as opposed to 486% for the low preload. The bottom-view microscopic image captured during the scan shows that the mechanism of contact has changed with the increasing preload to a more conformal state. The patterned friction traces are now much less "noisy" as the friction is much less-dependent on small aspereity interactions, and instead based on a much larger area of contact where the ability to continually recreate the area of contact is lost. However, the patterned surfaces did display the ability to retain some pockets of air at the interface beneath the probe, predominantly on the leading edge as the scan progressed, resulting in the observed slight drop-off in friction force measured over the duration. Additionally, the friction traces show a similar stiction trend for both the smooth and patterned samples at the onset of lateral motion due to comparable nature of contact. However, the stick-slip mechanism experienced for the smooth surface at the smaller preload is no longer present due to the greater loading force preventing the jumping of the probe.

To further characterize the load-dependent friction behaviour, the coefficient of friction (COF) defined as the ratio of the friction force $F_x$ to the preloading force ($F_z$) was calculated for each preload and listed in (Table 2). Figure 8 plots the COF

Table 2: A variable preload comparison of the friction properties for both and smooth and patterned PDMS samples.

<table>
<thead>
<tr>
<th>Preload (g)</th>
<th>Preload (mN)</th>
<th>Patterned 1</th>
<th>Patterned 2</th>
<th>Smooth PDMS</th>
<th>Difference</th>
<th>Patterned COF (avg)</th>
<th>Smooth COF</th>
<th>% Patterned of Smooth COF</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.2</td>
<td>1.96</td>
<td>2.65</td>
<td>2.52</td>
<td>12.12</td>
<td>9.535</td>
<td>1.319</td>
<td>6.184</td>
<td>21.33%</td>
</tr>
<tr>
<td>0.5</td>
<td>4.9</td>
<td>7.34</td>
<td>5.94</td>
<td>19.14</td>
<td>12.5</td>
<td>1.355</td>
<td>3.906</td>
<td>34.69%</td>
</tr>
<tr>
<td>1.0</td>
<td>9.8</td>
<td>17.62</td>
<td>14.31</td>
<td>27.24</td>
<td>11.275</td>
<td>1.629</td>
<td>2.780</td>
<td>58.61%</td>
</tr>
<tr>
<td>2.0</td>
<td>19.6</td>
<td>26.66</td>
<td>32.63</td>
<td>40.58</td>
<td>10.935</td>
<td>1.513</td>
<td>2.070</td>
<td>73.05%</td>
</tr>
<tr>
<td>3.0</td>
<td>29.4</td>
<td>52.81</td>
<td>46.24</td>
<td>53.26</td>
<td>3.735</td>
<td>1.685</td>
<td>1.812</td>
<td>92.99%</td>
</tr>
</tbody>
</table>
as a function of the preload for both the smooth and patterned samples. Comparing the data over the range of the tests, the COF of the smooth sample decreases as the preload is increased while the COF of the patterned sample is almost constant after a slight increase with the preload. The trend from largest to smallest coefficient of friction for the smooth PDMS sample showcases the transition from classical Amontons’ friction mechanism at the higher preload to the surface interaction mechanism of Bowden and Tabor at the lower preloads. The coefficient of friction for the smooth surface will plateau and continue at a steady-state value as predicted by Amontons’s friction law, where the friction force will lose dependence on the real area of contact. The COF for the patterned coefficient remains relatively constant throughout the different preload values, and eventually matches the smooth coefficient once conformal contact is achieved through the depression of the asperities achieving a complete contact area similar the smooth PDMS surface. The measured friction for high preload values may begin to increase and surpass the smooth surface values, which involves a complete conformal contact with the patterned surface. There has been much work to support the high adhesive ability of some patterned surfaces, such as the toe-pad of a gecko, where it is believed the directional configuration and setae shape of the nano-fibrils result in the increased adhesion [5,28,29,30]. Moreover, several studies have reported the enhancement of friction from the interlocking of one or two patterned surfaces such that there are boundaries and contact lines not parallel with the direction of crack propagation at the surface [31,32]. Thus it can be predicted that if the normal force continues to increase to form a complete conformal contact, the overall friction force observed for the patterned surface may surpass that of the smooth PDMS.

CONCLUSION

This work provides a means to mimic the natural micro-structured pattern of the Trembling Aspen leaf, while focusing on the subsequent characterization of the wetting and friction properties of the synthetic leaf. A two-stage pattern transfer was used for the fabrication of micro-patterned polymer films, which is an easily scalable process with a negative mould able to be used multiple times and the ability to generate synthetic copies of the initial mould. The application of a self-assembled monolayer of the releasing agent FDTS to the surface of the PDMS material allows a consistent and repeatable reproduction of synthetic Trembling Aspen leaf samples to scale. The resultant micro-patterned PDMS surface or the synthetic leaf offers a visually and microscopically accurate mimicry of the Trembling Aspen leaf. The synthetic leaf was found to be less hydrophobic than the natural sample but increased the hydrophobicity of the smooth polymer film because of the addition of surface pattern. Additionally, patterning the PDMS film results in a large decrease of the friction force at lower preloads where the contact mechanics resembled the laid contact mechanism. This was contrasted to the minimal decrease of the friction observed for the same surfaces at a higher preload, where the mode of contact evolved to a conformal state, with an area of contact similar to the smooth PDMS sample. The application of a pattern to the PDMS surface was observed to eliminate the stiction component observed on the smooth surfaces. The stick-slip mechanism of sliding for the
smooth surfaces is replaced with many different individual stick-slip contributions from the apex of each individual asperity while the system is within laid contact. The patterned PDMS was shown to have a relatively constant coefficient of friction within the parameters of this test, although it is predicted that the presence of the patterned surface will lead to an increased friction for the patterned PDMS. The modified friction properties of the synthetic leaf generate an appealing tactile feeling when the surface is rubbed, while the superior temperature range of the synthetic leaf generate an appealing tactile feeling when the surface is rubbed, while the superior temperature range of the synthetic leaf. The modified friction properties of the synthetic leaf will lead to an increased friction for the system is within laid contact. The patterned PDMS was shown to have a relatively constant coefficient of friction within the parameters of this test, although it is predicted that the presence of the patterned surface will lead to an increased friction for the patterned PDMS. The modified friction properties of the synthetic leaf generate an appealing tactile feeling when the surface is rubbed, while the superior temperature range of the synthetic polymer sample may allow for studies to be conducted outside of natural limits.

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