

Supplementary Information 1: Substrate Curing Effects

Supplementary Information1: Wavelength, amplitude, and substrate effective modulus as a function of curing time. Created from a substrate with a 10:1 oligomer: curing agent mixture of PDMS and cured at room temperature (25° C) and a PS film with *t*=18nm.

Electronic Supplementary Material (ESI) for Soft Matter This journal is The Royal Society of Chemistry 2011

Davis, et al. 2010



Supplementary Information 2: Smooth Surface G_c Calculation

Supplementary Information2:Representative force versus displacement plots for smooth probe contacting a smooth PS film supported on a PDMS substrate for two different film thicknesses. In order to measure the G_c of the PS-PS interface, we employed the relationship of P_{f} , E^* , and c to G_c (Johnson, <u>Contact Mechanics</u>, 1985):

$$G_{q} = \frac{P_{f}^{2}}{8\pi B^{*}c^{2}}$$

This equation assumes that at the point of separation, the interface is at thermodynamic equilibrium (implying that the entire interface separates instantaneously at P_f) so that $G=G_c$. The two tests shown here yield values of $G_c=49$ mN/m and $G_c=44$ mN/m, respectively.



Supplementary Information 3: Single Cylinder Adhesion

Supplementary Information3: Single cylinder adhesion experimental results with finite cylindrical punch probes. (a) Schematic of the testing geometry. (b) Optical micrographs of contact for several adhesion experiments of various probe and cylinder dimensions. The bottom three rows of images have been smoothed and subtracted from their respective background or reference images shown in the first row using ImageJ image processing software to allow the contact areas to be more easily seen. The scale bars apply to each column respectively. (c) Cylinder adhesion experimental results of separation force as a function of the cylinder radius of curvature for two different probe radii (c).

For these tests, elastomeric cylinders are formed by molding PDMS in optically smooth glass tubes. The cylinders are formed from a mixture of 10:1 oligomer to curing agent by weight, degassed for 30 minutes, and cured at 130°C for two hours. After curing, the cylinders are removed from the tubes, cut in half lengthwise, and affixed to a glass slide by attaching the flat side of the hemi-cylinder to a 1mm thick coating of uncured PDMS. A schematic of the final testing geometry is presented in **Supplementary Information 3a**. Cylinders range in size from 0.7mm<R<11.0mm and are tested with two probe sizes (c=0.50mm and c=1.25mm). Tests are conducted with an alumosilicate (Al₂SiO₅) or aluminum oxide (Al2O₃) flat probe. Although the probes consist of two materials, their surface energies are nearly identical and are determined by independent adhesion tests of flat cylindrical probes on smooth PDMS surfaces.

Contact images of the various probe and cylinder size combinations are shown in **Supplementary Information 3b**. Qualitatively, for testing geometries where $2c \sim R$, the contact areas are roughly rectangular and the width of the contact line changes as a function of the vertical displacement between the two contacting surfaces. However, for the contact geometries where the effective cylinder length is much smaller than R (2c << R), the contact area is more elliptical and upon retraction of the probe, both the length and width of the contact area decrease. Additionally, the flat probes used here are circular; therefore, the "short" ends of the contact area

have a noticeable curvature and the overall contact can be approximated more closely by an ellipse than a rectangle.

The cylinder adhesion relationship presented in equation 5 is based on a fracture mechanics argument where two mode I fractures occur simultaneously along the long sides of the inward rectangular contact between the cylinder and the flat surface. Effectively, two peel events occur at the same time and propagate toward the center of the contact area upon separation. This argument works well for long cylinders on flat surfaces. However, for finite contacts of cylinders, a similar relationship has not been proposed. Therefore, the cylinder adhesion experiments in **Supplementary Information 3** explore the separation behavior for a geometry where $2c \leq R$.



Supplementary Information 4: Single Cylinder Adhesion Relationships

Supplementary Information 4.Single cylinder adhesion results using the contact mechanics relationships for (a) an infinitely long cylinder contacting a flat substrate and (b) an elliptical contact area resulting from contacting an ellipsoid with a flat substrate

Supplementary Information 4ais plotted in accordance with the long cylinder scaling. The lines drawn on the plot are linear fits through the data for each probe radius. The slopes of these lines represent numerical prefactors and should be identical if the scaling is appropriate. The slope of the line for the larger probe is less than that for the smaller probe, indicating that the infinitely long cylinder model does not properly represent the finite cylinder adhesion results. If our individual wrinkles behave in accordance with equation 5, then the maximum separation forceis $P_s^{cyl}=3c(0.5E^*G_c^2R)^{1/3}$.

In **Supplementary Information 4b**, we plot the results of the cylinder adhesion tests in accordance with the scaling of equation 7. The slope is identical for each data set corresponding to different values of c; indicating that this scaling relationship appropriately represents the dependence of P_s on geometry and materials properties for the finite cylinder experiments.



Relationship

Supplementary Information 5. Separation force as a function of materials properties and geometry. The line is a linear fit to the data.

Utilizing the separation force relationship obtained using Barquins' prediction for a long cylinder:

$$P_{cyl} = 3\left(\frac{\pi E^* G_c^2 R}{16}\right)^{\frac{1}{3}}$$

and our scaling relationship:

$$P_s \sim \sum_{i=1}^n P_i \cdot l_i$$

we obtain a final relationship for the separation force of a wrinkled surface:

$$P_{S} \sim \left(\frac{E^{*}G_{c}^{2}}{b\lambda}\right)^{\frac{1}{3}} \cdot (c^{2})$$

The two plots above are included merely as a reference to allow the reader to ascertain the appropriateness of the fit of a long cylinder relationship over that of an elliptical contact which is used in Figure 7 in the main text.