Peel Mechanics of Barrier Materials on Soft Substrates

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Patient care is at the forefront of Hollister's products, and accurate testing of these products is critical. There were two goals of this project. First, develop a lab-made substitute for skin to allow for easy testing. Second, to develop a test setup and quantify the peel force of two adhesives for use in barrier materials of ostomy care products through 90-degree peel testing. 90-degree peeling testing was conducted for both adhesives on polymer bilayers to simulate human skin as well as hard surfaces for control.

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Project Background

Ostomy procedures are common surgeries that leave the patient with an ostomy bag (seen on the right) covering their stoma, an opening that allows waste to leave the body.

The team will be studying the pressure sensitive adhesives (PSAs) provided by Hollister via 90-degree peel testing. The peel force can be calculated by Equation 1. This research will allow Hollister to have a more complete characterization of their materials to help improve the quality of life for their patients.

Figure 1: An ostomy bag attached to a woman's abdomen[1].

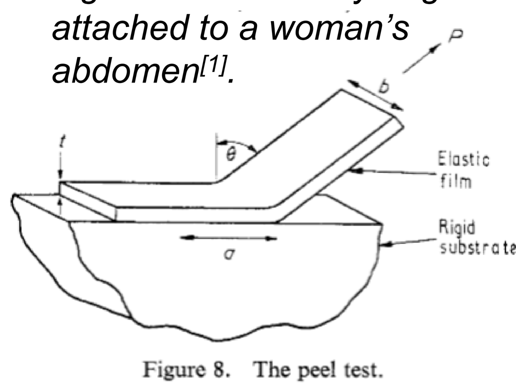


Figure 2: Schematic of the peel test [2]

Equation 1

$$P = \frac{b\gamma}{1 - \cos\theta}$$

P= Peel force
b= Width of adhesive
γ= surface energy of adhesive

Experimental Setup

Substrate Synthesis:
A bilayer substrate system was chosen to better represent the multiple layers in skin.

- Hypodermis: polydimethylsiloxane (PDMS) for mechanical properties
- Epidermis: polyethylene (PE) for surface energy properties
- The two were attached via plasma treatment

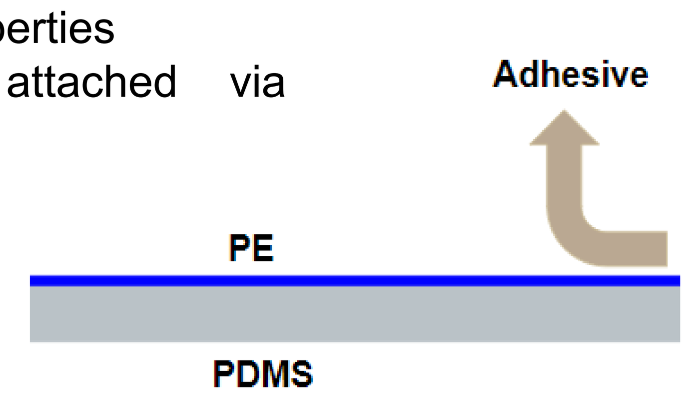


Figure 3: Schematic of a substrate.

Testing Method:

- The Davis Research Group's 90-degree peel fixture was used.

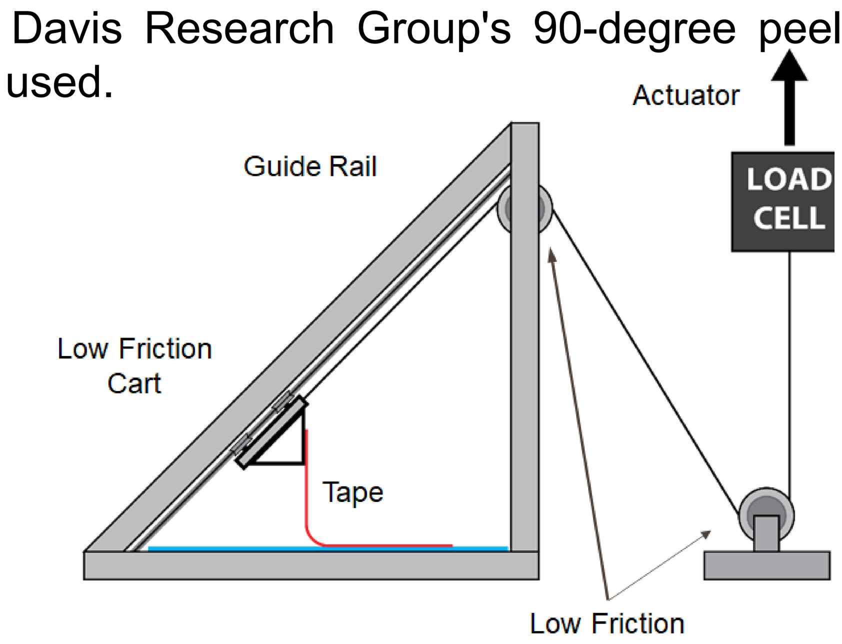


Figure 4: Schematic of the Davis Research Group's peel fixture.

- A slide mount was created and used to ensure the substrate was secure while the adhesive was peeled off.

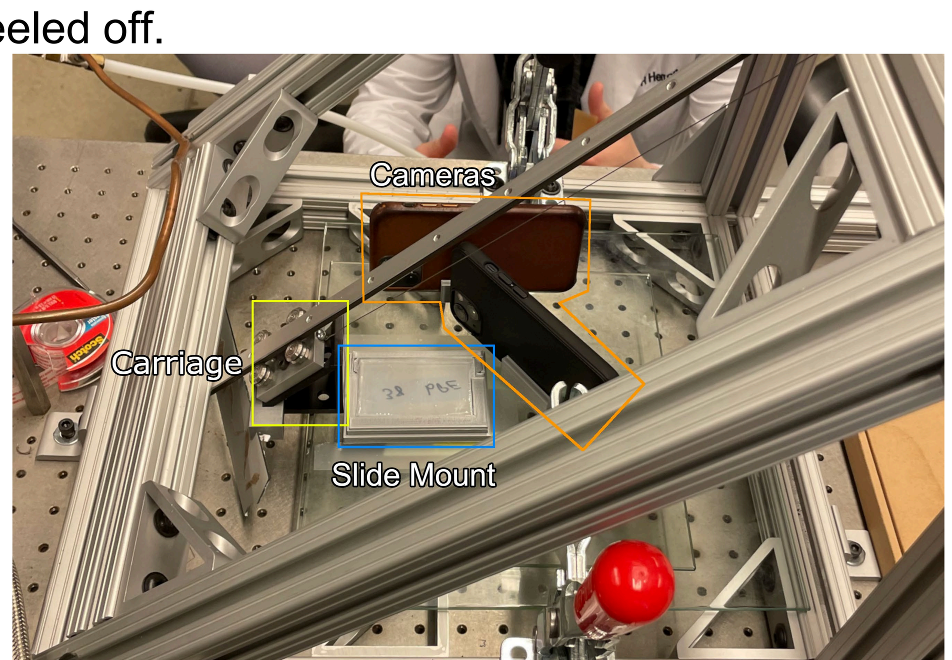
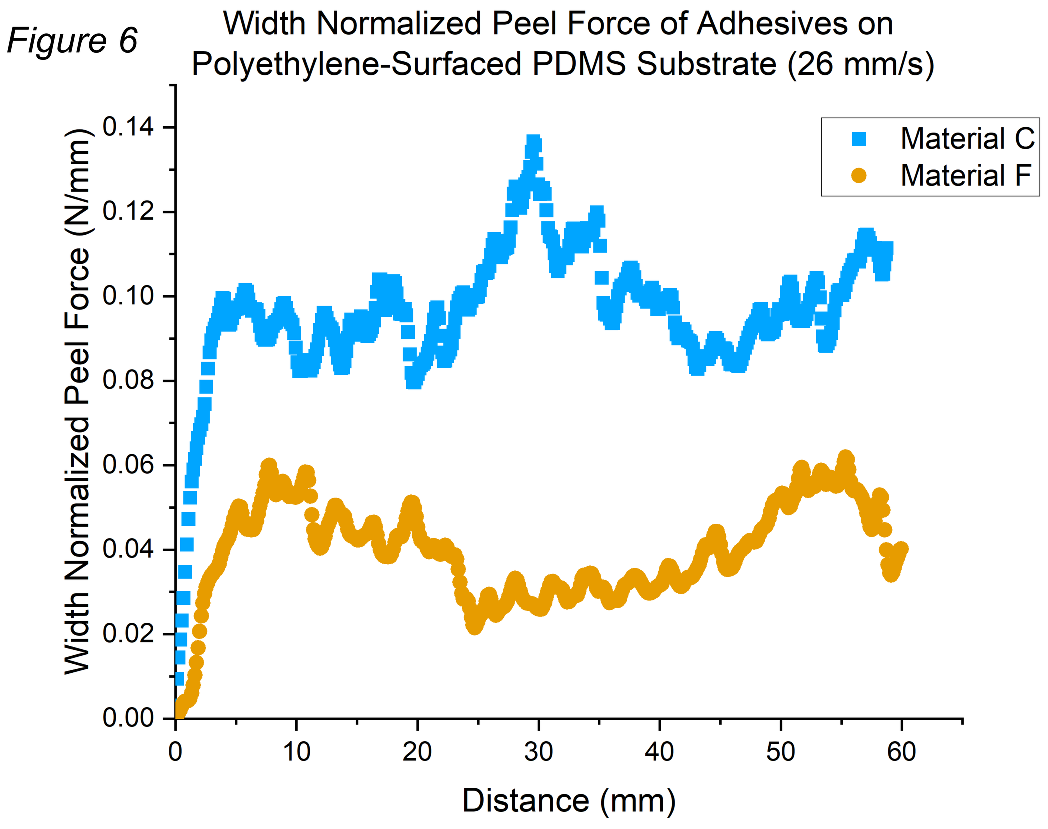


Figure 5: Example of the test setup

Results

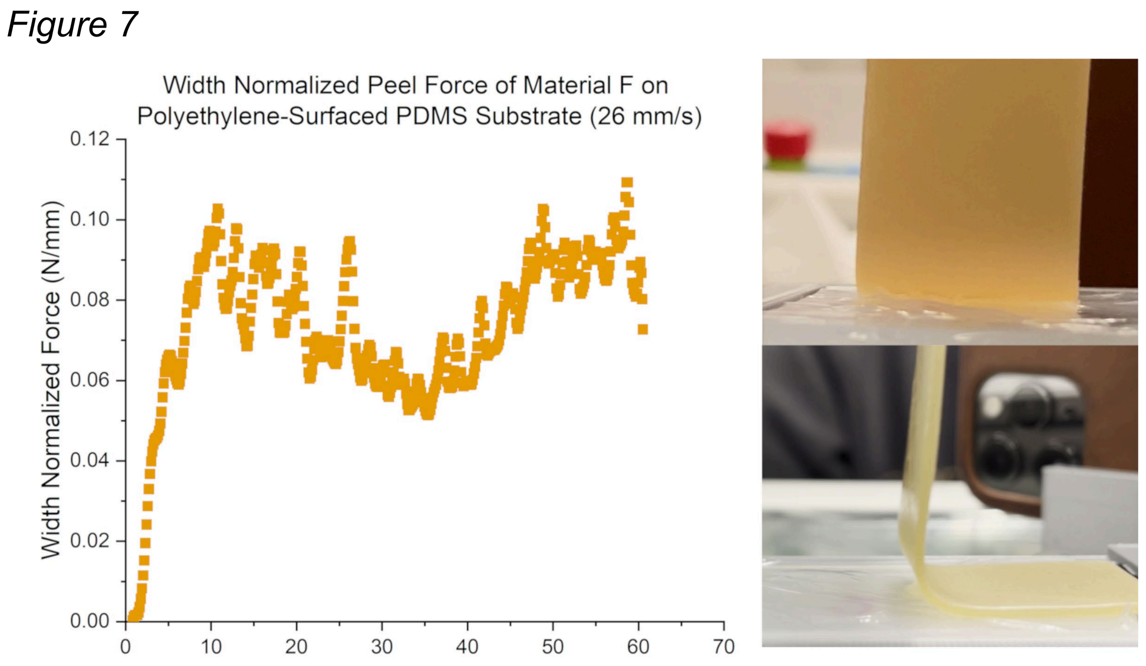
The data collected from peel tests are force from the load cell and the distance the carriage has moved. After calibrating the data to account for geometry and friction in the system, results are obtained as seen below in Figure 6. The tests have two regions in the data: the initial propagation (the sharp increase in force at the beginning), and the steady-state region (the rest).

Figure 6



Documentation of the peel tests was conducted via two phone cameras to capture a side view and a head on view as shown in Figure 5. These videos were lined up with the data collection. Figure 7 presents the end of a test from different angles.

Figure 7



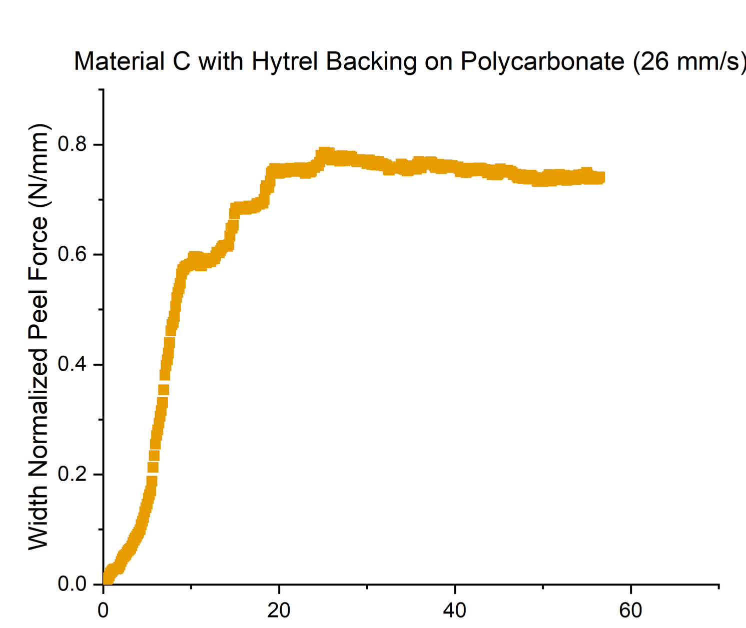


Figure 8: Peeling off PC with glass instead of PDMS. The stepping behavior between the initial propagation and steady-state peel may be a result of inconsistent contact with the surface, or perhaps looser tolerances on early versions of the substrate slide mount.

There were some deficiencies with the surface-substrate bonding, resulting in significant separation of the layers after a small number of repeated peels.

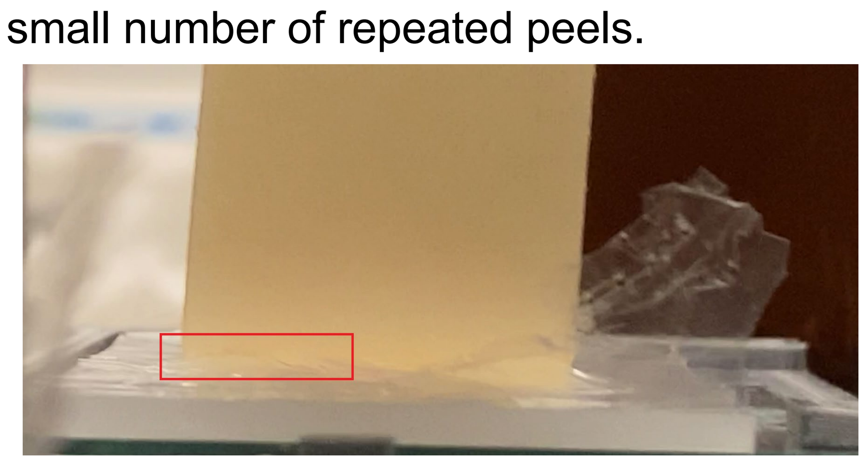


Figure 9: Material C being peeled off a polyethylene surface on a PDMS substrate. The polyethylene separating from the PDMS is highlighted.

Discussion

Using all the peel testing data, the average peel force for each adhesive and substrate combination was extracted and combined into Figure 10 showing how different adhesive-substrate combinations effected the results. All substrates had a polyethylene layer on top.

- Noticeable peel response differences were observed between all adhesives tested
- Regardless of the surface, using PDMS as the second layer of the substrate produced a much lower peel force compared to a rigid second layer (glass)
- Material C showed much higher variability in its average peel force than Material F when both were peeled from glass
- Both Materials C and F had higher peel forces compared to scotch tape

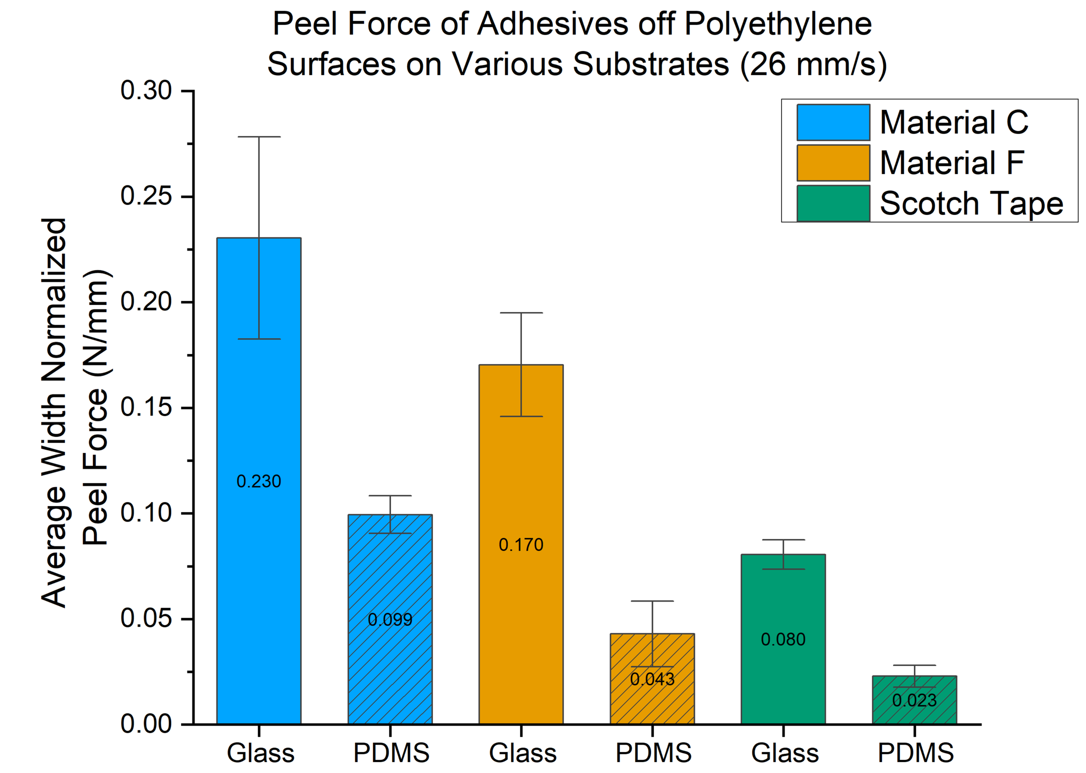


Figure 10: Bar graphs showing the average normalized steady peel force of different adhesives peeled from various surface-substrate combinations with error bars representing 1 standard deviation. Scotch tape included as a reference.

- The camera quality was inadequate to properly quantify the out of plane deformation of the substrate, Figure 9 is a good example of this
- Surface-substrate bonding with plasma treatment proved to be of inadequate strength and caused layer delamination during tests, as seen in Figure 9
- While Figure 10 shows high run-to-run variations on glass, Figure 8 shows that within the same test the steady-state peel was more consistent than soft substrate runs such as Figures 6 and 7

Future Work & Recommendations

- Develop a more robust method of attaching PDMS to PE to allow multiple tests per sample
- Investigate switching to a coating application on the substrate instead of bonding a surface layer material
- Test additional peel speeds to get a better understanding and characterization of Hollister's adhesives.
- Investigate different ways to qualitatively take photos and videos of the peel regarding substrate deformation

Acknowledgments & References

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[1] Cooke, Colin, "American Ostomy Census", The Phoenix, December 2009.
[2] Kendall, Journal of Physics D: Applied Physics 1971.