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Correlating Substrate Properties with Pressure Sensitive Adhesive Performance

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Pressure sensitive adhesive (PSA) performance is influenced by both the properties of the adhesive and the properties of the substrate. For bonding, the most important properties of the substrate are surface roughness and surface chemistry. The most common methods to test for adhesive performance are peel, shear, and tack. Shear is most sensitive to the bulk properties, while peel and tack are more strongly affected by interactions between the substrate and the adhesive.

For this investigation, common substrates were peel tested and then analyzed to correlate the surface chemistry and surface roughness with performance. Surface chemistry measurements were made with secondary ion mass spectrometry (SIMS), which provides information about the molecular and elemental chemistry in the top 2 nm and X-ray photoelectron spectroscopy (XPS), which yields quantitative elemental and chemical state information from the top 10 nm. Optical profilometry, or white light interferometry, was used to look at surface roughness, with scanning electron microscopy (SEM) providing supplemental information about surface texture.

HDPE bottles were examined. These samples have visually different surface textures (Figure 1), which are confirmed as differences in surface roughness by the optical profilometry data. However, there is no obvious correlation between the surface roughness and the peel values. (Table 1.) Typically, the surface chemistry of HDPE shows only C and O and possibly low levels of P from antioxidants. In this case, both the jug and the tan bottle also have N, Na, S, and Si at the surface. (Table 2.) Examination by SIMS shows the presence of polydimethyl siloxane (silicone) and lauryl sulfate on the surfaces of these two samples, both of which can negatively impact adhesion. The absence of these contaminants on the flame treated sample is consistent with the higher peel value.

Corrugated cardboard with different amounts of recycled material was also analyzed. The peel values are much lower for the 100% recycled cardboard, but the surface chemistry by XPS is similar. SEM images show that the 40% and 85% recycled samples have a similar appearance, with well adhered fibers and little organic material. The 100% recycled sample is not as smooth, and has loose fibers sticking up from the surface. (Figure 2.) This sample also has inorganic material present, which EDS shows to be Al, Ca, and Si. Optical profilometry confirms the observations made from the SEM images. The roughness values for the 40% and 85% samples are similar, while the 100% sample is significantly rougher. (Table 3.) For these samples, the differences in adhesion are likely due to higher surface roughness and loose fibers, and not related to surface chemistry.

In conclusion, it is important to consider the adhesion data and the analytical data together to determine the factors most important to adhesive performance. For the HDPE samples, visibly different surface roughness was not relevant to adhesion, but differences in surface chemistry correlate with differences in peel. For the corrugated cardboard samples, there was no obvious difference in surface chemistry, but differences in roughness and morphology indicate why performance varies.

Figure 1: Au/Pd coated HDPE bottles, showing differences in surface texture. From left to right: jug, tan bottle, and flame treated.

Sample	PSA Peel (oz/in)	Ra (mm) w/(StDev)	Rq (mm) w/StDev
Jug	8.7	4.8 (0.7)	6.4 (1.4)
Tan Bottle	5.7	1.7 (0.3)	2.2 (0.3)
Flame Treated	17.4	2.4 (0.4)	3.1 (0.5)

Table 1: Peel and Surface Roughness Data for HDPE samples, where Ra is the average roughness and Rq is the root mean square roughness.

Sample	C	N	Na	O	S	Si
Jug	93.2 (1.0)	0.3 (0.1)	0.3 (0.1)	4.6 (0.7)	0.2 (0.1)	1.2 (0.1)
Tan Bottle	89.0 (2.0)	0.4 (0.3)	0.4 (0.2)	8.0 (1.0)	0.2 (0.1)	1.8 (0.3)
Flame Treated	89.6 (0.9)	0.5 (0.3)		9.9 (0.6)		

Table 2: Average XPS Data in atomic % (and standard deviations) for HDPE samples.

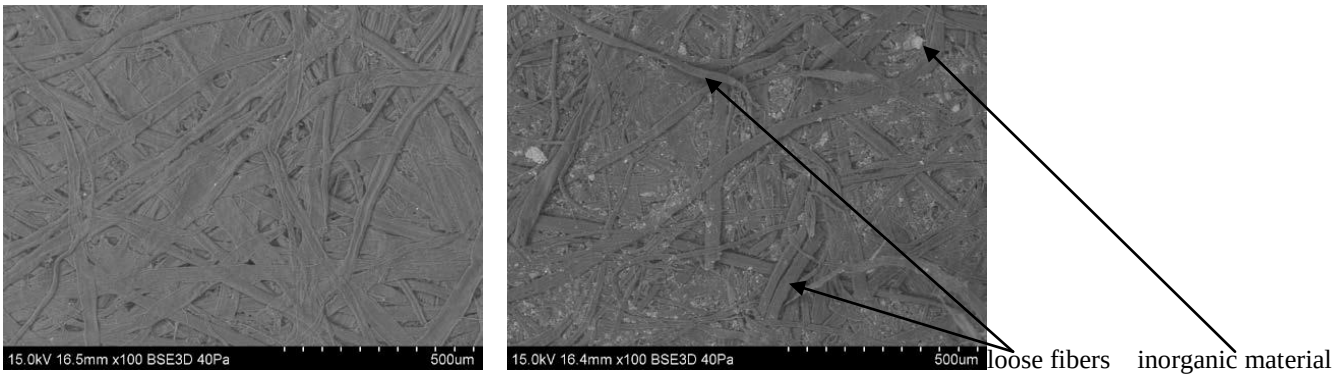

Figure 2: SEM Images of Corrugated Cardboard with 40% recycled content (left) and 100% recycled content (right). Note the loose fibers and inorganic material present in the 100% recycled cardboard.

Sample	Peel (oz/in)	Ra (mm) w/(StDev)	Rq (mm) w/StDev
40% recycled	22.9	6.6 (1.0)	8.2 (1.3)
85% recycled	22.3	6.2 (0.6)	7.7 (0.7)
100% recycled	6.8	8.7 (0.5)	10.7 (0.5)

Table 3: Peel and Surface Roughness for Corrugated Cardboard Samples.

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