Wettability Study of Materials Using Surface Free Energy Analysis

The wettability of a solid surface is of the utmost importance when designing products associated with bonding or coating materials, corrosion resistance, cleaning, lubrication, and moisture protection. Contact angle testing and surface free energy analysis can provide useful information into the wettability of materials. Materials with high surface free energy, i.e. high wettability, are ideal for bonding and coating, while samples with low surface free energy, i.e. low wettability, are better for corrosion and moisture resistance. By using different probe liquids with known polar, non-polar, and hydrogen-bond energy components, the surface free energy of a solid surface can be determined through contact angle measurement.

In this application note, different everyday materials, steel plate, copper plate, painted car panel, polycarbonate (PC) panel, PTFE tape strip, and glass slide were tested with three different probe liquids: de-ionized water, diiodomethane, and ethylene glycol. The testing was performed on the Kyowa DM-701 contact angle meter utilizing five popular surface free energy analysis theories, namely: Kaelble-Uy, Owens-Wendt, Wu, Acid-Base, and Kitazaki-Hata. The Kaelble-Uy, Owens-Wendt, and Wu theories require two probe liquids whereas the Acid-Base and Kitazaki-Hata theories require three probe liquids. The contact angle data of each probe liquid on each solid surface used for the calculation of surface free energy is shown in Table 1.

Table 1 Average Contact Angle Data for Each Sample and Probe Liquid

Specimen	**Average Contact Angle (°)**		
	DI Water	**Diiodomethane**	**Ethylene Glycol**
Steel Plate	74.8	46.4	63.8
Copper Plate	85.2	48.9	71.9
Painted Panel	69.9	43.6	59.0
PC Panel	82.7	36.9	51.8
PTFE Tape	114.9	67.9	92.2
Glass Slide	36.3	47.1	40.3

Table 2 presents the two-component theory surface free energy results, while Table 3 presents the three-component theory surface free energy results for each specimen. The d represents the dispersion component, p represents the polar component, and h represents the hydrogen bonding component in the surface free energy theories. For the Acid-Base theory LW represents Lifshitz-van der Waals component, AB represents the Lewis acid-base component, (+) represents the proton donor component, and (-) represents the proton acceptor component. Figure 1 shows the surface free energy results for each specimen and theory. As seen in Tables 2 and 3, the PTFE tape has the lowest surface free energy and is known to have very low wettability. Conversely, the glass slide has the highest surface free energy and can be described as possessing the highest wettability.

Table 2 Surface Free Energy Using Two-Component Theories

Specimen	Kaelble-Uy (mJ/m^2)			Owens-Wendt (mJ/m^2)			Wu (mJ/m^2)		
	d	p	Total	d	h	Total	d	p	Total
Steel Plate	30.8	7.9	**38.7**	32.0	7.5	**39.5**	27.6	13.6	**41.2**
Copper Plate	31.9	3.4	**35.3**	32.4	3.2	**35.6**	28.5	8.5	**37.0**
Painted Panel	31.3	10.2	**41.5**	32.7	9.7	**42.4**	28.2	15.8	**44.0**
PC Panel	38.4	2.9	**41.3**	38.8	2.8	**41.6**	33.8	8.3	**42.1**
PTFE Tape	23.6	0.0	**23.6**	23.3	0.0	**23.3**	27.6	0.0	**27.6**
Glass Slide	23.1	36.7	**59.8**	26.2	34.3	**60.5**	24.3	36.7	**61.0**

Table 3 Surface Free Energy Using Three-Component Theories

Specimen	Acid Base (mJ/m^2)					Kitazaki-Hata (mJ/m^2)			
	LW	AB	+	-	Total	d	p	h	Total
Steel Plate	34.4	0.0	0.0	12.8	**34.4**	20.6	35.1	5.1	**60.8**
Copper Plate	32.4	0.0	0.0	5.8	**32.4**	22.2	24.4	1.7	**48.3**
Painted Panel	36.1	0.0	0.0	16.3	**36.1**	21.0	38.9	6.9	**66.8**
PC Panel	41.1	0.0	0.0	3.9	**41.1**	41.0	0.9	0.7	**42.6**
PTFE Tape	21.5	0.0	0.0	0.0	**21.5**	16.0	7.6	0.0	**23.6**
Glass Slide	35.6	0.0	0.0	56.0	**35.6**	11.5	94.6	31.1	**137.2**

For the samples described herein, the two-component theories present consistent values, the Acid-Base theory was slightly lower than the two-component theories, and the Kitazaki-Hata theory presents the highest surface free energy values. There is no one theory that can be universally applied to all materials, and some probe liquids only work with certain theories. It is therefore useful to look at multiple theories when testing for surface free energy to achieve reliable results.

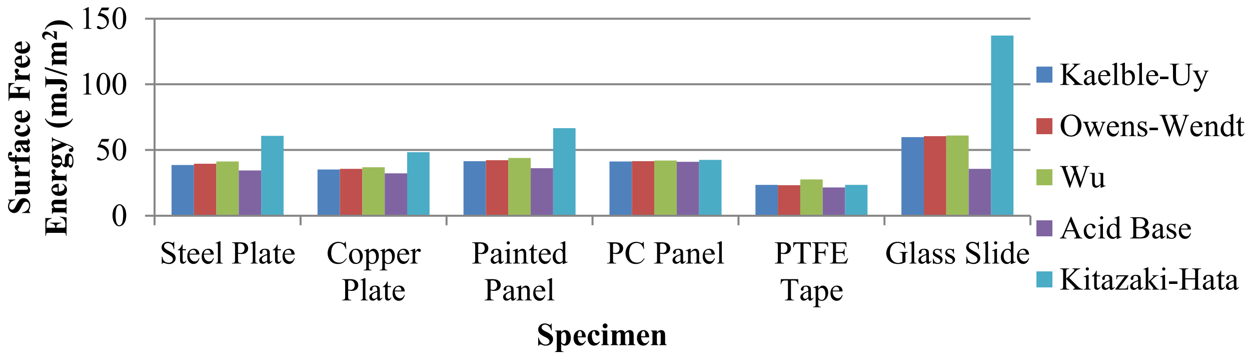

Figure 1. Surface free energy values for each sample using each theory.

Surface free energy measurements are a proven tool in studying the wettability of a material, and thereby its usefulness in a particular application. For example, PTFE is commonly used for anti-stick coatings, which corresponds perfectly with its low surface free energy. Meanwhile, glass slides have a high surface free energy, which allows for aqueous lab samples to wet over the slide for easier examination under a microscope. Analyzing materials for their surface free energy can ensure that the optimal materials are used to best suit one's needs.