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Application Report

Corona Treated Polypropylene Packaging Film

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Method: 

Drop Shape Analyzer – DSA100

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Correlation of Receding Water Contact Angle Data with Moisture Vapor Transmission Rate (MVTR) for Corona Treated Polypropylene Packaging Film

Abstract

Polypropylene film is widely used to package foodstuffs including meats, crackers, cookies, etc. Two of the major issues in packaging film are moisture vapor transmission rate (MVTR) and printability. In this work we study polypropylene film with varying levels of corona treatment – which was applied to increase printability by increasing surface energy. Samples are measured for surface energy, receding contact angle with water and MVTR. I am not aware of any prior studies on polyolefin films which attempt to correlate surface energy or advancing water contact angle with MVTR. And, in fact, we found poor correlation between both of those properties and MVTR. However, throughout the range of treatments applied (even at high treatment levels wherein the advancing contact angle with water is no longer changing significantly with increasing amount of corona treatment) we found the receding contact angle with water to show continued decreases with increasing treatment and to correlate in near linear fashion with the MVTR.

Background

MVTR is the measure of how much gaseous H_2O (moisture) can pass through a film in a given time frame. It is commonly expressed in units of grams of moisture passed per unit surface area of film per 24 hour period, when the film is used as a barrier between a low humidity and a high humidity environment. MVTR, along with oxygen permeability (which is not discussed further in this note), essentially determines how well the film performs in keeping the food inside fresh. The goal is to have low MVTR per unit cost or unit thickness of film.

Printability refers to the ability of an ink to wet and adhere to outer surface of the film. After all, in addition to being fresh, food ought to be labeled at minimum, and perhaps even creatively marketed with pleasing printed packaging. Printability is well understood to be an issue for untreated polyolefin films[1], because the films have low surface energies – typical values in the high 20's to low 30's of mJ/m^2 (or "dynes" if you prefer the industrial term). Therefore, it is common to use corona treatment to raise the surface energy of the film into the high 30's to mid 40's of mJ/m^2 in order to achieve better printing or label adhesion.

Corona is ionized air created by discharging high frequency, high voltage, energy across an electrode. The electrode is positioned over a grounded surface. The space between the electrode and ground is typically a few millimeters, through which the film can be passed to alter its surface. Corona treatment done in air oxidizes the surface of the film by deleting electrons from the surface[2], thus causing it to bond chemically to available oxygen and ambient moisture in the air. This raises its surface energy and surface polarity[3,4] (the fraction of the overall surface energy which is due to polar interaction capability) of the film thus providing for better print quality or label or laminate adhesion. However, more treatment is not always better. If the surface energy and surface polarity are raised too much, ink may run (wet out) too thin. Charge migration effects can also occur leading to a heterogeneous surface. And, since corona treatment is making the surface more hydrophilic, particularly for thin films, there can be a detrimental effect of increased MVTR. Thus, proper tuning of in-line corona treaters in packaging plants is necessary.

The effects of corona treatment in terms of printability are typically studied by advancing contact angle analysis with water – lower angle means higher surface energy created – or by full surface energy analysis using water and diiodomethane and Owens/Wendt theory[5]. The MVTR of films, on the other hand, is studied by using (most typically) a 15 mm diameter circle of film as the barrier between a desiccated environment and a 98% humid environment at 38°C, and monitoring the mass uptake of the desiccant (which equals the mass of moisture transferred through the film) over a 24 hour period.

Experiment

In this work we have studied 30 µm thick propylene films of initial surface energy = 29.73 mJ/m^2 and initial surface polarity = 1.94% which had been treated by point-to-plate corona discharge in air (temperature = 22°C and relative humidity = 50%), with an applied voltage of 4000V and a distance between electrodes of 3 mm. The variable among the various films studied was corona treatment time.

Contact angle experiments with water and diiodomethane were performed with a Krüss DSA100 using 2.0 µl drops. The volumes of the water drops placed were also contracted (by needle-in drop suction) to 1.0 µl following advancing contact angle measurement so that we could also measure receding contact angles for the water on the treated films. MVTR studies were performed on a IGAsorp Moisture Sorption Analyzer from Hiden Analytical.

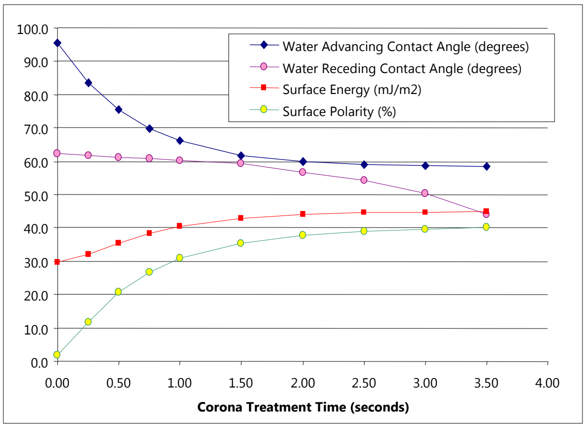
Results

Corona Treatment Time (seconds)	Water Advancing Contact Angle (degrees)	Diiodomethane Advancing Contact Angle (degrees)	Water Receding Contact Angle (degrees)
0.00	95.5	59.0	62.3
0.25	83.5	60.5	61.8
0.50	75.3	60.8	61.2
0.75	69.8	60.9	60.7
1.00	66.1	61.1	60.2
1.50	61.8	61.5	59.2
2.00	59.9	62.1	56.5
2.50	59.0	62.3	54.2
3.00	58.6	62.5	50.3
3.50	58.4	63.0	44.1

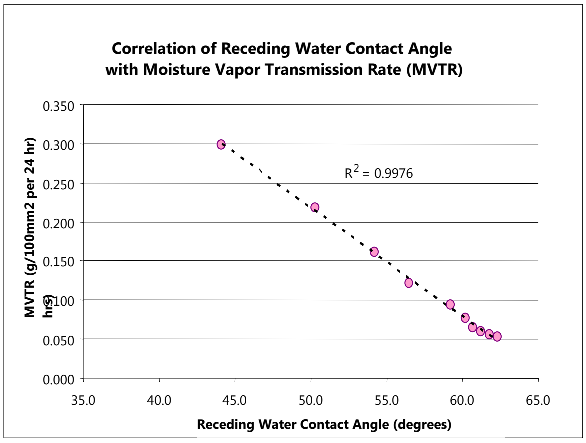
Table 1: Contact Angle Data

Corona Treatment Time (seconds)	Overall Surface Energy (mJ/m^2)	Surface Polarity (%)	MVTR (g/ 100mm^2) in 24 Hours
0.00	29.73	1.94	0.053
0.25	32.04	11.71	0.055
0.50	35.41	20.59	0.059
0.75	38.25	26.66	0.065
1.00	40.34	30.74	0.076
1.50	42.91	35.41	0.094
2.00	43.99	37.80	0.121
2.50	44.54	38.82	0.161
3.00	44.76	39.38	0.218
3.50	44.79	40.05	0.298

Table 2: Surface Energy and MVTR Data



Plot 1: Contact Angle and Surface Energy Data



Plot 2: Receding Contact Angle Correlation with MVTR

You will note in the graphical and tabular data above that, while the advancing water contact angle data, and correspondingly the overall surface energy and the surface polarity plateau after about 2.0 seconds of corona treatment, the receding angle with water continues to decay as more treatment is applied. There is also an excellent correlation found between receding water contact angle and MVTR.

Optimal treatment is likely at around 1.0 seconds in this case, at which point the surface energy is raised to above 40 mJ/m^2 and the surface polarity is raised to above 30 %, while MVTR has only risen by about 50 % from the value for the untreated film. Beyond this treatment level there are diminishing returns in terms of added surface energy increase and large increases in MVTR. Nearly a 500 % increase in MVTR is found after 3.5 seconds of treatment.

Summary

I wanted to share these data, and to note that while advancing water contact angles are clearly (and quite rightly) entrenched as the “check” of corona treatment level on the surface of films, it probably does make intuitive sense that lower dewetting (receding) angles (meaning that the surface has greater affinity to already adsorbed water) correlate with the ability of the hole film to pass water through it (with all other factors such as film thickness and porosity being equal). Perhaps, these findings will cause others to take a closer look at what information might be gained from receding contact angles on treated films. Receding contact angles are largely ignored in the majority of open literature which focuses almost exclusively on advancing contact angles.

Literature

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