

# Occurrence of Reverse Side Effects in Corona Treatment of Dispersion-coated Paperboard and its Influence on Grease Barrier Properties

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## ABSTRACT

*The uncoated side of dispersion-barrier-coated paperboards was exposed to positive and negative direct current corona treatments in order to confirm the occurrence of backside treatment and clarify its effects on the usability of the paperboard. The main component of the coating dispersions was hydroxypropylated potato starch and the effects of talc and styrene-butadiene latex additions on backside treatment were evaluated. Coatings with a high talc proportion showed excellent initial grease resistance, but corona-induced strikethroughs caused a drastic decrease in grease penetration time. The root-mean-square roughness measurements revealed moderate surface roughening at the backside, indicating thus backside treatment. The alterations in surface free energies and rapeseed oil contact angles confirmed the occurrence of backside treatment. The high polarization potential of latex played a key role in these observations. At the same time, the inertness of talc had a stabilizing effect but it did not prevent backside treatment completely. X-ray photoelectron spectroscopy results verified that backside treatment occurs also when the barrier-coated side of the substrate is treated with corona, indicating that a dispersion coating layer does not prevent this undesired phenomenon. Bearing in mind that expressing customized information or including personalized elements in food*

*food packages or disposable cups and plates is under great interest, it can be assumed the exposure of packaging materials to corona will become more common in the near future, and the need for optimizing bio-based packaging materials for such purposes is obvious.*

*Key words: Corona treatment, dispersion coating, oil and grease resistance, reverse side effects*

## 1.0 INTRODUCTION

The customer-oriented demand to be able to use digital printing methods together with conventional methods to provide customized information on packages is of great interest. [1, 2] Using both digital and conventional printing methods is called hybrid printing, and this may increase the number of corona treatments (CT) that the packaging material experiences during its manufacturing and finishing processes. Together with plasma treatment, CT is a widely used method for the pretreatment of either polymeric or fiber-based materials. During CT, the surface is affected by high energy ions such as O-, CO<sub>3</sub>, O<sub>3</sub>- [3] forming short-lived high-polarity species, which cause changes in surface energy that last weeks, and thus provide e.g. better heat-sealing properties for packaging materials [4]. A higher surface energy also improves the adhesion of polymer film to paperboard. [5] Increased surface energy also improves printability and print quality. For instance, improved ink adhesion and higher dot gain has been reported with flexography, the latter being related to the faster spreading of the water-based ink. [6] In the case of dispersion coatings, CT may increase the surface energy more than plasma treatment, but it does not oxidize the surface as effectively as plasma treatment. Furthermore, impaired barrier properties can be expected if CT is used instead of plasma treatment. [7]

In the field of print media, the effects of CT on liquid-substrate interactions are relatively well-known, but only a limited amount of information is available relating to the backside treatment on barrier-coated substrates. On the treated side, CT increases the

roughness of pigment-coated papers [8], but affects plastic film roughness less [9] or even makes the film smoother [10]. Roughness, together with the viscosity of the liquid and its surface tension, are significant factors behind liquid spreading. For instance, Khan and Nasef [11] found that surface roughening reduces the spreading of silicone oil and glycerol on coated papers. Typically fluids with a low contact angle spread rapidly, but it has also been suggested that a minor increase in roughness leads to a smaller contact angle, indicating better wetting. However, a large increase in roughness leads to a larger contact angle if the liquid is evaporating during the measurement. [12]

For rough substrates such as paper and paperboard, the Wenzel's roughness correction for a contact angle (Eq. 1) can be used if the substrate is hydrophilic (CA < 90°) [13]. The equation states that the relationship between the measured contact angle ( $\theta_m$ ) and the roughness-corrected angle ( $\theta_c$ ) in an ideal smooth surface may be written as:

$$\cos\theta_m = r \cos\theta_c \quad (1)$$

where  $r$  is the topographical correction factor. This factor can be calculated by using the  $S_{dr}$  roughness parameter, which is the ratio between the interfacial and projected areas and can be measured e.g. with an AFM:

$$r = 1 + (S_{dr}/100) \quad (2)$$

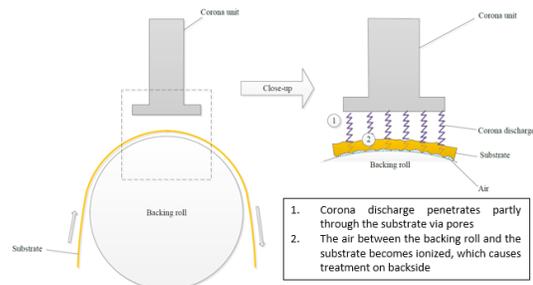
Corona-induced polarization depends on the chemical composition of the substrate. A large number of hydroxyl groups has been reported to decrease the polarization potential of inorganic fillers, but cellulose, which contains several –OH groups, is easily polarized and is thus the component that dominates in the polarization of paper [14]. Pykönen [8] suggests that the effect of corona treatment on the O/C ratio of calcium carbonate is very small compared to the effect on latex, which indicates that the polarization potential of synthetic polymers is substantially greater than that of inorganic materials. According to Sirviö et al. [15], coated papers also have a higher charge acceptance than uncoated grades and their charging potential has a material-dependent limiting value after which the potential does not increase further with increasing corona voltage.

Surface polarization increases with increasing corona intensity, but problems such as strike through [16], which occurs particularly when the substrate is light-weighted [17], limit the use of high treatment levels at a high corona voltage. Such an electrical breakdown occurs when the applied voltage of the corona treatment is sufficiently high to make electrically weak points in the substrate electrically conductive. Perforation of the substrate by such a discharge allows liquid or gas to penetrate through the material and thus compromises its barrier properties.

An increase in the corona discharge intensity may also increase the water vapor transmission rate through a dispersion-coated paperboard [7]. On the other hand, the oxygen and water vapor transmission rates through extrusion-coated boards with PE or PLA may be reduced by CT [18]. The coating layer thickness is a probable explanation of why some coatings are more sensitive to corona discharge [19] but the effect of the power level cannot be ignored.

A typical challenge in corona treatment is to achieve the desired treatment level without

decreasing the usability of the substrate due to e.g. reverse side treatment or perforation. Particularly with rough materials, the air trapped between the substrate and the supporting roller may become ionized either due to strikethroughs or substrate porosity, leading to corona treatment of the reverse side [16], as shown in Fig. 1. Because the amount of applied energy is constant, there will be a reduction in the treatment level on the top side while the reverse side becomes treated, and this may affect the surface roughness and surface energy. The reverse side treatment may also lead to blocking and picking [20, 21]. The blocking tendency of a dispersion coating can be reduced by introducing a mineral filler into the top coating [22]. Blocking and picking phenomena are well recognized in paper printing applications, but there is little literature dealing with the effects of reverse side corona treatment from the viewpoint of food packaging materials.



*Figure 1: The origin mechanism of backside treatment on rough, porous substrate.*

This work is a continuation for our earlier paper [23], in which the effect of corona treatment on the top surface was discussed in detail. The main objectives of the current study were to investigate the effects of CT on oil and grease resistance and to characterize the corona-induced effects on the barrier-coated side of a paperboard whose uncoated side is treated with direct current corona and. This is most typical case for

packaging materials, since the current legislation in many European countries does not accept direct contact between ink and the packed food, and for this mean the corona treatment is directed to the outer side of the packaging material. The occurrence of reverse side treatment in dispersion-barrier-coated substrates in the present study was confirmed with several measurement techniques including surface energy and rapeseed oil contact angle determinations, roughness measurements using atomic force microscopy, and chemical surface analysis with X-ray photoelectron spectroscopy. The particular emphasis was on grease resistance, but roughening of the barrier-coated reverse side is also discussed. It is obvious that the usability of corona-treated paperboard may suffer from several treatments regardless of whether the packaging material is used for packing greasy food or is used as a substrate for printing. The occurrence of reverse side treatment when the coated side of the paperboard is corona-treated is discussed and ways to reduce the reverse side treatment in such cases are presented.

## 2.0 MATERIALS AND METHODS

### 2.1 Materials

Commercial A4 SBS paperboard sheets (Stora Enso Oyj, Imatra) with a grammage of 350 g/m<sup>2</sup> were used as the base substrate. The following chemicals were used in the preparation of the coating dispersions: barrier-grade talc with a mean aspect ratio of 0.6 (Finntalc C15B, Mondo Minerals B. V., Finland), low-viscosity hydroxypropylated potato starch (Solcoat P55, Solam GmbH, Germany) (HPS), and styrene-butadiene latex (Styron HPW-184, Styron Europe GmbH). The particle size of the latex was 0.15 μm and its glass transition temperature was -9°C.

### 2.2 Coating process

The studied coatings consisted of blends of talc and starch. Talc was used to replace starch in the recipe at levels of 0, 10, and 30 pph. The SB-latex proportions were 0 and 10 pph, calculated on the total dry mass of HPS and talc. The dry solids content of all the coating dispersions was 16.5%. The smoother side of the paperboard sheets was coated twice with a bent steel blade in a pilot coater from DT Paper Sciences. The blade angle was adjusted between the sheets in order to obtain the total targeted coat weight of 8 g/m<sup>2</sup> (4 g/m<sup>2</sup>/layer). The machine speed was 10 m/min. Coated samples were dried with an infrared dryer with a heating power of 6 kW. The drying time was 9–12 seconds, depending on the proportion of pigment in the coating dispersion.

### 2.3 Corona treatment

The corona treatment was carried out with a modified Bristow Absorption Apparatus, whose structure and use were presented in an earlier paper [17]. In summary, a commercial Bristow wheel was equipped with a special corona charger. The sample was mounted on the wheel uncoated side upwards, the direct current corona charge was switched on and, while the wheel rotated, the uncoated side of the paperboard was subjected to a negative or positive corona discharge. The CT level, which depends on the corona voltage, corona current flowing through the sample and treatment time, was expressed as the corona current energy flow through the paper in W\*min/m<sup>2</sup>. The applied treatment levels were 0, -400, and +400 W\*min/m<sup>2</sup>.

### 2.4 Testing of paperboard samples

All the dispersion-coated samples were conditioned for at least 24 hours at 23°C and 50% relative humidity before the measurements. Coat weight was calculated by subtracting the grammage of uncoated paperboard from the grammage of the coated material, determined in accordance with ISO

536:2012. Coating coverage was evaluated visually from scanning electron microscopy (SEM) images. The images were taken with a JeioTech JEOLJSM-5800 SEM using a secondary SEI-detector at an acceleration voltage of 15 kV.

Chemical compositions of the topmost 10 nanometres were evaluated using XPS, X-ray photoelectron spectroscopy (Axis ULTRA from Kratos Analytical), with low power monochromated Al K $\alpha$  irradiation (at 100W), under neutralisation. Low resolution survey scans (80 eV pass energy, 1 eV step) were used to determine the elemental surface composition, and high resolution C 1s regions were recorded for more detailed chemical information, especially on carbon compounds observed. The area of analysis was 400  $\mu\text{m}$  x 800  $\mu\text{m}$  and each sample was analysed at 3-5 locations. According to the in-situ reference data (from a pure cellulose specimen measured with every experimental batch, [24]) the ultra-high vacuum conditions remained satisfactory during the experiments.

Apparent contact angles were determined with a Theta optical tensiometer from Biolin Scientific AB equipped with a 420 Hz camera (Basler A602F-2 with Navitar optics). The probe liquids were commercial rapeseed oil ( $\gamma=28.6$  mN/m, Bunge Finland Oy), deionised water ( $\gamma=72.8$  mN/m), ethylene glycol ( $\gamma=48.0$  mN/m, VWR S.A.S. International, France) and diiodomethane ( $\gamma=50.8$  mN/m, Alfa-Aesar GmbH & Co KG, Germany). The drop volumes were 3  $\mu\text{l}$  for water and ethylene glycol, 1  $\mu\text{l}$  for diiodomethane, and 5  $\mu\text{l}$  for rapeseed oil. The contact angle value was read 1 s after dispensing the drop. The contact angles of water, ethylene glycol and diiodomethane were used for surface free energy calculation, in which the average value of three independent contact angle measurements was used. The calculation was carried out using the acid-base approach, which allows a closer inspection of solid surfaces [25].

Root mean squared surface roughness (RMS) was measured with scanning probe microscope BRUKER Multimode 8 in PeakForce Tapping mode. Selected

coated samples were tested before and after the corona treatment at the uncoated sides, i.e. on the surface of the samples, which was opposite to the surface with coating layer. A stiff AFM probe (NCHV-A type, BRUKER, USA) with a spring constant of approx. 40 N/m, resonant frequency of approx. 337 kHz and tip radius of 10 nm was used. With help of Peakforce QNM (Quantitative Nanomechanics) procedure it became possible to track the surface with precisely known force of probe-sample interaction. Thus, the setpoint interaction force applied to the surface was kept at approx. 20 nN with a Peakforce frequency of 2 kHz and a Peakforce amplitude of 80 nm. Image resolution was 512x384 pixels, leading to rectangle size of each imaged pixels to be approx. 16x21 nm, since scan size was 8x8  $\mu\text{m}$ . Moreover, tip velocity of movements across the surface was 2.4  $\mu\text{m/s}$ , accounting the scan rate 0.15 Hz. Such combination of tracking speed, tracking force and lateral resolution was considered appropriate for roughness measurements in nanoscale for a considerably flat sample.

Oil and grease resistance (OGR) was determined using palm kernel oil dyed with Sudan red in accordance with ISO 16532-1 at 60°C. The average and standard deviation of three parallel measurements were reported. The volume of pipetted palm kernel oil was 200  $\mu\text{l}$  and only the coated sides were tested. The test piece was exceptionally approx. 2.5 x 5 cm in size.

### 3.0 RESULTS AND DISCUSSION

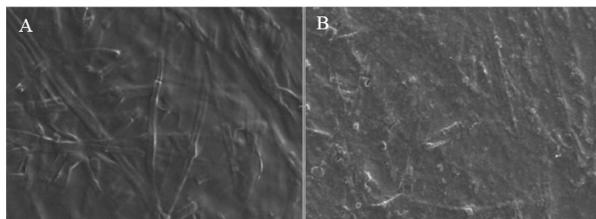
#### 3.1 Coat weight and surface topography of the corona-treated paperboard

The coat weights of the dispersion-coated paperboards were slightly below the target value of 8 g/m<sup>2</sup>, as shown in Table 1. In order to confirm that the coating coverage was adequate, SEM images were taken for the samples (Fig. 2). The root-mean-square (RMS) roughness was measured for coatings 1, 5, and 6. The initial roughness of the coatings was very similar in

all cases, but the results showed that both positive and negative corona treatment of the uncoated side induced nanoscale roughness on the coated side, regardless of coating composition, suggesting the occurrence of reverse side treatment. The starch coating (material 1) exhibited a moderate corona-induced roughening, especially with negative treatment, but the most severe roughening was found on a latex-containing sample (material 6), probably due to the high polarization potential of latex, since the initial roughness of the sample did not differ substantially from the other substrates. Only minor changes in the roughness were detected in material 5, which was latex-free, and whose talc content was 30 pph. These findings indicate that the inert nature of talc effectively reduces corona-induced roughness changes on the untreated reverse side, provided if latex is not present.

*Table 1: Coating composition, coat weight (g/m<sup>2</sup>) and RMS roughnesses (nm) of the dispersion coatings with corona treatment levels 0, +400, and -400 W\*min/m<sup>2</sup>. S denotes starch, T talc, and L latex.*

Material	Composition			Coat weight, (g/m <sup>2</sup> )	RMS roughness, (nm)		
	S	T	L		0	+400	-400
1	100	0	0	7.6	80	152	240
2	100	0	10	7.1	-	-	-
3	90	10	0	6.9	-	-	-
4	90	10	10	7.4	-	-	-
5	70	30	0	7.2	137	157	117
6	70	30	10	7.0	109	467	292



*Figure 2: SEM image (150x magnification) of A) material 1 and B) material 6. The scale bar is 200 μm.*

### 3.2 Effect of reverse side treatment on surface free energy of coated surface

The surface energy measurements revealed significant differences between the coatings (Table 2). The initial surface energy of the uncoated surface was lower than that of the coated samples, obviously due to the presence of hydrophobic sizing agents in the surface of the uncoated paperboard, but the presence of latex in the dispersion reduced the difference. The total surface energy of the experimental dispersion coatings always changed when the uncoated side was treated with corona, indicating a moderate reverse side treatment. In the case of materials 1-5, the total surface energy of the coating decreased after corona treatment. This exceptional finding might be caused by surfactants that migrated towards the coated surface or the increased roughness that brought out the talc particles. The XPS analysis (not shown here) supports both of these theories, since a minor increase in the atomic concentrations of nitrogen, silicon and magnesium on the surface was detected after CT from the material 5. In the case of material 6, corona treatment led to an increase in the surface energy, which was possibly a joint effect of the presence of a highly inert component (talc) at high concentration and a component with high polarization potential (latex). However, the sign of the corona treatment had very little impact on the total surface free energy of the coating.

Introducing latex into the coating resulted in a significant decrease in the base component of the surface free energy whereas the presence of talc without latex increased the initial base value. The results suggest that when the reverse side of paperboard is treated with corona, positive treatment has a greater influence on the base value if the sample does not contain latex. However, the result is the opposite if latex is present. Neither corona treatment nor the addition of latex or talc had a significant effect on the acid value that was low even initially: only a minor increase was observed in the case of corona-treated samples, albeit the percentage changes were substantial. Both talc and latex

inhibited the effect of corona treatment on the dispersive component, but the value of this component decreased moderately on the pure starch coating (material 1). A minor alteration in the acid-base polar component was also observed. This increase was probably due to a high initial concentration of oxygen molecules in the coating and the phenomenon was controllable by talc addition

Table 2: Surface energy components (mN/m) of the coated side of the paperboard after corona treatment of the uncoated side.

<b>Material 1</b>	<b>Dispersion</b>	<b>Acid-base</b>	<b>Acid</b>	<b>Base</b>	<b>Total, [mN/m]</b>
<i>Untreated</i>	40.0	9.4	0.9	24.6	49.4
<i>+400 W*min/m<sup>2</sup></i>	35.7	10.6	0.8	36.6	46.3
<i>-400 W*min/m<sup>2</sup></i>	32.2	14.2	1.6	31.4	46.4
<b>Material 2</b>					
<i>Untreated</i>	39.2	6.4	0.8	11.9	45.6
<i>+400 W*min/m<sup>2</sup></i>	39.6	4.0	1.7	2.4	43.6
<i>-400 W*min/m<sup>2</sup></i>	40.3	3.6	1.2	2.8	43.9
<b>Material 3</b>					
<i>Untreated</i>	39.5	8.6	0.4	46.5	48.1
<i>+400 W*min/m<sup>2</sup></i>	36.9	10.6	0.8	35.8	47.5
<i>-400 W*min/m<sup>2</sup></i>	38.3	4.8	1.1	5.4	43.1
<b>Material 4</b>					
<i>Untreated</i>	43.2	2.2	0.4	2.7	45.4
<i>+400 W*min/m<sup>2</sup></i>	41.3	0.6	0.4	0.1	41.9
<i>-400 W*min/m<sup>2</sup></i>	41.7	2.0	1.0	-1.0	43.7
<b>Material 5</b>					
<i>Untreated</i>	38.3	10.0	0.6	42.6	48.3
<i>+400 W*min/m<sup>2</sup></i>	38.7	7.8	0.4	42.5	46.5
<i>-400 W*min/m<sup>2</sup></i>	37.3	6.6	0.5	23.2	43.9
<b>Material 6</b>					
<i>Untreated</i>	38.3	1.2	0.1	2.1	39.5
<i>+400 W*min/m<sup>2</sup></i>	41.4	1.4	0.6	-0.9	42.8
<i>-400 W*min/m<sup>2</sup></i>	40.6	2.2	0.9	-1.4	42.8
<b>Reference (uncoated)</b>					
<i>Untreated</i>	37.0	1.2	0.4	-0.9	38.2

### 3.3 Effect of reverse side treatment on oil repellence and resistance

The contact angles of rapeseed oil on experimented coatings after treating the uncoated side with corona are presented in Fig. 3. The contact angle of an uncoated and untreated substrate was  $24.7 \pm 2.7^\circ$ , which is in the same range as the coated surfaces. The contact angles on coated samples were initially not significantly different, nor did the introduction of oleophilic talc decrease the oil contact angle. The presence of oleophobic latex in the untreated samples had a negligible influence on the contact angle. However, corona treatment of the uncoated side of the paperboard substantially increased the contact angles of oil on the coated side. Especially the pure starch coating became more oil repellent after treating the reverse side with corona, but the presence of latex led to a decrease in the magnitude of the effect. The results also indicate that the presence of latex boosts the contact angle, increasing the effect of negative corona treatment, whereas latex-free coatings seemed to be more sensitive to a positive treatment. The presence of talc in the latex-free coatings intensified the effect of positive corona treatment on the coated side, thus indicating a more severe reverse side treatment. Pykönen et al. [26] observed that CT decreased the contact angle of polar liquids, i.e. slightly polar vegetable oils, which does not agree with the present observations. However, in the earlier study, the contact angle was not measured on the untreated reverse side and the coatings consisted mainly of inorganic pigments. Thus, a direct comparison cannot be made between the present results and those published in earlier literature.

Figure 4 shows the contact angle of rapeseed oil on the coated side of material 6 after treating the uncoated side with corona as a function of time. The difference between the non-treated sample and the sample treated with a positive discharge is small, but negative voltage polarity increased particularly the initial contact angle. This indicates that there were no major differences in oil wetting and spreading behavior. However, treating the uncoated

side of the substrate with negative discharge led to a higher contact angle on coated side. Furthermore, the contact angle became stabilized after one second, suggesting that the negative voltage polarity increases the capability of coated paperboard to repel oil.

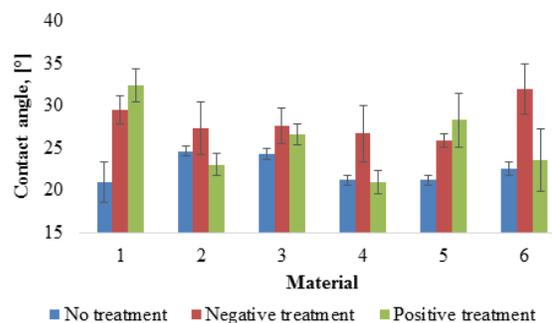


Figure 3: Rapeseed oil contact angles on the coated side after treating the uncoated side with corona.

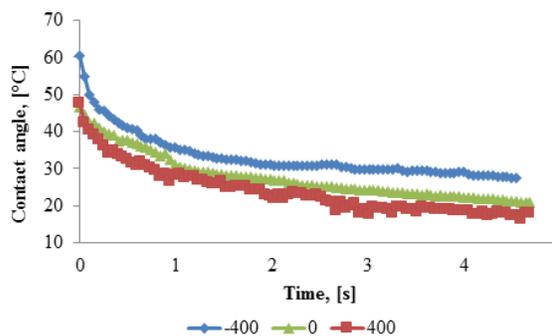


Figure 4: Rapeseed oil contact angle on the coated side of material 6 as a function of time after treating the uncoated side with corona.

The oil and grease resistance of dispersion-coated paperboards whose uncoated side was treated with corona is presented in Figures 5–6. For comparison, the grease resistance of uncoated reference board was 0-1 minutes. The latex-free coatings with talc proportions of 0 and 30 pph (Fig. 5) showed a faster oil penetration after corona treatment. However, the oil penetration time with 10 pph

talc was almost the same after positive and negative treatments. Among the untreated samples, 30 pph talc prolonged the oil penetration time significantly, which was obviously due to the increased tortuosity of the coating. The results of latex-free coatings were very similar to those of our earlier study [23], which showed that a drastic decrease (typically approx. 40–90%; positive voltage polarity slightly more detrimental if talc is present) in grease penetration time can be seen after treating the similar coating layers with corona.

The presence of latex changed the oil penetration time in the talc-free coating (Fig. 6). A minor increase in the penetration time was seen after CT compared to that of the latex-free test point. In addition, the presence of latex slightly increased the oil resistance of the coating with 10 pph talc, and corona treatment had very little impact on the oil penetration time, indicating that the coating remained unharmed. However, the observed differences in penetration times in the case of the coating with a 10 pph talc were so small that the result cannot be considered significant. Interestingly, the oil resistance of the coating with 30 pph talc decreased drastically. Visual evaluation of the test pieces revealed a large number of small grease stains on the reverse side of these samples (see Fig. 7), which indicates that the material was perforated by the corona. With the pure starch coating, however, the grease penetrated evenly through the tested area after the uncoated side of the sample had been treated with corona, suggesting that there was no strike through, but that corona treatment facilitated the penetration of grease through the sample. The results are comparable to the work of Ovaska et al. [23], in which the grease resistance of corona-treated coatings was reported with the exception of test point with 30 pph talc. In this earlier study, such a drastic decrease in penetration time was not seen, indicating that the talc in the coating is not able to resist the negative effect of corona if the talc is present on the opposite side of the substrate.

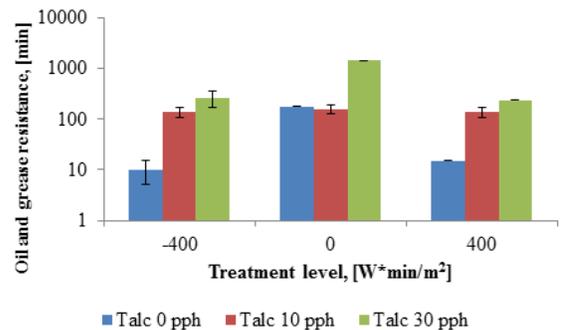


Figure 5: Oil and grease resistance (min) of latex-free materials with different talc proportions. In the experiment, the reagent was applied on coated side, whereas the uncoated side was treated with corona. Note logarithmic scale on y-axis.

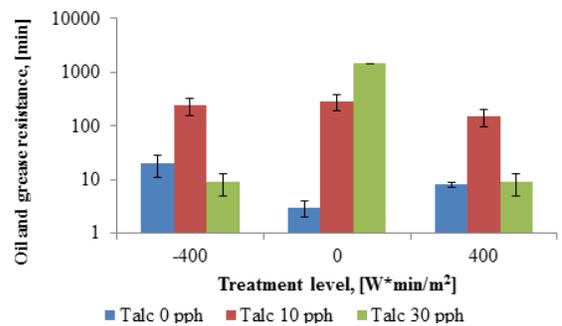


Figure 6: Oil and grease resistance (min) of latex-containing material with different talc proportions. In the experiment, the reagent was applied on coated side, whereas the uncoated side was treated with corona. Note logarithmic scale on y-axis.

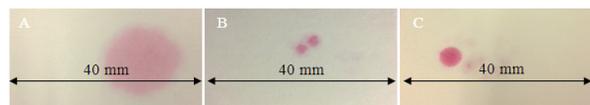


Figure 7: Photographs of reverse sides of samples demonstrating A) material with poor initial grease resistance, B) grease penetration as strike through in a material with good initial grease resistance, and C) perforated material with moderate initial grease resistance.

The finding that an initial grease resistance of >24 h was reduced to 9 min in the case of latex-containing sample with 30 pph talc is particularly troublesome, and a clear indication that such a material should not be treated with corona in the printing and finishing phases of end-product production. However, it is probable that the observation was not linked to reverse side treatment but to corona strike through, which can be controlled by adjusting the treatment level. Thus, a dispersion-barrier-coated paperboard should not be judged to be a poor substrate offhand. It is more probably a question of printing process optimization in order to preserve the grease-barrier properties of the barrier-coated side.

### 3.4 Effect of corona treatment of the coated side on the uncoated reverse side

To demonstrate that treating the coated side with corona also results in reverse side treatment, the chemical composition of the uncoated reverse side was determined using X-ray photoelectron spectroscopy (XPS). In Fig. 8, the oxygen/carbon ratio of dispersion-coated materials 5 and 6 is shown before and after corona treatment. The reverse side O/C ratio of both untreated samples was close to 0.4. Reverse side treatment had a more severe effect on the latex-free sample (material 5), which corresponds to the work of Pykönen [8], whose findings indicate that polymers have a higher polarization potential than inorganic minerals. Hence, it is probable that the presence of latex in the dispersion coating (material 6) reduced the reverse side effect, and that this in turn led to a lower O/C ratio than in the latex-free material. However, the voltage polarity was an important variable when latex was present. Negative corona treatment led to a minor increase in the O/C ratio of the uncoated reverse side, but a slightly greater increase was observed after positive treatment. It thus seems that the use of a negative corona discharge and the addition of a small amount

of synthetic polymer to a starch/pigment dispersion is a reasonable practice to minimize undesired reverse side effect and maximize the treatment on the coated side.

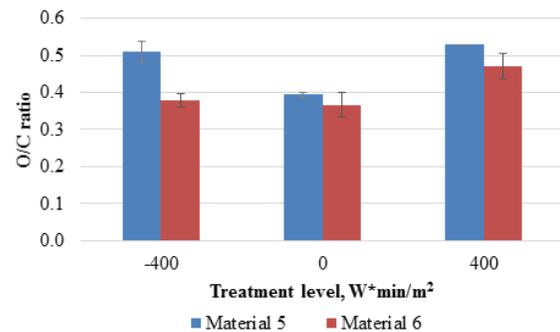


Figure 8: Oxygen-carbon ratio of uncoated side after treating the dispersion-coated side with corona.

## 4.0 CONCLUSIONS

Reverse side effects clearly occur on dispersion-barrier-coated substrates regardless of whether the uncoated side or the coated side of the paperboard is treated with corona. Both positive and negative direct current coronas lead to alterations in e.g. surface roughness, surface free energy, and oil repellence on the reverse side. However, oil and grease resistance is evidently affected more by strike through effects, as a result of poorly optimized corona treatment, and too high corona voltage. A drastic decrease in oil penetration time was seen in materials whose initial grease resistance was excellent, decreasing the usability of dispersion-coated paperboard for food packaging applications that require long-term grease resistance. It was also shown that reverse side treatment occurs on the uncoated side of paperboard if the coated side of the substrate is treated with corona. To ensure adequate end-use performance, applying negative corona treatment and introducing latex into the barrier coating are thus effective ways of reducing the reverse side effect. Further efforts

could concentrate on the optimization of corona treatment for the uncoated side of dispersion-barrier-coated substrates in order to minimize the detrimental effect on the coated surface and the occurrence of strike through, resulting in a functional concept for the special requirements of hybrid printing and package personalization. This study also leaves a topic for determining the effects of plasma treatment on the reverse side of filled HPS-based coatings and their barrier properties after the treatment.

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