Occurrence and Causes of Uncovered Areas in Water-Borne Flexographic Print on PE-extrusion-coated Packaging Papers

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ABSTRACT

Uncovered area (UCA) in water-born flexogarphic prints of three commercially printed PE-extrusion-coated packaging papers has been characterised in incident light using light microscopy. Besides repeated UCA;s, caused by impurities on the printing form, three categories of UCA;s were identified: 1) Rings with a white spot in the middle, 2) rings without a white spots in the middle and 3) spots without ring. These categories of UCA;s were analysed using profilometric and microscopic methods with the aim to trace paper related causes for the UCA;s. The result of the analysis showed that rings with a white spot in the middle and rings without a white spots in the middle were caused by deep and shallow depressions respectively in the PE-surface, and that spots without a ring were caused by some kind of imperfection in the PE-surface, probably poor wetting, or elevations. The depressions in the PE-surface coincided with pin-holes or less dense structure in the base paper. The occurrence of UCA;s caused by depressions was somewhat higher than the occurrence of UCA caused by poor wetting or elevations. An attempt to correlate the occurrence of UCA;s with the surface roughness parameters, PPS, R_a and variance within the wavelength range 0.01-1mm was also done. This attempt showed that the occurrence of UCA;s, caused by depressions did not rate the material in the same way as these parameters. Increased thickness of the PE reduced the occurrence of UCA;s caused by depressions.

Keywords: Printability, water-borne flexography, polyethylene-extrusion coated paper, corona treatment, uncovered area, UCA

INTRODUCTION

Polyethylene (PE) is widely used in various applications due to its abundant supply, low cost, good process-ability, low energy demand for processing, and its resistance to chemicals and harsh environments. It is used directly or in the form of laminates with paper, aluminium foil, paper, etc. [1]. However, its surfaces are chemically inert and it is non-porous and hydrophobic, and it needs to be made more hydrophilic in nature, to improve printability, paintability, or adhesion to adhesives or inorganic substances [1-2]. Satisfactory printing quality is most problematic with water-borne inks, included flexographic inks on non-porous, low surface energy substrates such as polymeric films. Proper wetting and adhesion, in particular, are necessary [3].

One of the most commonly used processes in industry to modify the surface properties of PE and improve the printing properties of PE-extrusion-coated papers is corona treatment (CT). In corona treatment the PE-surface is subjected for a high-energy electrical discharge as it passes through a capacitor or treating unit [4-5] When such electrical discharge, as CT is applied to a PE-surface, the surface energy, the polarity and adhesive character of the surface increase; the stronger the treatment, the higher surface energy and the polarity [5-6].

A common and at the same time serious problem in flexographic printing of PE-extrusion-coated papers in with water-borne inks is uncovered areas (UCA;s). As the name suggests, UCA;s are areas which are supposed to be covered by ink but which are not. The cause for UCA;s can be that the paper does not accept the ink or that the ink from an already printed area is flaked-off. The area of UCA;s is generally found within the range 0.04-0.9 mm^2 [7-8].

UCA; s in water-borne flexographic prints on PE-coated papers are generally associated with poor wettabilty [9-12]. The relationship between the occurance of UCA;s and the wettabilty is however difficult to establish because the relevant wettabitity is the local wettability right where the UCA is and not the average wettability the surface. The local wettability is difficult to measure. Depressions in the printing surface is another possible cause for UCA;s. and for not PE-coated papers fair correlations between the occurrence of UCA;s and the surface roughness are reported [13-16]. The influence of the surface roughness on the occurrence of UCA;s has been studied on a more detailed level by Barros et al. [17]. These researchers characterised the surface profile on 14 commercial liner boards using Opti-Topo-technique [18]. The acquired surface profile was frequency analysed. The best relationship between the occurrence of UCA;s and the variance in surface profile was found within the wavelength ranges 0.125-0.25 mm, 0.25-0.50 mm and 0.5-1.0 mm. These wavelength ranges corresponds to typical equivalent diameters of the UCA:s.

In this work we have examined UCA;s on three PE-extrusion-coated packaging papers, which were printed in flexography with water-born ink, using microscopic methods including cross-sections. The objective was characterise the UCA;s with respect to origin and to identify paper related causes for the UCA;s.

MATERIAL AND METHODS

PE-extrusion-coated papers

The papers studied in this work consisted of three PE-coated packaging papers which were extrusion coated and corona treated at Mondi Packaging AB, Örebro, Sweden and printed at Mondi Packaging AB, Sunne, Sweden. The printing took place three weeks after the extrusion coating and at the time for the printing, the surface energies of the papers were 42±2 dyne/cm, measured using the dyne test ink (Vetaphone, Denmark).

The papers were characterised by measuring their grammage, thickness and surface roughness using SCAN-Test methods (SCAN-P 6:75, SCAN-P 7:96, SCAN-P 76:95). The thickness of the PE-layer was given by the supplier. The paper properties data are given in *Table 1*.

Table 1. Paper data.

Type of base paper	**A** Kraft paper	**B** Kraft paper	**C** Copying paper
Grammage of base paper (g/m^2)	80	50	80
PE-layer	Transparent	White-pigmented (Titan oxide)	Transparent
Grammage of PE-layer (g/m^2)	10	20	15
Thickness (µm) mean±s.d.	96.1±5.5	67.1±6.2	107.8±4.0
PPS $_{(0.5MPa)}$ (µm) mean±s.d.	2.5±0.1	3.2±0.1	2.5±0.0

Printing
The printing was performed on an industrial scale using a W&H Astraflex 8 Colour CI press and using water-borne inks (supplied by Sun Chemical). For paper A the ink used was red and for papers B and C it was blue. The papers A and B were also varnished using Aquaboard 767-01767 supplied by Sun Chemical. The varnishing took place in line with the printing. The printing conditions are given in *Table 2*. The line load between the printing plate and impression cylinder was controlled and expressed as the distance (µm) from kiss print to the printing position.

Table 2. Printing conditions

PE-extrusion-coated papers ⇒		**A**	**B**	**C**
Printing Plate	Thickness (mm)	1.14	1.14	1.14
	Hardness (°Shore A)	69	69	69
Anilox	Volume (ml/m^2)	8	12	8
	Screen ruling (line/cm)	140	100	140
Printing	Line load from zero kiss print level (µm)	40	58	30
	Printing speed (m/min)	220	190	220

It should be pointed out that the printing was not performed with the objective to study UCA. The papers used in this study were taken from the production, in a random fashion.

Characterisation and examination of Uncovered Covered Areas (UCA;s)
The UCA;s were characterised and examined using white light interference microscopy and light microscopy in incident light and scanning electron microscopy (SEM) on cross-sections. In an attempt to link the occurrence of UCA;s to surface depressions of a given length scale the surface profile was also measured and frequency analysed.

The white light interference microscope used was of the brand Wyko NT 3300 Surface Profiler (Veeco Metrology Group, Tuscon, USA) equipped with 20 x 0.5 magnifications and high-speed camera. Two microscopes were used for examination in incident light. The one was of the brand Zeiss Axioscope 2 MOT microscope (Carl Zeiss, Jena, Germany), and it was equipped with a blue MF-09 filter set and a digital camera (ORCA-ER, Hamatusi Photonics K.K. Japan). The other microscope was the brand Zeiss Axioplan (Carl Zeiss, Jena, Germany), and it was used in differential interference contrast (DIC) mode, and using a Nikon DXM 1200 digital camera for capturing images.

The cross-sections for the SEM were prepared from strips, 8 x 20 mm, which were cut out from the papers and mounted in a sample holder. The paper sample in the sample holder were then evacuated and embedded in epoxy resin (EPOFIX Struers, Denmark). The embeddings were cured at room temperature for 48 hours prior to grinding and polishing. Grinding and polishing was performed using a ROTOPOL device (Struers, denmark) in four steps: 1) 30 s using a 500# SiC paper, 2) 3 min using 6 µm polycrystalline diamond spray on a Largo disc, 3) 3 min using 3 µm diamond spray an a DAC cloth and finally 4) 2 min on a NAP cloth using 1 µm diamond spray (the diamond sprays used were of the polycrystalline type). Prior to examination in the SEM the imbedded cross sections were coated with Au/Pd in an Agar sputtercoater for 30 s.

The surface roughness was measured using a profilometer instrument (Perthometer C5D from Perthen, Germany). In this instrument the surface is scanned with a diamond stylus (FRW-750, radius 2 µm), the height and length positions of which are registered digitally. Here an area 60x60 mm^2 was scanned in 20 lines separated 3 mm from each other. The variance about the mean value was computed and frequency analysed. Here the surface profile is reported as the variance within the wavelength band 0.125-0.75 mm which is reported to be the wavelength band relevant for predicting UCA;s [17, 19].

RESULTS AND DISCUSSION

Characterisation

Figure 1 shows an image captured in incident light in the light microscope of a printed area of paper A. The white spots in the prints are what is generally called uncovered area (UCA) and it is these areas which have been characterised and examined in this work. As is evident in Figure 1 the occurrence of UCA;s is very frequent. It is also evident that the UCA;s vary in size. Some are small and some are large. (Note that the image shown in Figure 1 is not larger than 1.3 mm^2). Images of printed areas of papers B and C and exhibited the same appearance.

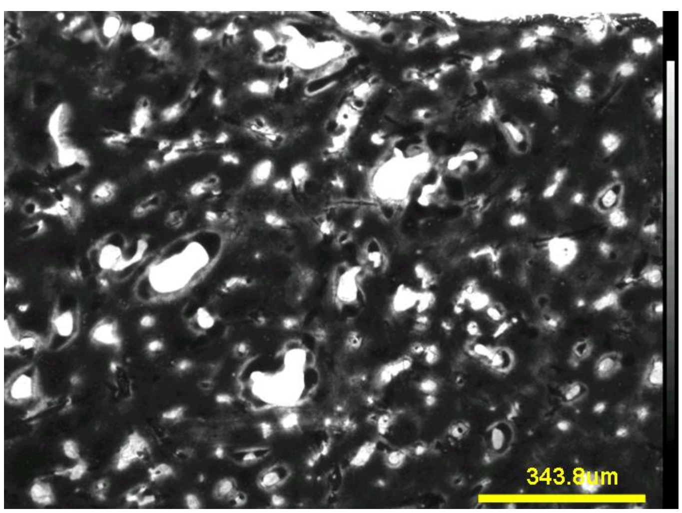

Figure 1. Printed area on paper A exhibiting UCA;s. The image was captured in incident using light microscopy.

A great number (>100) of UCA;s on each paper were inspected and characterised in incident light using light microscopy. Four categories of UCA;s were identified: 1) Repeated UCA;s, 2) rings without a white spots in the middle, 3) rings with a white spot in the middle and 4) spots without ring. Category 1, repeated UCA;s, can be assumed to be caused by impurities on the printing form because they appear in the same position on a great number of sheets printed in a sequence. The occurrence of repeated UCA;s were few in comparison with the occurrence of UCA; of categories 2, 3 and 4. Figure 2 shows a microscopy image of a repeated UCA on paper A and paper B. A typical value of the equivalent diameter of repeated UCA;s was found within the range 200-500µm. Repeated UCA;s will not be discussed further in this work.

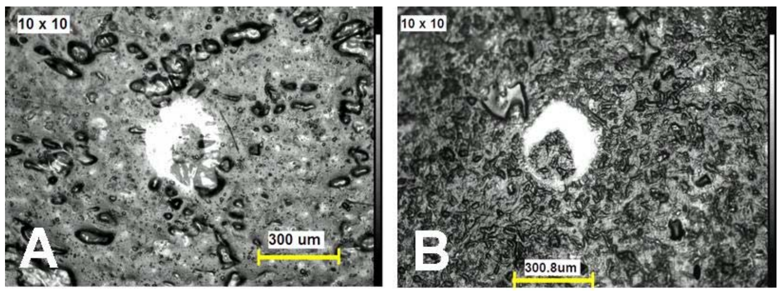

Figure 2. Example of the appearance of repeated UCA;s. The image was captured in incident using light microscopy.

A typical equivalent diameter of UCA;s of category 2, 3 and 4 was found within the range 50-500 µm. A comparison between the equivalent diameters of repeated UCA;s category 1 and UCA;s category 2 and 3 shows that the latter can be smaller or of the same size.

A closer inspection of UCA;s of category 2 and 3, by focusing the microscopy on the centre of the ring, showed that the ring then came out of focus. This showed that the centre of the ring was on a lower level than the ring itself. Moreover this way of inspecting UCA;s also suggested that the centres of the rings without white spots in the centre (category 2) were on a higher level than the centres of the rings with a white spot (category 3). Since the centre of the rings were on a lower level than the rings themselves a reasonable interpretation of this is that the rings show the edges of depressions in the printed surface not coved by ink The difference in level of the centre between rings with (category 2) and without (category 3) white spot in the middle also shows that shallow depressions (category 2) are filled with ink whereas deeper depressions (category 3) are not filled with ink. The same type of inspection of the spots without ring (category 4) revealed that these spots were in the plane.

In order to able to observe the edge of a depression as a white ring, both sides of the ring must be covered by ink. That this condition is fulfilled for rings without white spots in the centre (category 2) is trivial. For rings surrounding depressions without any ink in the bottom (category 3) the ink on the inner side of the ring must come from ink on the walls of the depression. A possible explanation for the existence of ink on the walls is that ink was printed over the openings which initially sealed these. During the drying of the ink (consolidation) this ink film was broken up and transported, with the help of surface tension forces, downwards in the depression. In the shallow depressions, the ink was transported all the way down to the bottom, in the deeper depressions it stayed on the walls. Schematic illustrations of UCA;s of category 2, 3 and 4 are shown in Figure 3.

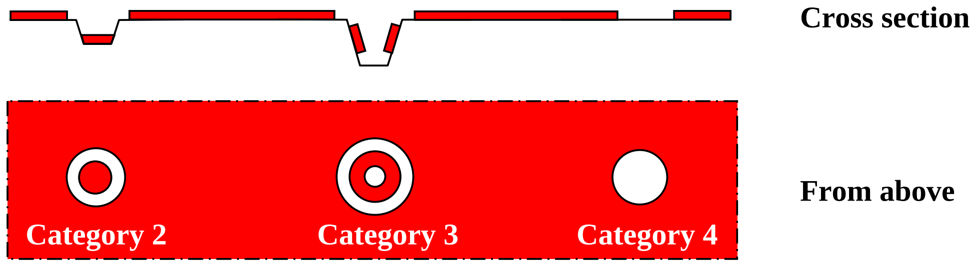

Figure 3. Schematic illustrations of UCA;s of category 2, 3 and 4..

Analysis

A random selection of UCA;s of categories 2, 3 and 4 was analysed using white light interference microscopy, light microscopy in incident light and scanning electron microscopy (SEM) on cross-sections. The aim with the analysis was to supplement the characterisation with information which could help to trace the causes for the different categories of UCA;s.

Figure 4 shows a topographical map (a) and a height profile curve (b) for three adjacent UCA;s of category 3 (ring with white spot) on paper C acquired using white light interference microscopy. As is evident in the Figure 4 the depth of the depressions (marked by profile line) were 5 µm (two depressions) and 10 µm (one depression) respectively.

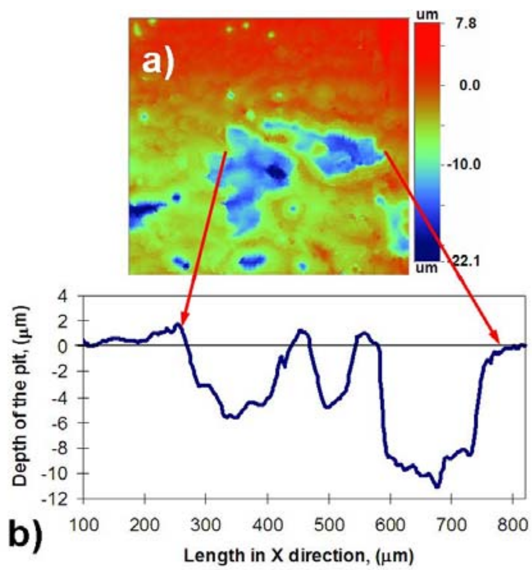

Figure 4. Topography map (a) and height profile curve (b) for three adjacent UCA;s of category 3 on paper C acquired using white light interference microscopy.

Cross-sections of the same category of UCA;s on paper A, Figure 5, exhibited the same depths of the depressions. The images shown in Figure 5 were captured using differential interference contrast microscopy for the viewing. This allows the ink-layer to be identified. Figure 5 shows that there is ink on the walls of the depressions and that there is no ink in the bottom or on the edges. This ink distribution is agreement with characterisation of UCA;s already discussed and shown in Figure 3. In Figure 5 it is also evident that the depressions in the PE-layer coincide with depressions or a less dense structure in the base paper beneath the UCA.

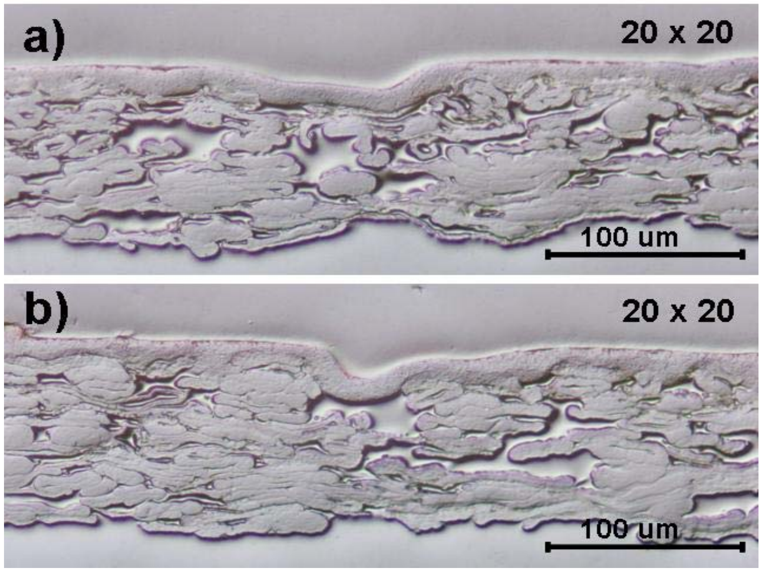

Figure 5. Cross sections through UCA;s of category 3 on paper A.

The structure of the base paper beneath a depression was also examined using light microscopy in incident light and with a blue filter (MF-09) in the light path for the reflected light, which absorbs the reflection from red prints. Using this filter the base paper structure beneath the print and the PE-layer can be visualised. However, only paper A was printed in red, and therefore the examination was restricted to that paper. Figure 6 shows images of an UCA of category 3 (ring with white spot) captured with and without the filter. In Figure 6 it is evident that the fibre structure of the base paper beneath the PE-layer exhibits a normal appearance around the UCA and loose and open structure right under it.

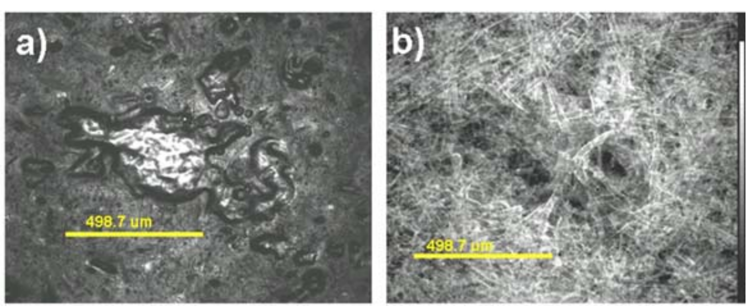

Figure 6. Images of an UCA of category 3 on paper A captured in incident light using light microscopy. (a) without MF-90 filter and (b) with MF-90 filter in the light path.

A representative image of an UCA of category 4 (in the plane), captured in incident using light microscopy, is shown in Figure 7. These UCA;s are most likely due to local areas or spots in the PE surface with low surface energy. Corona treatment is known to give non-uniform surface energy of the surface treated [20] and this could be the cause for this type of UCA. Treatment with plasma is reported to yield a more uniform treatment [20].

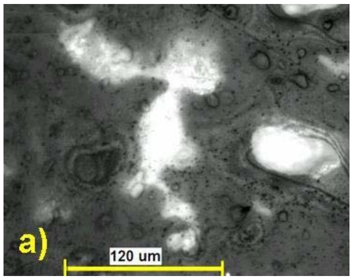

Figure 7. Typical appearance of an UCA of category 4 (in plane). The UCA on image originates from paper A.

The examination of the UCA;s of category 4, which were characterised as being on a planar part of the surface, showed that some of these also due were to elevations in the PE-layer. Figure 8 shows a height map (a) and a height profile curve for such an UCA on paper C acquired using white light interference microscopy. Figure 8 shows that the height of the elevation was 4.5 µm and that the walls of the elevation were steep.

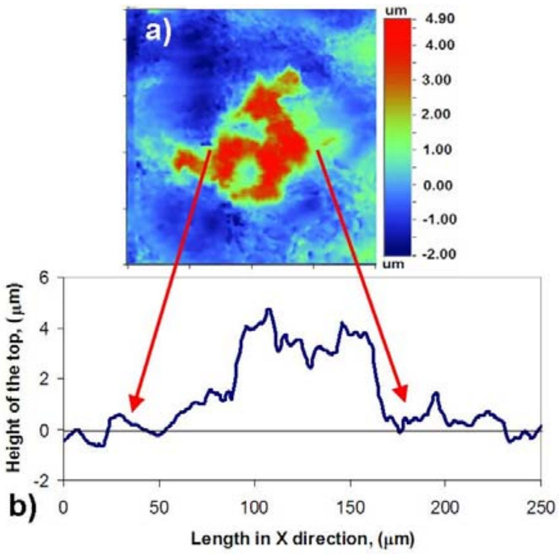

Figure 8. Topography map (a) and height profile curve (b) of an UCA on an elevated area on paper B acquired using white light interference microscopy.

Figure 9 shows images of cross sections of UCA;s of category 4 on elevated areas on paper B and C. The images were captures in incident light using differential interference contrast microscopy. The cross-sections show that there is no ink on the elevated areas and that these areas can be significantly higher than 4.5 µm.

There is a distinct difference in appearance between the elevated areas causing UCA;s on paper B and C. On paper C they are longer and rounded whereas they on paper B are shorter and spiky. Moreover the elevated area on paper C seems to have been lifted from the base paper which suggests poor adhesion between the PE-layer and the base paper right beneath the elevation. For the spiky elevations on paper C picking and filament formation on the chilling roll might be a cause. (The white PE-layer on paper C is due to that the PE is filled with titanium dioxide). For both papers there are no signs that the structure of the base paper beneath the elevation is divergent in any respect.

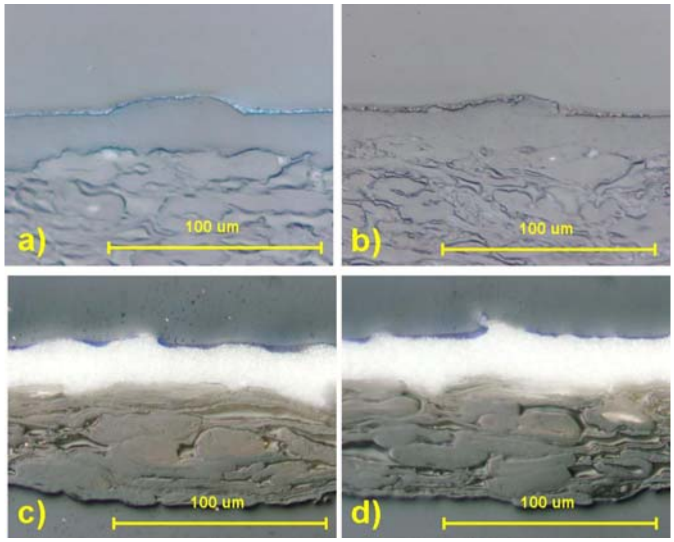

Figure 9. Cross sections through UCA;s of category 4 on elevated areas on paper C (a) and (b) and on paper B (c) and (d).

Figure 10 shows three examples of UCA;s on elevated areas, and as is seen in the figure their appearance differ. It is difficult to suggest a cause for this type of UCA, based on their appearance, but one can be that ink has been forced away from the peaks of the elevation to the lower surrounding areas. However, poor wetting can not be excluded.

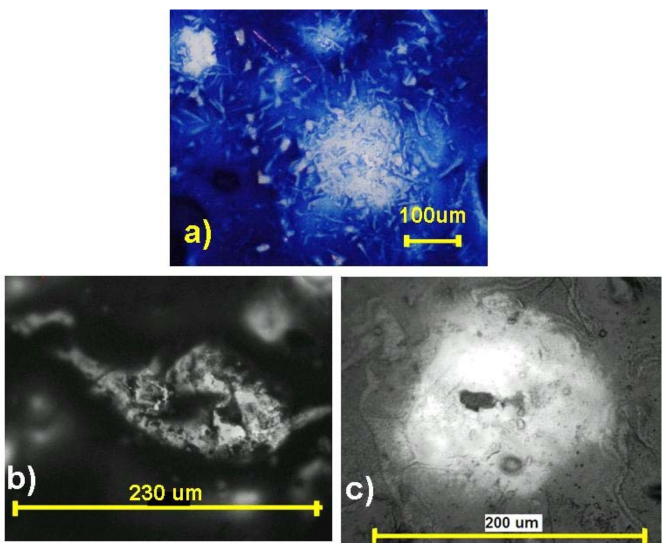

Figure 10. Images of UCA;s of category 4 on elevated areas on paper B (a) and paper C and on paper C (c) and (d).

Quantification of UCA;s

The occurrence of UCA;s per unit area, separated on the categories 2, 3 and 4, where estimated by examining and counting the number of UCA;s in 6 randomly chosen areas each of 5x5 mm^2 in incident light using light microscopy. The result is summarised in Figure 11.

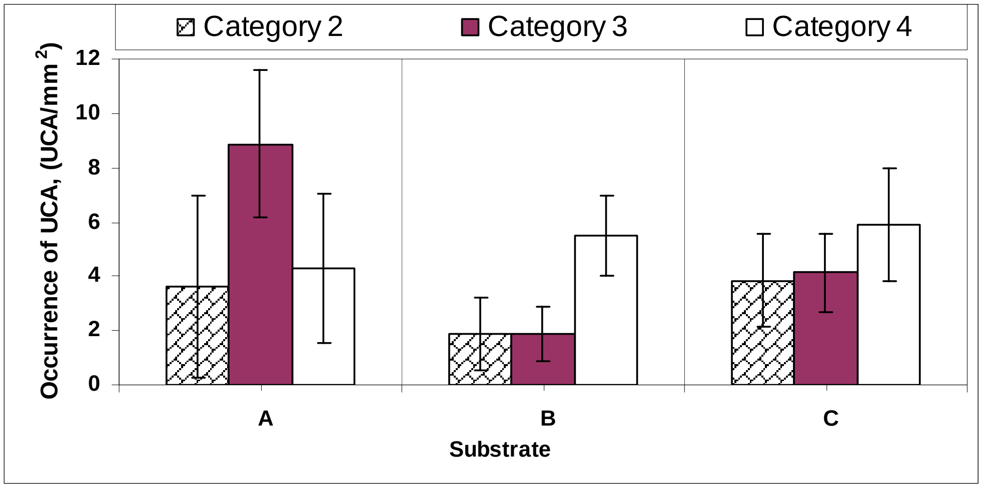

Figure 11. Occurrence of UCA;s per mm^2 of categories 2, 3 and 4 on papers A, B and C.

From Figure 11, a rating of the papers with respect to UCA;s of categories 2, 3 and 4 can be produced according to:

- Category 2 (shallow depressions) Paper A = Paper C > Paper B
- Category 3 (deep depressions) Paper A > Paper C > Paper B
- Category 4 (in the plane) Paper A = Paper B = Paper C

Figure 11 also shows that only UCA;s of category 2 and 3, i.e. UCA;s caused by depressions in the PE-surface were influence by the type of paper. Not UCA;s of category 4 (in the plane). The occurrence of UCA;s of this category was the same for all the papers. Since the most probable reason for UCA;s of category 4 is non-uniform corona treatment (surface energy) or picking on the chilling roll (elevations) and since the three paper were extrusion coated in the same machine under the conditions it is reasonable to believe that these UCA;s were caused by shortcomings in the extrusion process.

For the UCA;s caused by depressions, the cross sections, cf. Figure 5 and the and the examination of them in incident light in the light microscope using the MF-09 filter, cf. Figure 6, showed that these depressions in turn were caused by pin-holes, loose structure or similar in the base paper.

Figure 12 shows cross sections of the three papers examined in this study. Two observations can readily be made. 1) The base paper for paper A and paper B have the most non-uniform bulk structure and 2) The thickness of the PE-layers was the lowest on paper A, somewhat higher on paper C and highest on paper B. This rating is identical with the grammage of the PE-layer given by the supplier, cf. Table 1. Considering the non-uniformity in bulk structure of the base paper and the low thickness of the PE-layer it is natural that paper A exhibited the highest occurrence of UCA;s caused by depressions in the printing surface.

Moreover the observations shows that the rating in UCA;s did not follow the rating in non-uniformity in pore structure of the base papers, but the rating in thickness of the PE-layer. This shows that the imperfections in the base paper, which may cause depression in the final PE-coated surface and UCA:s, can be suppressed provided the PE-coating is thick enough.

However, it should be pointed out that paper B, which exhibited the lowest occurrence of UCA;s, was printed with slightly higher anilox volume and printing load than paper A and C. This suggest improved ink coverage which may have lead fewer UCA;s.

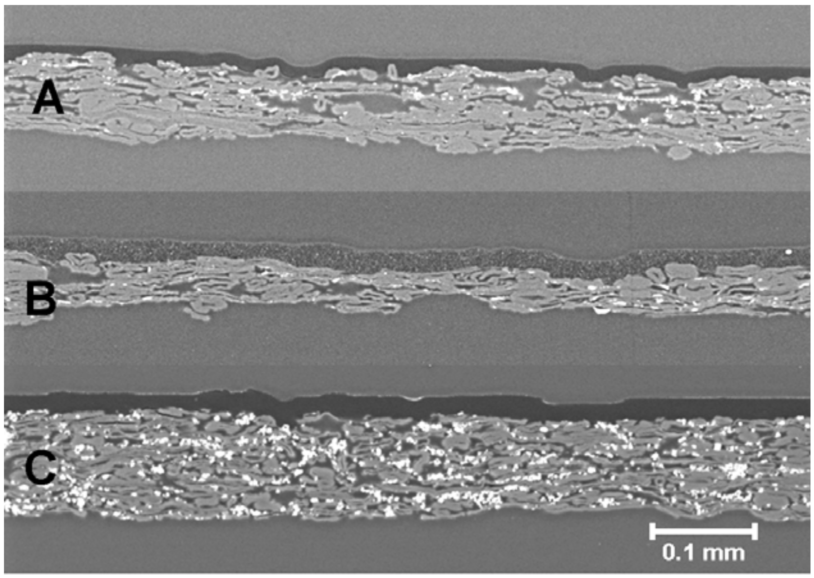

Figure 12. Cross sections of paper A, B and C.

Relationship with surface topography characteristics

The surface roughness of the paper has been suggested to be a cause for UCA;s [13-16]. However, most of the UCA;s are found within a certain size range and that must be considered when studying the relationship between surface roughness and the occurrence of UCA;s. The STFI-Packforsk measuring system for UCA:s identify and estimate UCA;s with an equivalent diameter with in the range 0.042-1 mm (using image resolution of 600 dpi). This range coincide within the range of the equivalent diameters of the UCA;s examined in this work cf. paragraph Characterisation on page 5. Barros et al. [17] report a good relationship between the amplitude of the surface profile of the paper within the wavelength range 0.125-1.0 mm, and the occurrence of UCA;s, for flexographic prints on liner board.

Figure 13 shows a comparison between the variance in surface profile within the same wavelength range and the occurrence of UCA;s caused by depressions for the prints examined in this study. As is evident the amplitude and the occurrence of UCA;s are not rated in the same manner. The lack of agreement may be due to that the papers were printed, as already mentioned, under slightly different conditions. Provided this is true it shows that the printing conditions had a greater impact on the occurrence of UCA;s than the surface roughness. Neither the R_a-value of the surface profile nor the Parker Print Surface (PPS) roughness correlated with the occurrence of UCA;s.

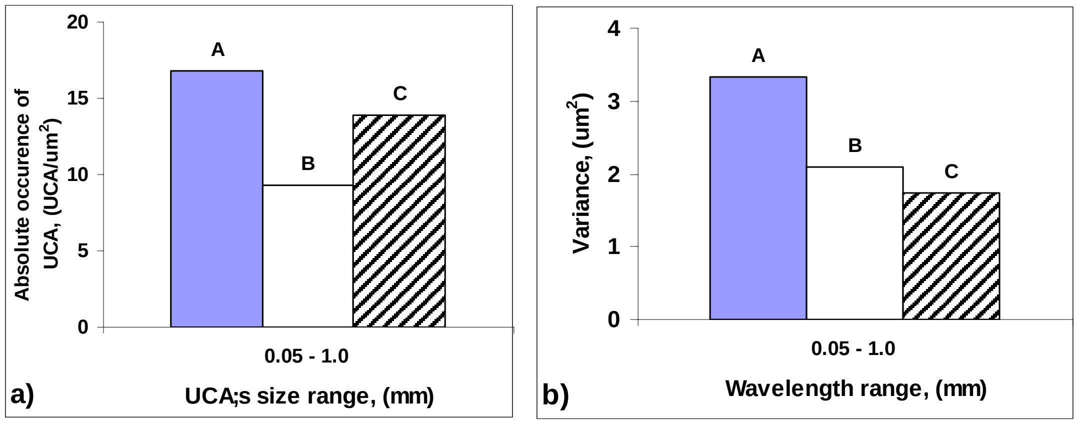

Figure 13. Occurrence of UCA;s caused by depressions (a) and variance in surface roughness (b) within the wavelength range 0.05-1.0 mm for the examined papers.

CONCLUSIONS

This work has shown that the UCA;s in the examined papers were located both in the plane and in depressions in the printing surface. Some UCA;s also coincided with elevations in the printing surface. We believe that the UCA;s in the plane are caused by poor wetting due to non-uniform corona treatment [20].

The occurrence of UCA;s in the plane was the same for all the papers studied. Since all papers were extrusion coated and printed in the same way it is reasonable to believe that this category of UCA was caused by imperfections in these processes.

The occurrence of UCA;s caused by depressions in the PE-surface decreased with the thickness of the PE-coating. This shows that thick PE-coatings cover imperfections, such as pin-holes etc, in the base paper surface better than a thin coating. The coverage of the base paper is therefore crucial. Cross sections through UCA;s on depressions showed that this depression in turn was caused by a depression or less dense structure in the base paper.

The occurrence of UCA;s caused by depressions was marginally greater the occurrence of UCA;s caused by poor wetting. However, the difference in occurrence was so small that it can not be stated that one category is more frequent than the other.

The occurrence of UCA:s did not correlate with any of the measured surface roughness parameters.

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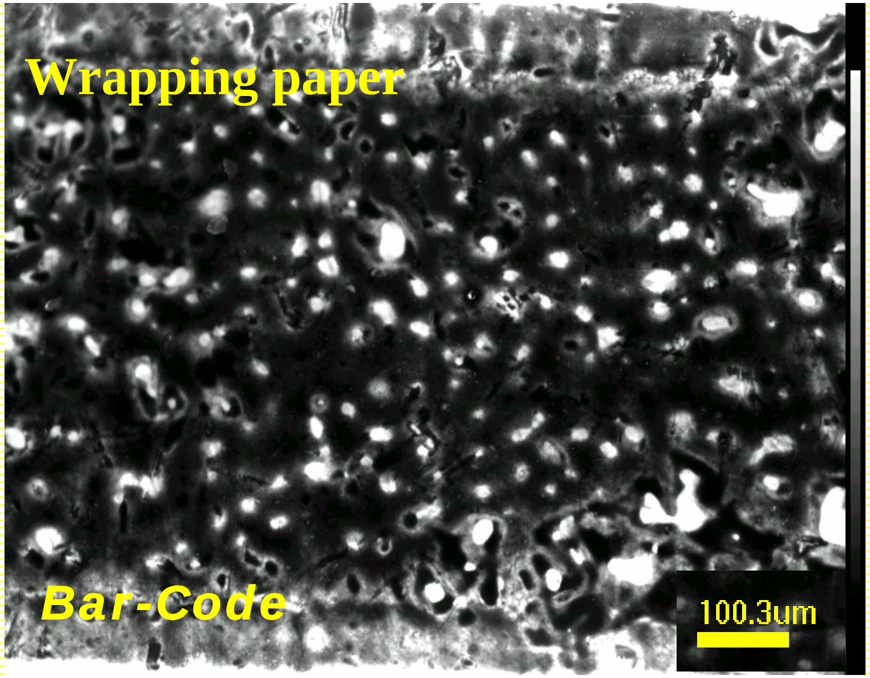
Occurrence and causes of uncovered areas in water-borne flexographic print on PE-extrusion-coated packaging papers

Background

- The emergence of uncovered areas (UCA;s) in water-borne flexographic print of PE-coated packaging material



- The want of fundamental information

Paper data

Type of base paper	**A** Kraft paper	**B** Kraft paper	**C** Copying paper
Grammage of base paper (g/m^2)	80	50	80
PE-layer	Transparent	White-pigmented (Titan oxide)	Transparent
Grammage of PE-layer (g/m^2)	10	20	15
Thickness (µm) mean±s.d.	96.1±5.5	67.1±6.2	107.8±4.0
PPS $_{(0.5MPa)}$ (µm) mean±s.d.	2.5±0.1	3.2±0.1	2.5±0.0

Printing conditions

W&H Astraflex 8 Colour CI press
(at Mondi Packaging AB, Sunne, Sweden)

PE-extrusion-coated papers ⇒		**A**	**B**	**C**
Printing Plate	Thickness (mm)	1.14	1.14	1.14
	Hardness (°Shore A)	69	69	69
Anilox	Volume (ml/m^2)	8	12	8
	Screen ruling (line/cm)	140	100	140
Printing	Line load from zero kiss print level (µm)	40	58	30
	Printing speed (m/min)	220	190	220

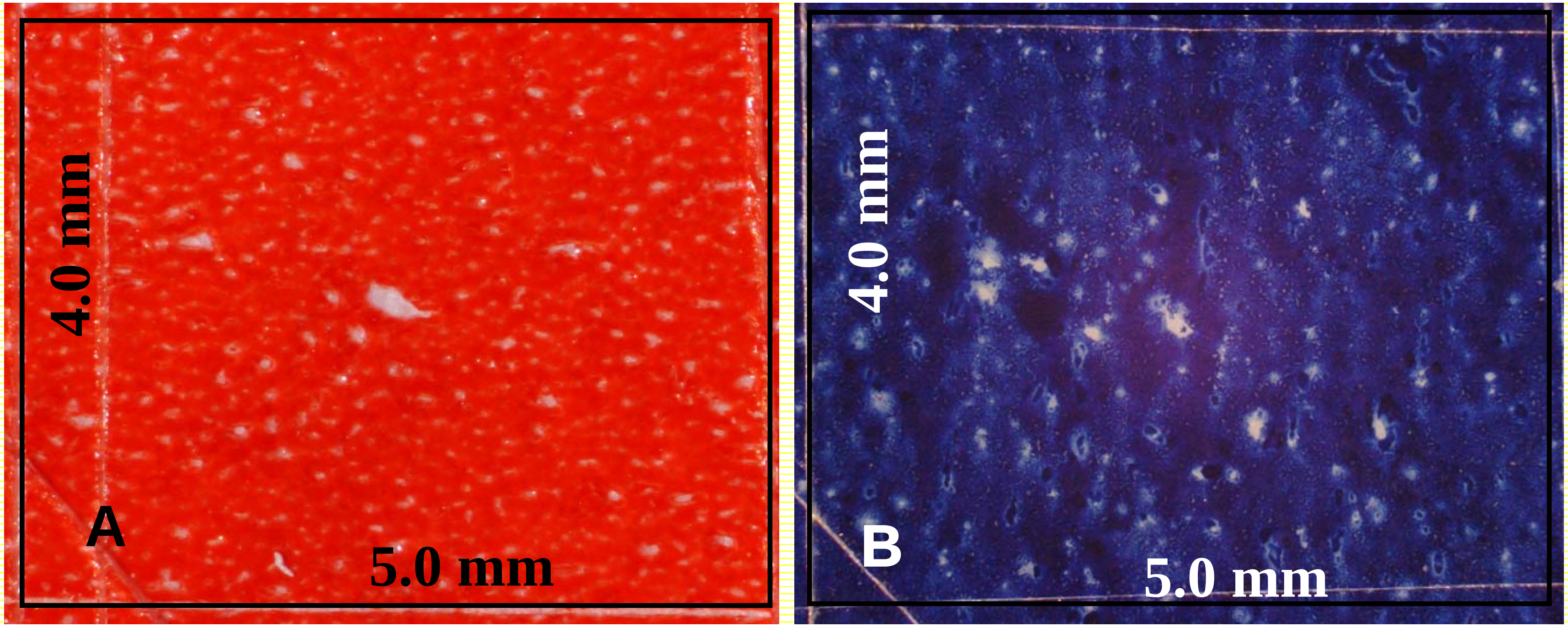
Characterisation

- The white light interference microscope Wyko NT 3300 Surface Profiler (Veeco Metrology Group, Tuscon, USA) equipped with 20 x 0.5 magnifications and high-speed camera.

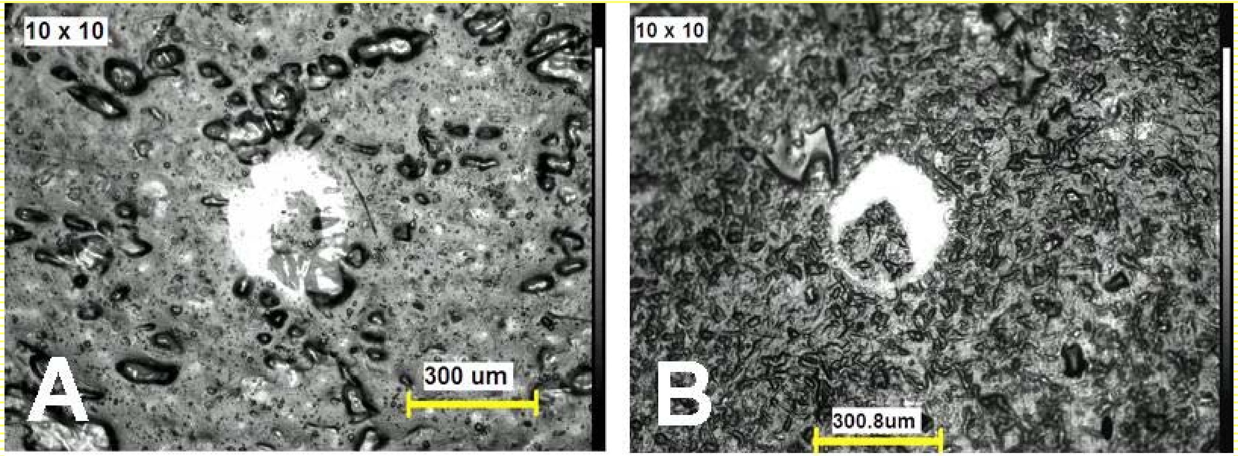
- Microscopes in incident light equiped wit a digital camera:
  - Zeiss Axioscope 2 MOT (Carl Zeiss, Jena, Germany), equipped with a blue MF-09 filter set.
  - Zeiss Axioplan (Carl Zeiss, Jena, Germany), used in differential interference contrast (DIC) mode.

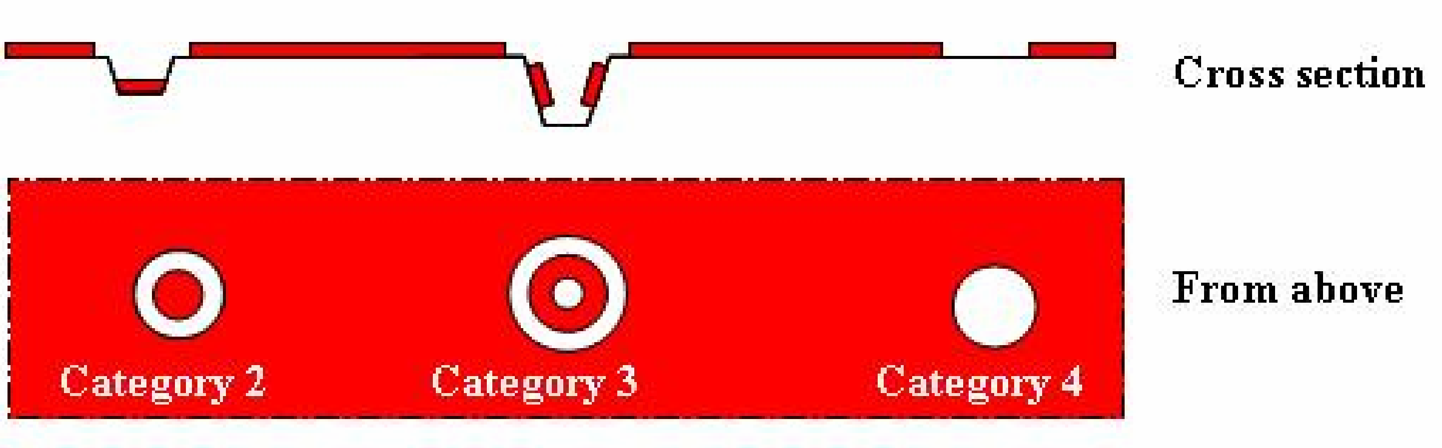
- Scanning electron microscopy (SEM), LEO 435 VP (LEO, UK) operating at 25 kV and using Back Scattering Electron (BSE) contrast.

Results

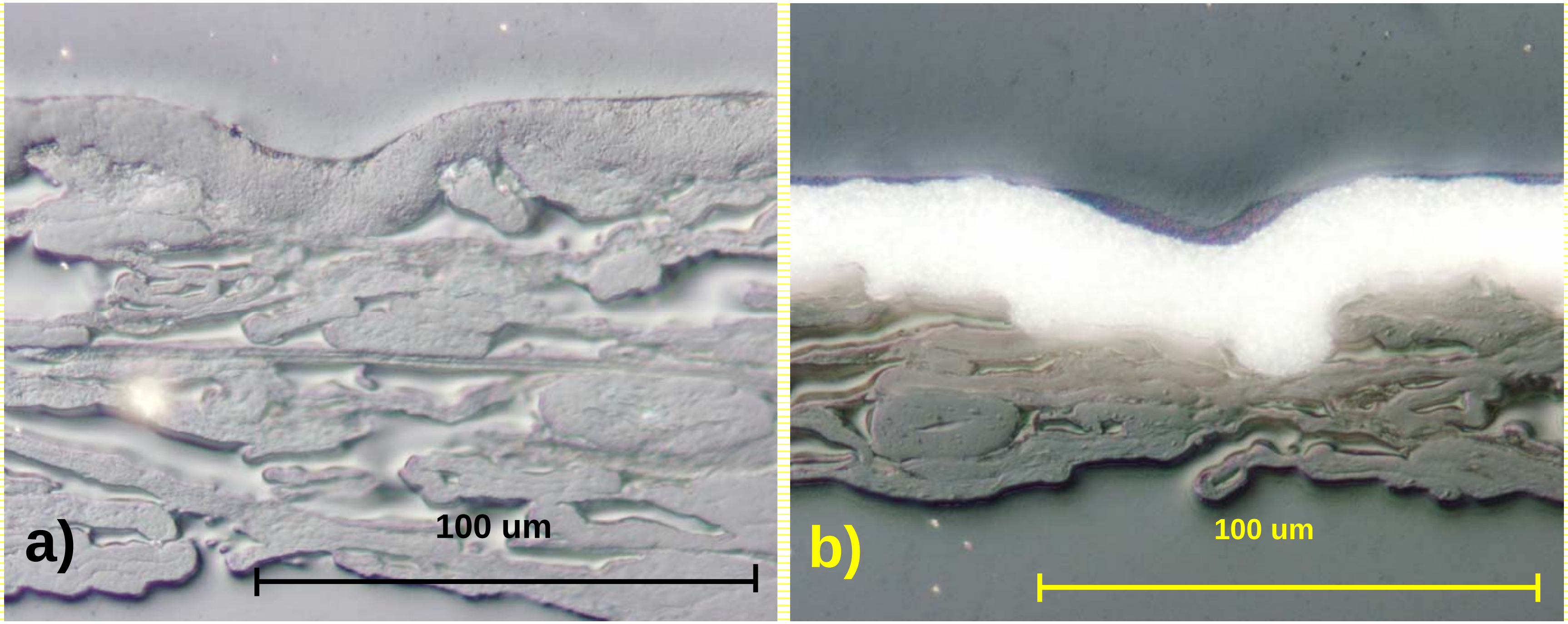


Results

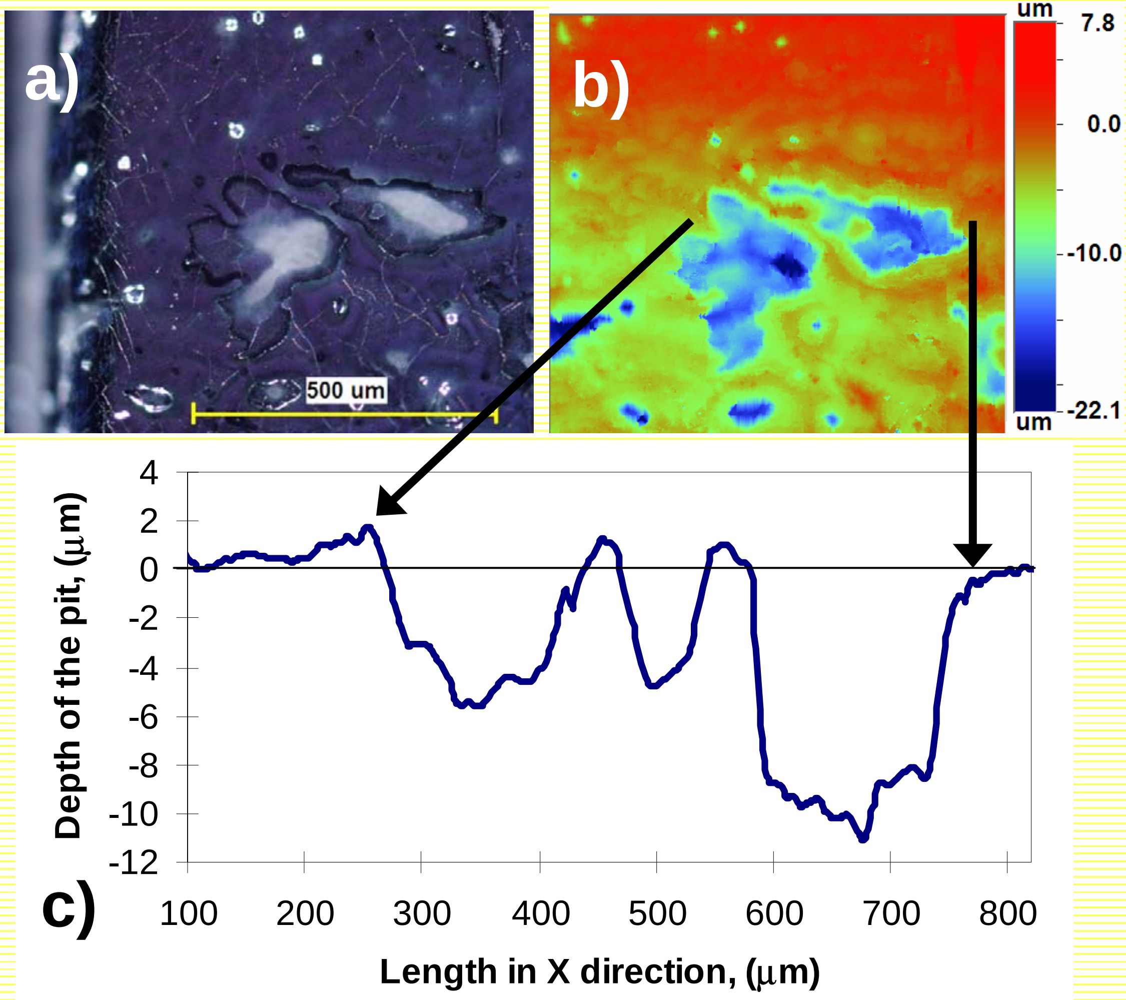

10 x 10
300 um
A
10 x 10
B
300.8um


Cross section
From above
Category 2
Category 3
Category 4

Results

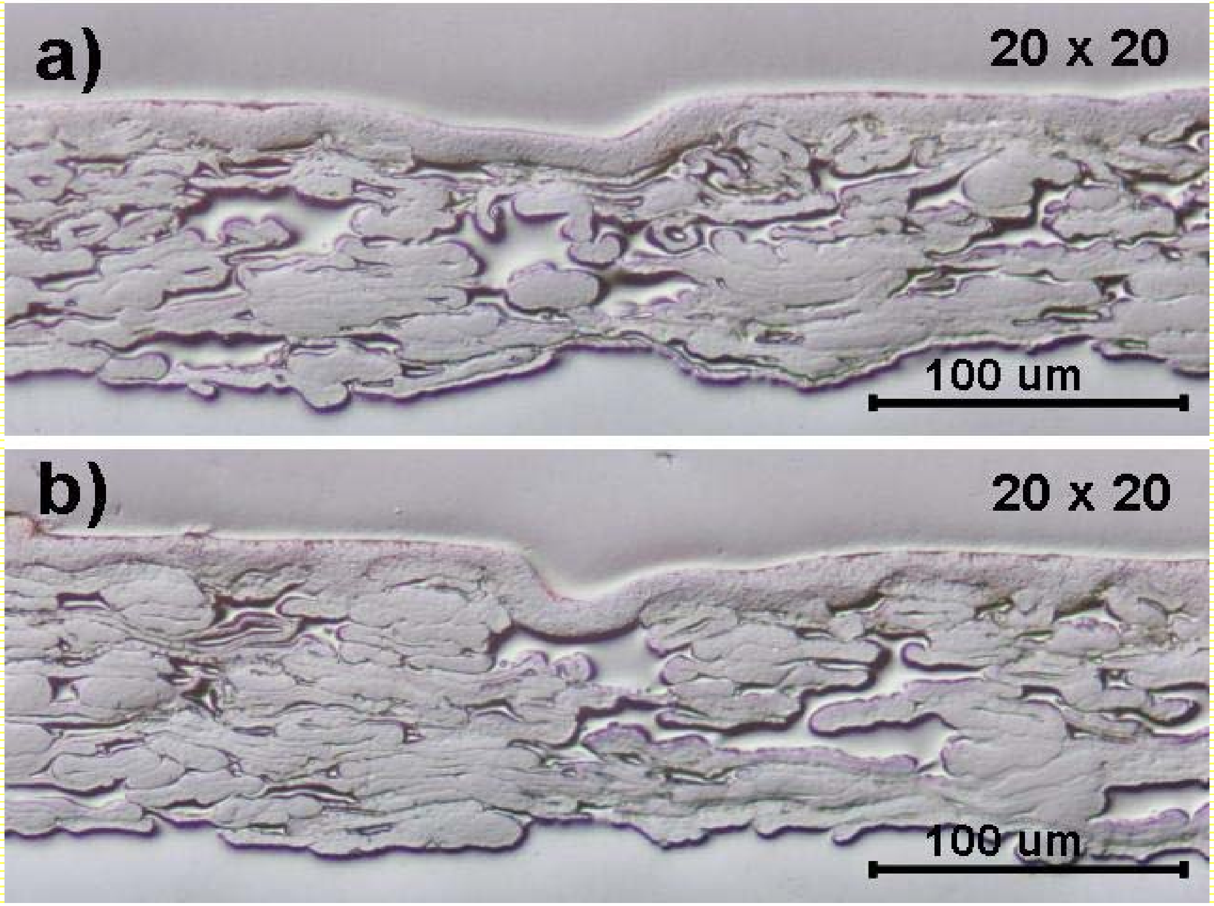


Results

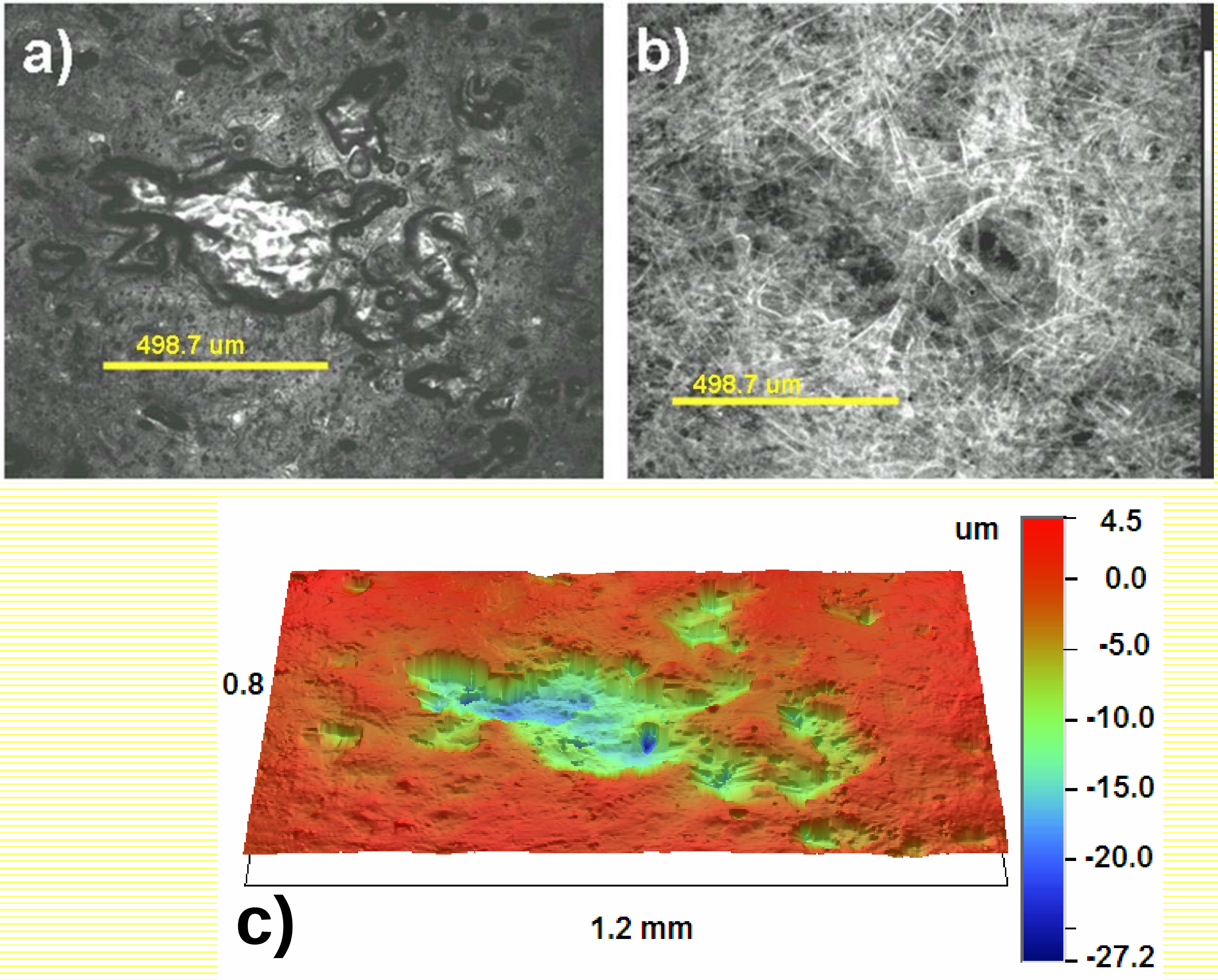


a)
500 um
b)
um
7.8
0.0
-10.0
-22.1
um
c)
Depth of the pit, (µm)
4
2
0
-2
-4
-6
-8
-10
-12
100
200
300
400
500
600
700
800
Length in X direction, (µm)

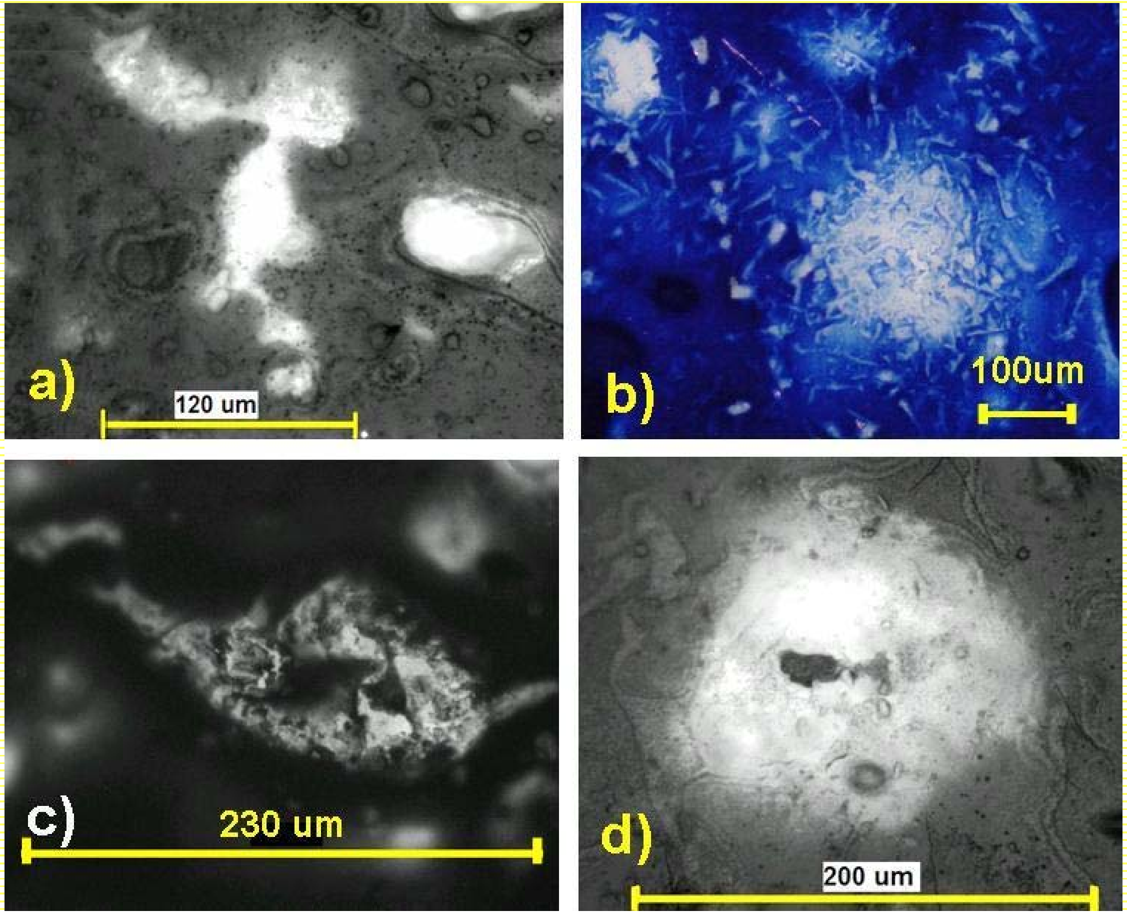
Results



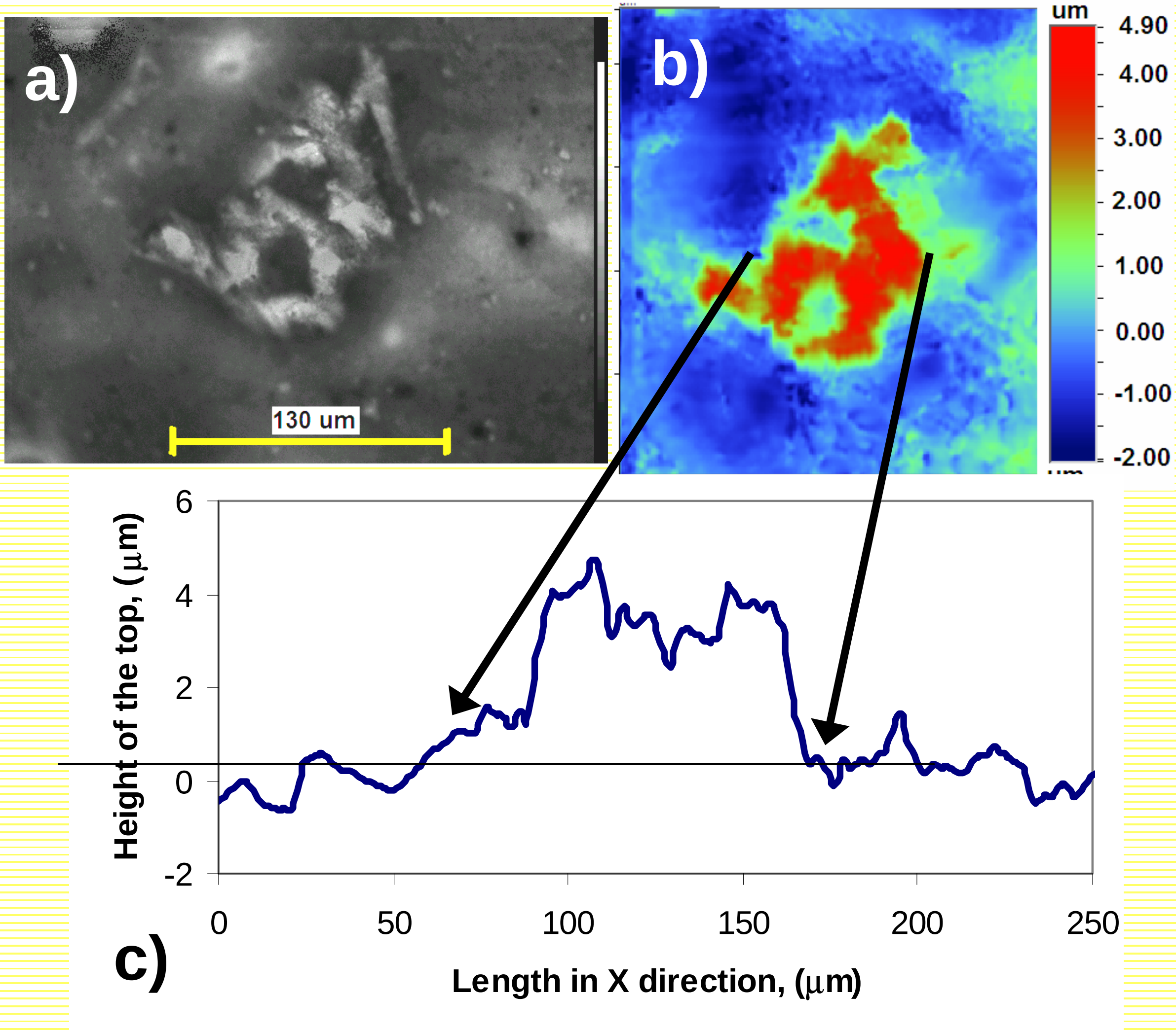
Results



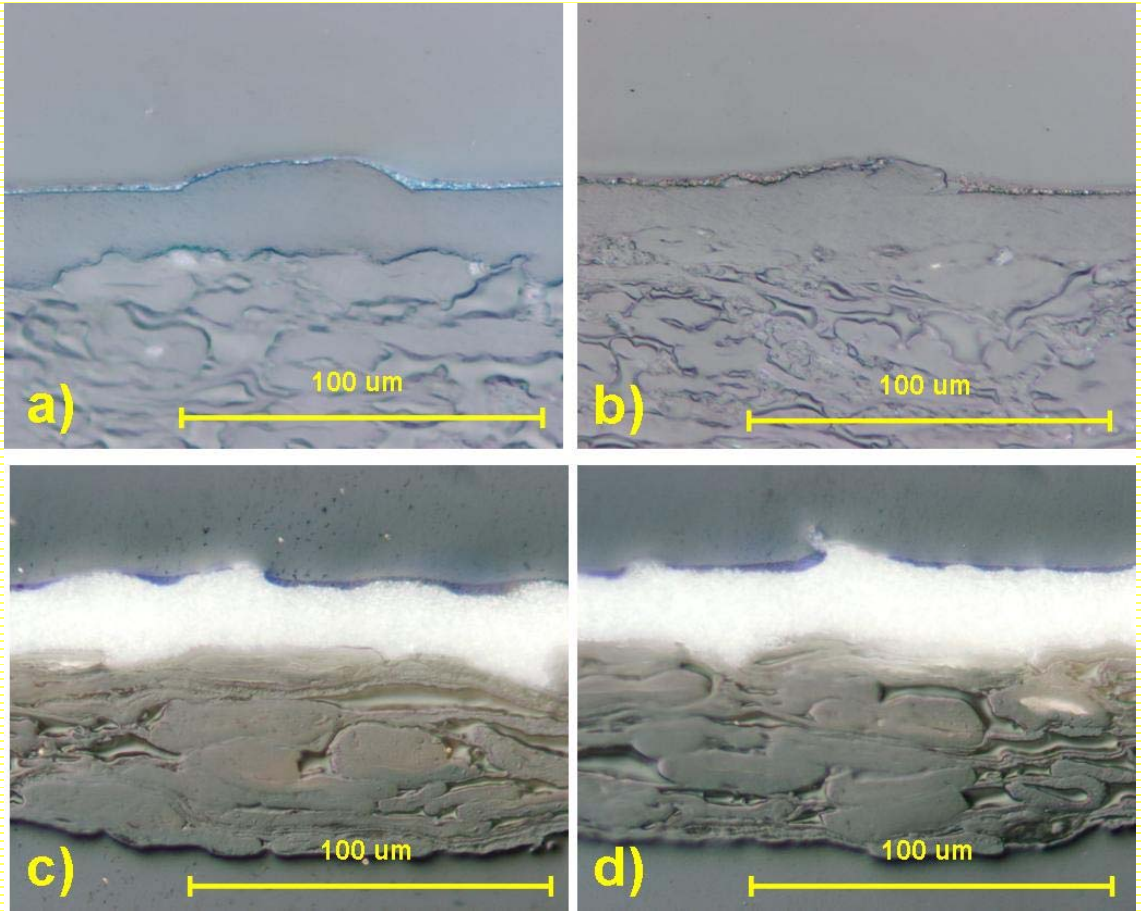
Results



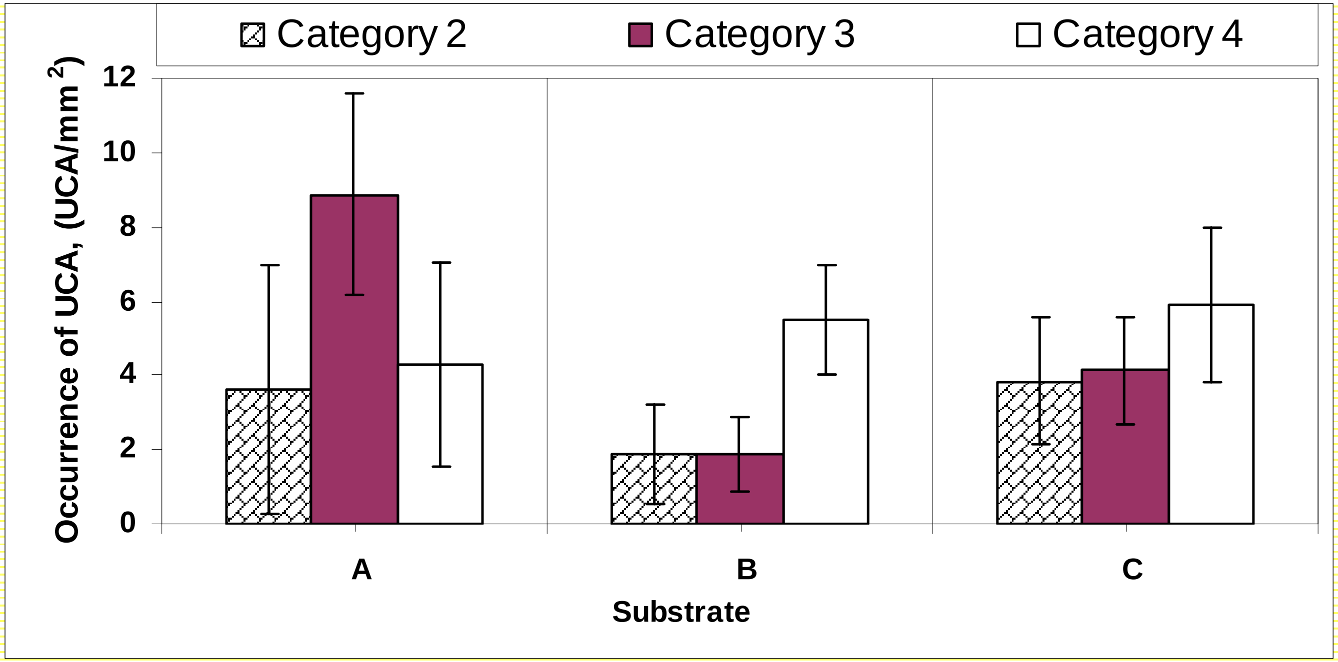
Results


a)
130 um
b)
um
4.90
4.00
3.00
2.00
1.00
0.00
-1.00
-2.00
c)
Height of the top, (µm)
6
4
2
0
-2
0
50
100
150
200
250
Length in X direction, (µm)

Results

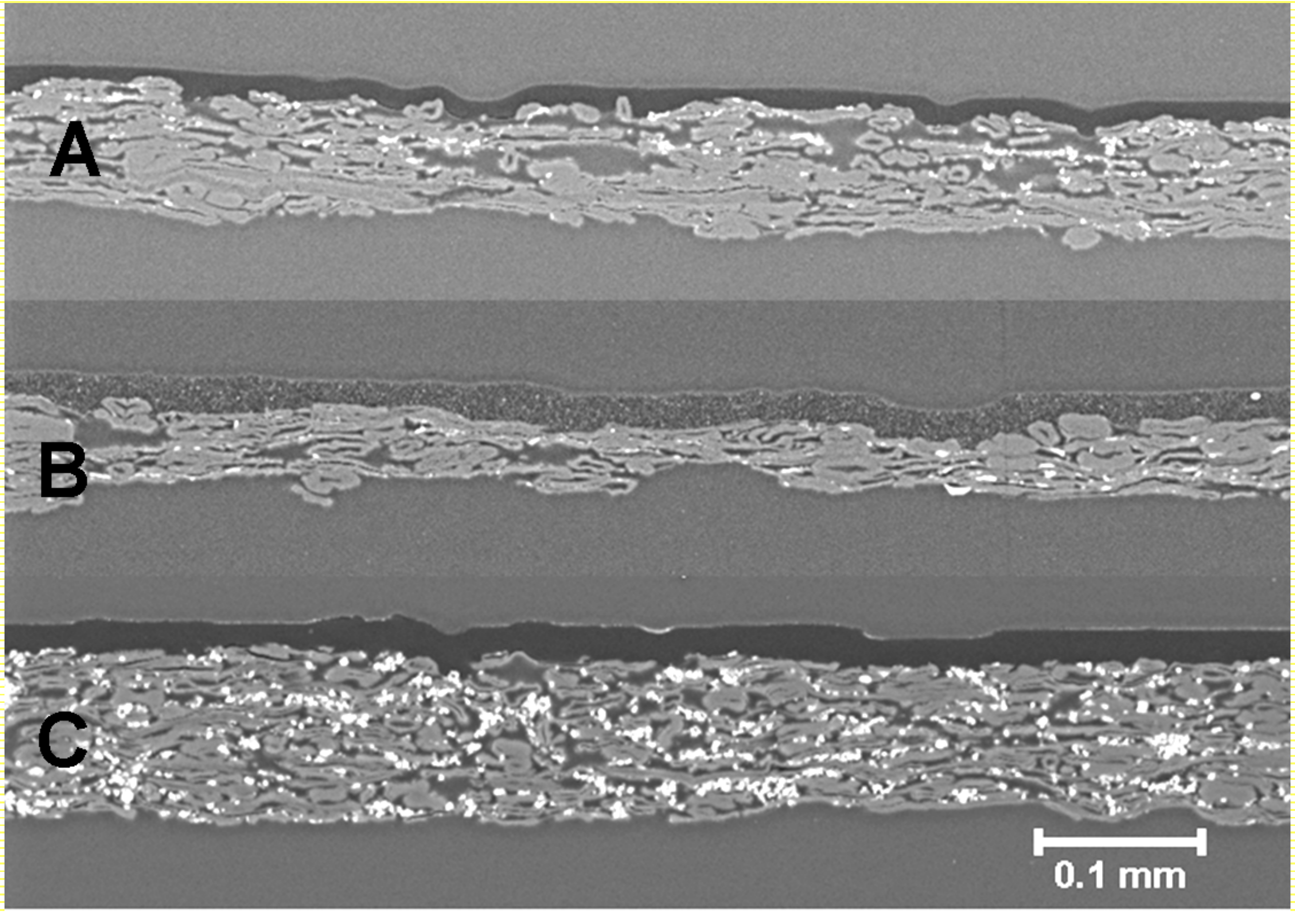


Results

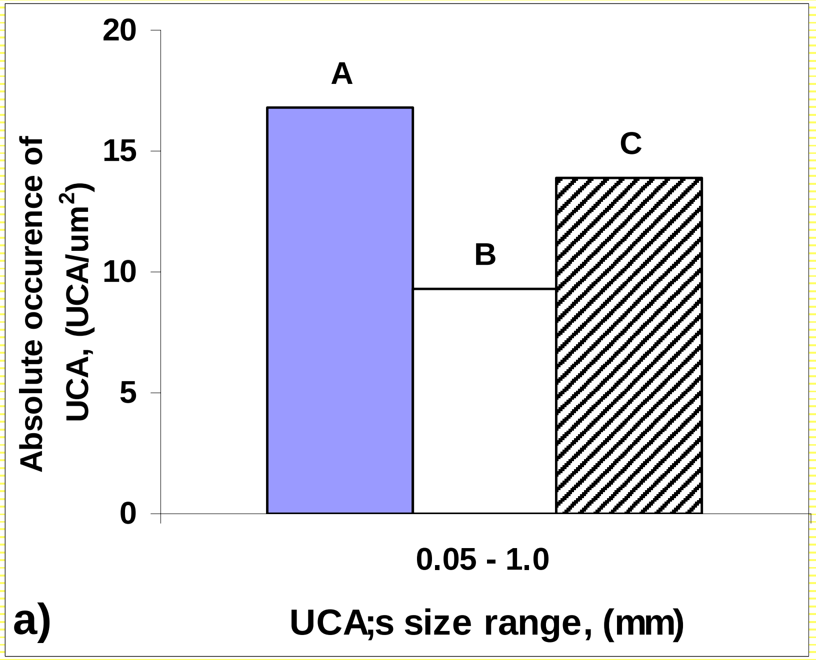


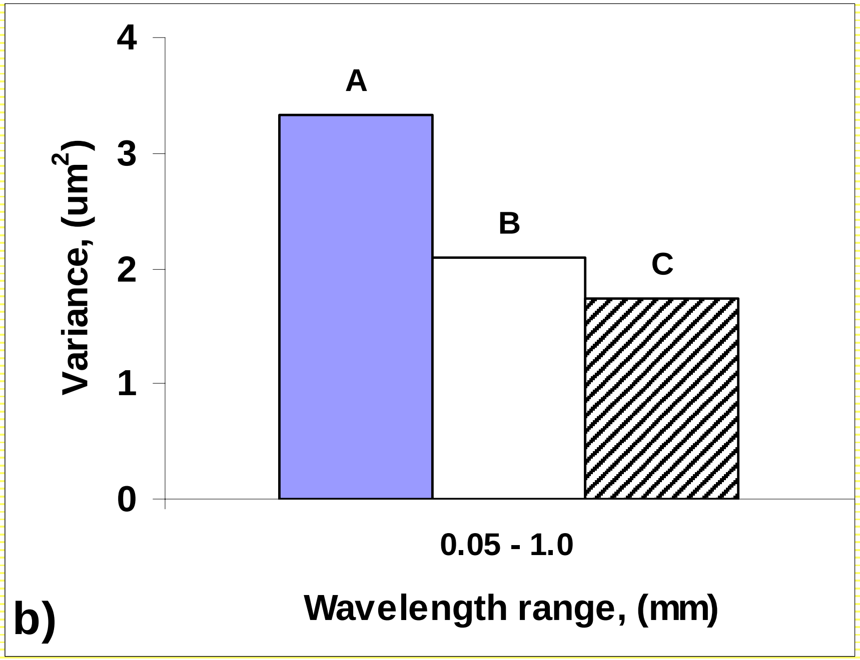
Category 2 (shallow depressions)	Paper A = Paper C > Paper B
Category 3 (deep depressions)	Paper A > Paper C > Paper B
Category 4 (in the plane)	Paper A = Paper B = Paper C

Results



Results





Surface roughness, Ra

A = 1.40 µm B = 1.24 µm C = 1,01 µm

Conclusions

- The UCA;s were located both in the plane and in depressions in the printing surface. Some UCA;s also coincided with elevations in the printing surface.
- We believe that the UCA;s in the plane are caused by poor wetting due to non-uniform corona treatment. Because occurrence of these UCA;s was the same for all the papers and since all papers were extrusion coated and printed in the same way it is reasonable to believe that this category of UCA was caused by imperfections in these processes.
- The occurrence of UCA;s caused by depressions in the PE-surface decreased with the thickness of the PE-coating. Cross sections showed that depression on the PE-surface in turn was caused by a depression or less dense structure in the base paper.
- The occurrence of UCA;s caused by depressions was marginally greater the occurrence of UCA;s caused by poor wetting.
- The occurrence of UCA:s did not correlate with any of the measured surface roughness parameters.

Thank you for your attention !

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