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UBRZANO STARENJE SVJETLOŠĆU BIJELE BOJE OTISNUTE U TEHNICI UV LED SUŠEĆEG INKJETA

LIGHT ACCELERATED AGEING OF WHITE INK PRINTED IN UV LED INKJET TECHNIQUE

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SAŽETAK

Trajnost svijetlih bojila još nije dovoljno istražena. Razlog su anorganski pigmenti čije su čestice relativno velike, te se sve ne mogu primijeniti u digitalnim tehnikama tiska. Cilj rada utvrđivanje je moguće postojanosti bijelih otisaka otisnutih u tri različite debljine nanosa (6.18 µm, 14.27 µm, 16.45 µm) te njihovo starenje ubrzanom simulacijskom metodom pomoću UV svjetlosnog izvora (Xeno test). Pritom će se analizirati vremena od: 0h, 6h, 12h, 24h, 48h, 72h, 144h i 244h. Najveće promjene događat će se nakon 144h starenja. Rastrirane površine imat će veće kolorne promjene, a koje će se ostvariti i povećanim nanosom bojila ($\Delta E_{1\ sloj}$=1,44, $\Delta E_{2\ sloja}$=1,72, $\Delta E_{3\ sloja¸60\%\ RTV}$=2,74).

Ključne riječi: ubrzano starenje UV svjetlošću, otiskivanje bijele boje, UV LED sušeći Inkjet

SUMMARY

Durability of light inks have not been explored enough. This is due to inorganic pigments whose particles are relatively large, so all of them can't be applied in digital printing technologies. The goal is to determine the possible persistence of white prints, printed in three different thicknesses of layers (6.18 μm, 14.27 μm, 16.45 μm) and later aged with accelerated simulation method using UV light source (Xeno test). This will be analyzed in different times of 0h, 6h, 12h, 24h, 48h, 72h, 144h and 244h. The biggest color changes white prints are going to gain after 144h of accelerated ageing. Screened areas are going to have bigger changes, which are going to increase with thicker layers of white ink ($\Delta E_{1\ layer}$=1,44, $\Delta E_{2\ layers}$=1,72, $\Delta E_{3\ layers,\ 60\%\ dot\ gain}$=2,74).

Keywords: UV light accelerated aging, white ink printing, UV LED Inkjet

1 INTRODUCTION

Packaging and other graphic products which are made for outdoor advertising have to be durable as much as possible. Although the durability of color prints (using CMYK inks) have been researched quite enough, that is not the case with special inks (metallic and achromatic inks). In design of graphic products there is rising need for black or extremely dark substrates. Such designs demand thick layers of ink, which leads to uneven overlapping and problems with screen accuracy. New Inkjet printing machines can print on almost any substrate, also by using white inks. That enabled printing on transparent materials, where white ink is used as background.

Nowadays, titanium dioxide (TiO_2) is the most used white pigment. It is used in 80% of all white inks. [1] Printed layers of TiO_2 have excellent mechanical properties (resistance to fraying), good lightfastness (color is permanent when affected by light) and are resistant to high temperatures. All those properties of titanium dioxide pigment suggest the importance of changes that could occur during longer ageing of prints.

2 THEORY

In addition to electrophotography, Inkjet is the the most developed digital printing technology. This is non-impact technology, in which ink is sprayed directly from tiny nozzles onto substrate. Inks used in Inkjet technology are liquids, so that they can form a single drop. Average radius of ink drop in Inkjet is about 30 μm, while its volume amounts 14pL.

There are two main principles of Inkjet technology: continuous Inkjet and drop on demand (DOD) Inkjet. Nowadays, DOD principle is much more used, and it comes in three different systems: bubble jet, piezo Inkjet and electrostatic Inkjet. In piezo Inkjet, drop is generated and ejected from the nozzle using deformation of ink microchamber. This deformation is caused by the electric signals that come to piezoceramic microelements, which have distortion properties during electric charge activity.

Structurally, there are two forms of TiO_2: anatase and rutile. Rutile pigments have higher refractive index, higher opacity and somewhat rougher structure.

Anatase pigments are much more stable and for their softer structure they are much more used in liquid printing inks. [2] Rutile is also used as a hardener, which will be more opaque for its refractive index (2.71) than anatase (2.55). Such form of TiO_2 in combination with other ink can generate up to 400 color tones. [3]

Generally speaking, lightfastness of Inkjet prints is not particularly high. That is why this subject was researched in numerous papers. The same Inkjet ink can't be used for generating different graphic products, mainly caused by low lightfastness. Color difference can be tracked as a function of spectral energy distribution of UV light source. Inkjet prints can also be exposed to different conditions.

Ageing of substrate itself surely also impacts color differences of prints. In their paper, authors Bolanča, Bolanča and Majnarić researched color differences of the prints printed on aged paper, new paper and aged prints. Using accelerated ageing method and Inkjet technology, they showed that the biggest color difference fluctuations can be expected on prints printed on aged paper. Prints printed on new paper and aged prints didn't significantly differ. [4] That leads us to conclusion that ageing process will differently impact different types of substrates. Inkjet prints, printed on coated and non-coated papers, will show bigger color differences on coated papers, after being exposed to artificially ageing. [5] The question is how completely different substrates will react (black coated paper).

Research results can be useful in producer-buyer relation, or while establishing quality control. However, they are also important in research and development of future graphic products. While determining relative lightfastness, two parameters are being observed: measurement of color difference using instruments and optical density difference.

3 EXPERIMENTAL

Accelerated ageing processes aim to assure faster changes in lightfastness of prints. While determining lightfastness, prints need to be exposed in several time periods, during which color changes are observed.

For implementing accelerated ageing of white ink experiment, it was necessary to prepare and print samples. Substrate used in experiment was Splendorlux Color Intenso Nero, grammage 250 g/m^2. This is multiply one-side cast-coated paper made of ecological chlorine free pulp. [6]

Inkjet printing machine Roland VersaUV LEC-300, that works on piezo Inkjet principle, was used for printing of samples. Printer uses ECO-UV inks, and in accordance with our experiment, only white ink was printed. Components of used ink, expressed in weight percentages, are: acrylic esters (30-40%), titanium dioxide (10-20%), hexamethylene diacrylate (10-20%), tri(propylene glycol) diacrylate (10-20%), phosphine oxide derivative (5-15%), other photo sensitive monomers (0-5%) and synthetic resins (0,5-5%). Ink is white liquid, viscosity 6 – 8 mPa·s. It has characteristic odor and flash point (66°C). [7] For immediate UV ink-curing two UV LED lamps are being used. [8]

Connection of DTP computer and Roland VersaUV LEC-300 printing machine was made through RIP software VersaWorks, which enables image conversion in screened form, using PostScript 3. RIP was set up for three different types of printing: printing of white ink in one layer, printing of white ink in two layers and printing of white ink in three layers. Plate with white printing elements was generated using Adobe Illustrator CS3, and it consisted 20, 40, 60, 80and 100% halftone value areas.

In order to determine thickness of ink layer, cross-section of prints was made. Created samples were magnified 400 times by microscope Leica DM 2500, while using polarization filter, which eliminates reflection. (Figure 1.)

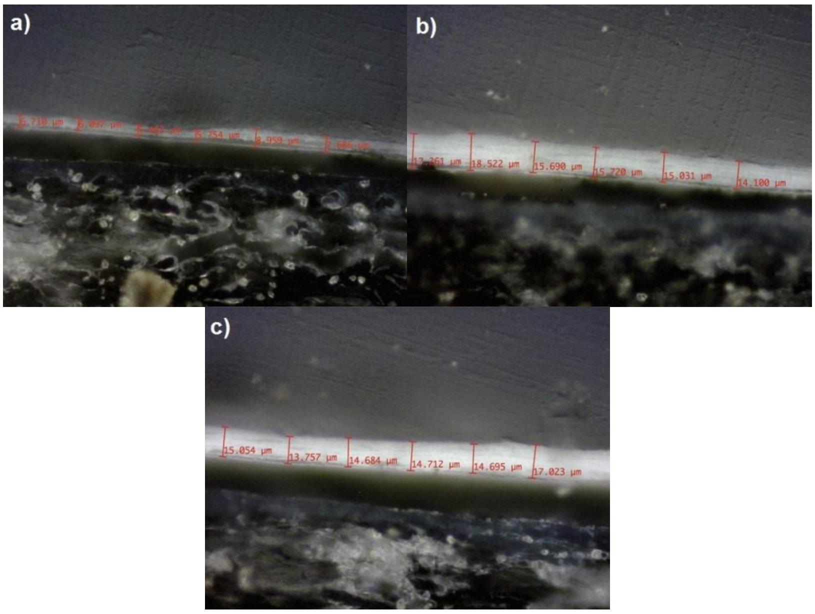


Figure 1 Magnified view of prints: a) with one layer of TiO_2, b) with two layers of TiO_2, c) with three layers of TiO_2

Because of the uneven surface, layers of ink are not leveled on the whole area of the samples. Thickness of the layers was measured by DinoXcope software at twelve spots, while average thickness was calculated as their arithmetic mean. Average thickness of one layer of TiO_2 amounts 6.18 µm. Two layers of white ink have the average thickness of 14.27 µm, while average thickness of three TiO_2 layers amounts 16.45 µm.

For the ageing process itself, climatic chamber SolarBox 1500e was used. Relative humidity in the chamber was set to 60%, and radiation energy to 615 W/m^2. Luminous energy that affected samples was twice as big as sunlight energy. Such energy was provided by xenon lamp which simulates whole sunlight spectrum.[9] Sample sets were exposed to simulated ageing in chamber in following periods of time: 6h, 12h, 24h, 48h, 72h, 144h and 244h.

After ageing, all of the samples were measured by spectrophotometer X-Rite DTP20 „Pulse“. This instrument measures the reflection of colored sample, and as a results it shows L*a*b*, and C* and H* valuables. Every single sample was measured six times, and measuring results were simultaneously showed on the computer by ColorShopX software. Based on the measured valuables, there were calculated average valuables that were later used for calculating color difference, ΔE. Thereby, mathematical formula ΔE_{2000} was used.

Obtained results were then graphically shown, converted to two and three-dimensional diagrams, which were generated with Origin 8.5 software.

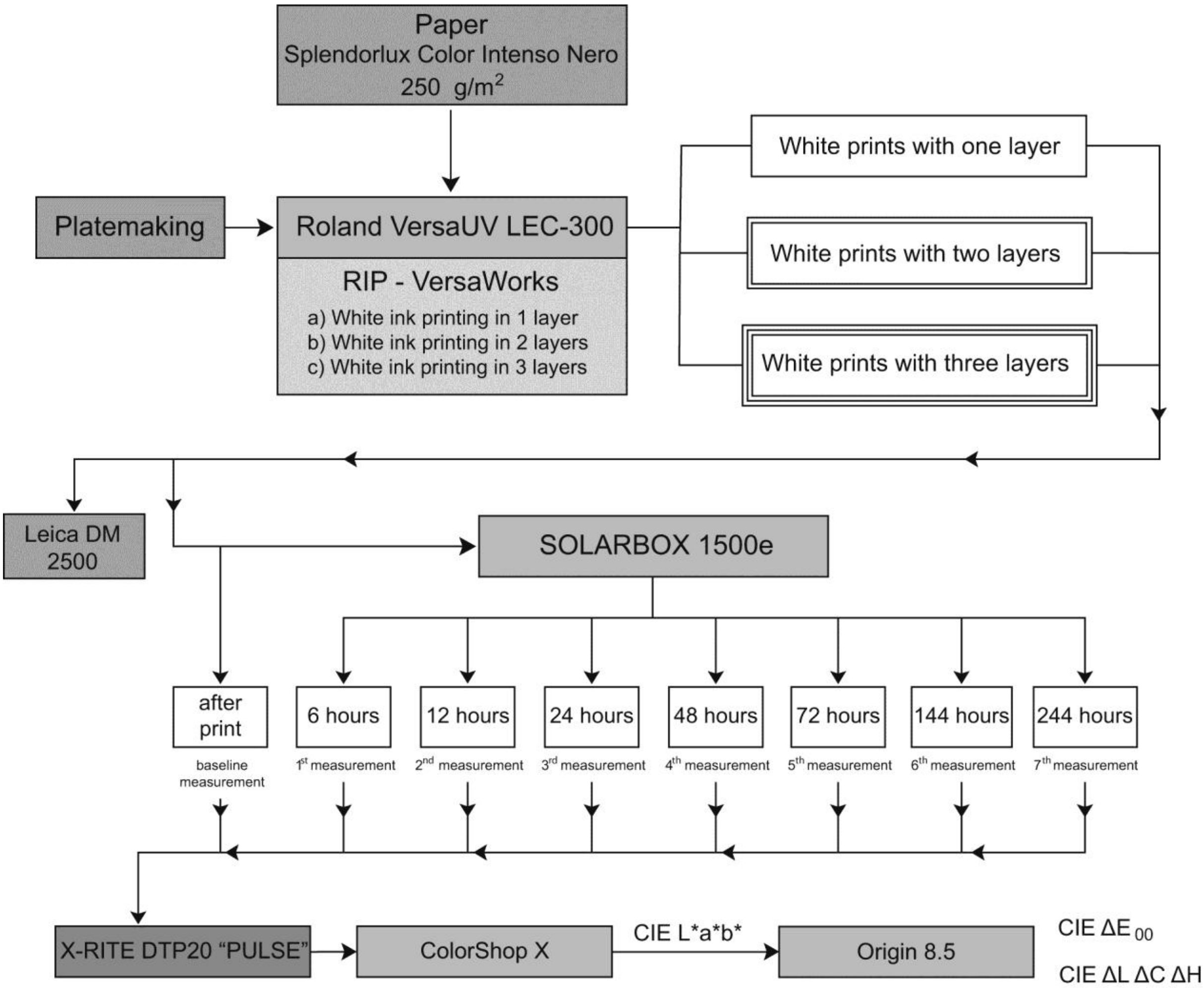


Figure 2 Chronologically plan of the experiment

4 RESULTS AND DISCUSSION

The best way to detect color changes of the prints caused by ageing is analyzing their coloration. The more layers of ink we apply, the deeper layer of white pigments will be. Figure 3 shows color values for all analyzed tone areas generated by printing of the white ink.

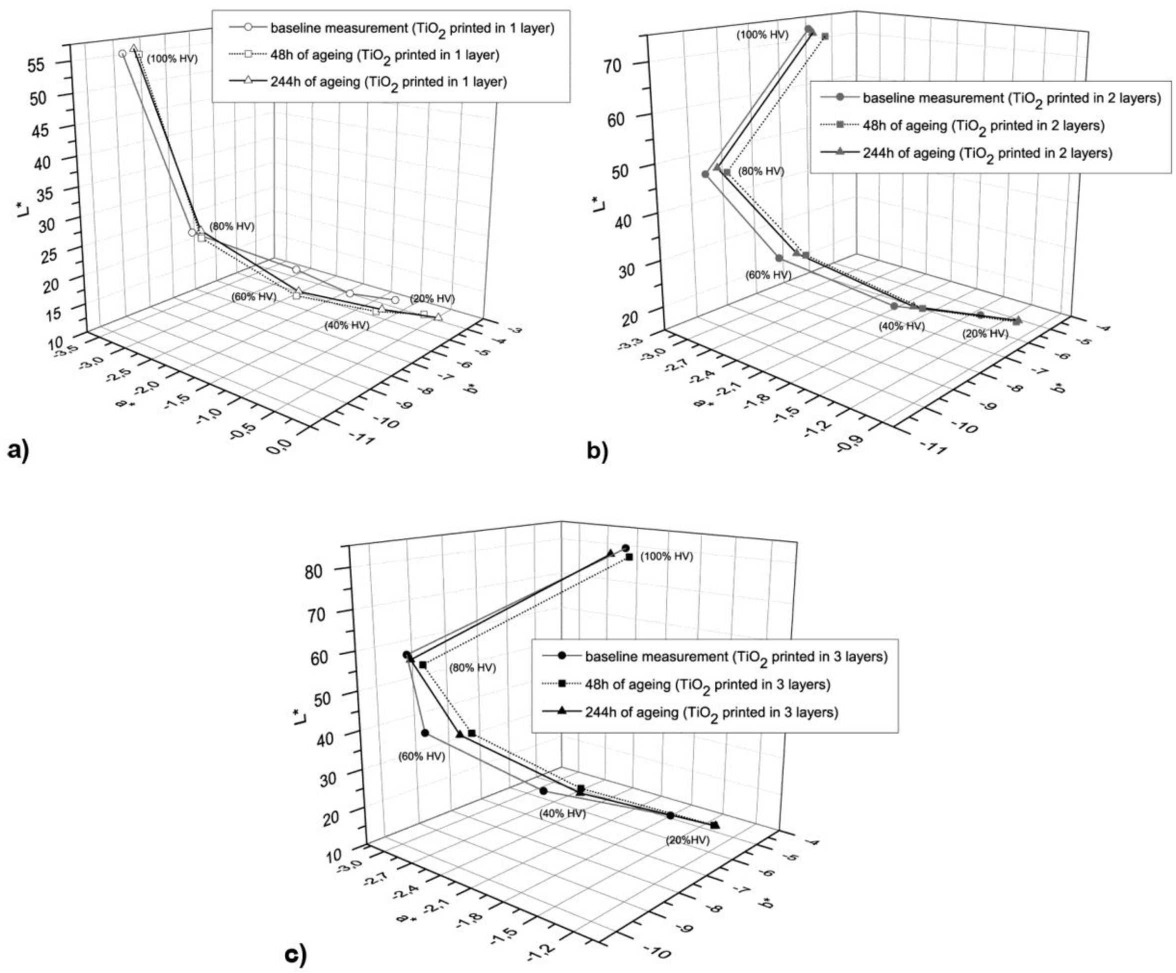


Figure 3 L*a*b* values of white prints generated during experiment: a) with one layer of ink, b) with two layers of ink and c) with three layers of ink

The biggest color changes happened on the solid tone areas. With one layer of ink the change is evident only at 100% halftone value.

Those color changes are detectable on the coordinate b* (prints are getting yellowish). With two layers of TiO_2, the same change is also evident at 80% halftone value.

Prints with three layers of ink show the biggest color change, where beside this characteristic color change on the coordinate b*, color change on the coordinate a* (reddish prints) is also noticeable.

Looking at the figures, it is also obvious that the biggest fluctuations during the ageing process happened on the areas of 40% and 80% halftone values, same as the solid tone areas. This is the reason why those areas are going to be additionally analyzed. (figure 4, 5 and 6).

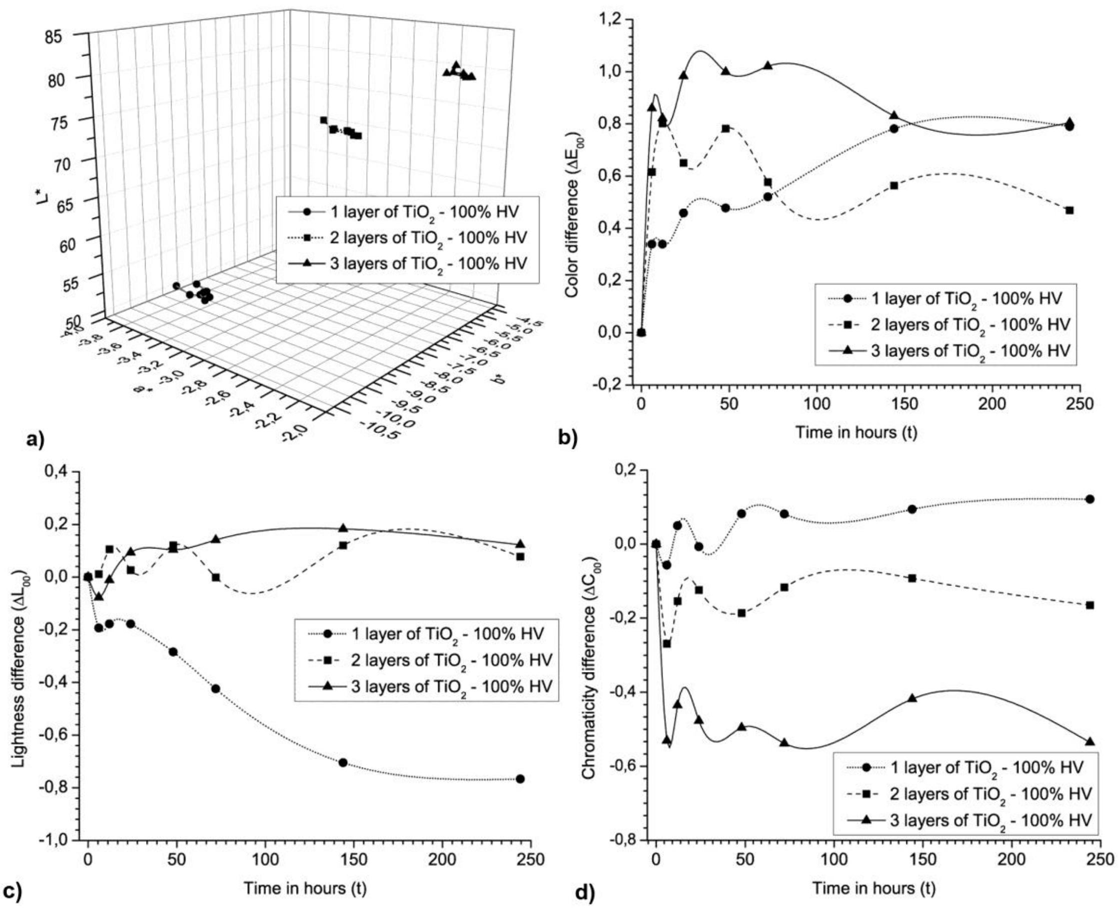


Figure 4 Changes of L*a*b* valuable for the areas of 100% dot gain, due to number of TiO_2 layers: a) 100% halftone value areas, b) ΔE of 100% halftone value, c) ΔL of 100% halftone value, d) ΔC of 100% halftone value

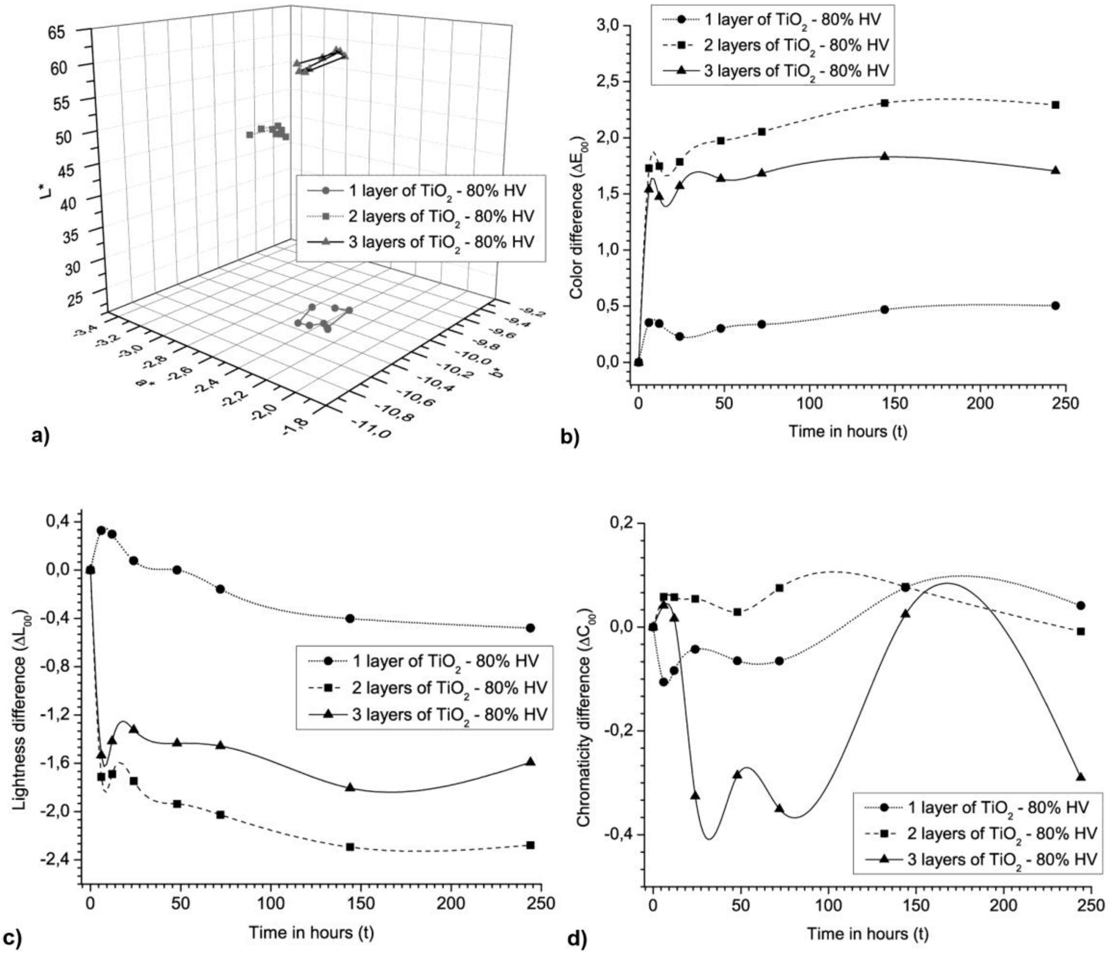
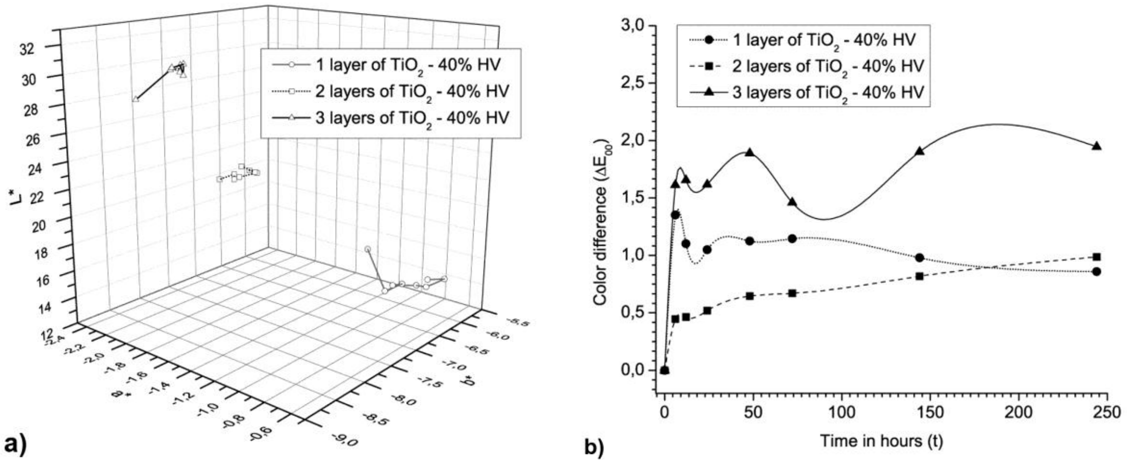
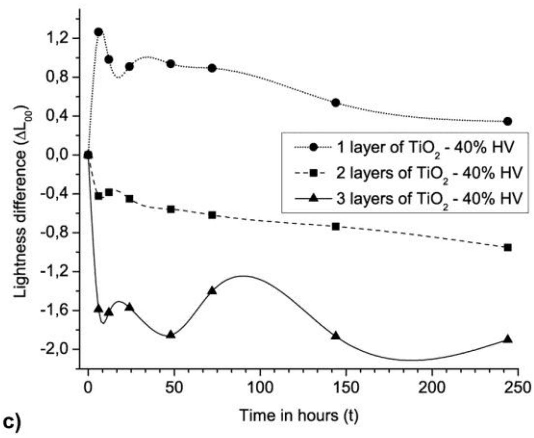
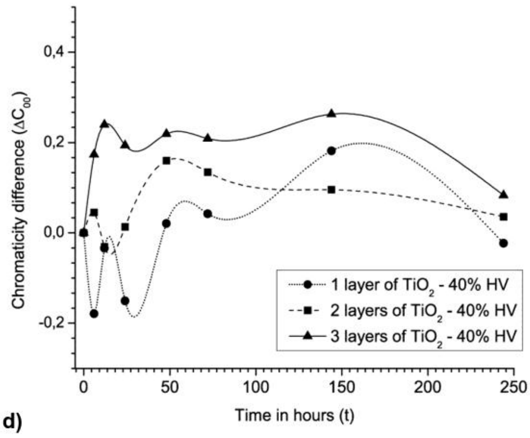


Figure 5: Changes of L*a*b* valuable for the areas of 80% halftone value, due to number of TiO_2 layers: a) 80% halftone value areas, b) ΔE of 80% halftone value, c) ΔL of 80% halftone value, d) ΔC of 80% halftone value





c)



d)

Figure 6: Changes of L*a*b* valuable for the areas of 40% halftone value, due to number of TiO_2 layers: a) 40% halftone value areas, b) ΔE of 40% halftone value, c) ΔL of 40% halftone value, d) ΔC of 40% halftone value

On the figures 4, 5 and 6 color differences (ΔE_{00}), lightness differences (ΔL_{00}) and chromaticity differences (ΔC_{00}) are shown. It is evident, on all three figures, that the biggest change happened in first six hours of ageing. After that, samples are stabilizing and are not significantly changing.

Observing solid tone areas (figure 4), color changes are more prominent on one and two layers of TiO_2. However, they are visually imperceptible and possible to detect only by measuring instruments (ΔE_{00}<1).

Looking at the lightness parameter only, it is noticeable that prints with one layer of ink have constant lightness reduction. In order to make that reduction perceptible, ageing process period should be notably extended.

Figure 5 shows color changes for 80% dot gain areas. After first six hours of accelerated ageing in climate chamber, color changes that happened are also insignificant, but still bigger than at 100% halftone value areas ($\Delta E_{2\ layers\ -\ 1\ layer,\ (144h)}$=1,84). The biggest change occurred after 144 hours of ageing, where visible color change was detected (ΔE_{144h}=2,31) on the samples with three layers of ink. Changes in lightness are also detected (prints with two and three layers of ink became darker), while chromaticity changes stayed insignificant.

On the figure 6 color differences for middle tone values (40% halftone value) are illustrated. Same as at the previously analyzed areas, the biggest changes occur on the prints with three layers of TiO_2. Color differences are also slightly visible and only after 144 hours of ageing on prints with three layers of ink (ΔE_{144h}=1,9). Results suggest that in first few hours of ageing rapid changes happened on the prints, while also the main volatile solvent evaporation is being released.

5 CONCLUSION

Thicker layer of ink will provide print with higher contrast and better quality. Thereby, lightness parameter (L*) will be higher. Modification of halftone areas will also occur, causing light and dark tones to disappear (due to problems with register overlapping). White prints have shown to be very stable and during 244 hours of ageing have not experienced significant color changes. The biggest change happened in the first six hours, whereupon prints are stabilizing. Black substrate also contributes this stability. Substrate does not change when exposed to UV light, mainly due to its coating.

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