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APPLICATION OF MODERN PHYSICAL RESEARCH METHODS FOR THE TECHNOLOGICAL PROCESS CONTROL OF THE ACCURATE PRINTING

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APPLICATION OF MODERN PHYSICAL RESEARCH METHODS FOR THE TECHNOLOGICAL PROCESS CONTROL OF THE ACCURATE PRINTING

Introduction

- Growing importance of the authenticity of printed information, documents with special security marks and various other objects and products.
- Graphics solutions characterised by high resolution (20–40 μm) of printed elements used to protect printed production.
- Ink layer thickness (0.3–5μm) on the high resolution printed elements.
- Necessity to use more accurate physical control methods for printed production applied in materials science and semiconductor physics.

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Introduction

- To protect the authenticity of printed information, special security marks are used:
  - guilloche elements,
  - micro text,
  - latent images,
  - complex 3D background images,
  - barrier elements limiting copying, etc.

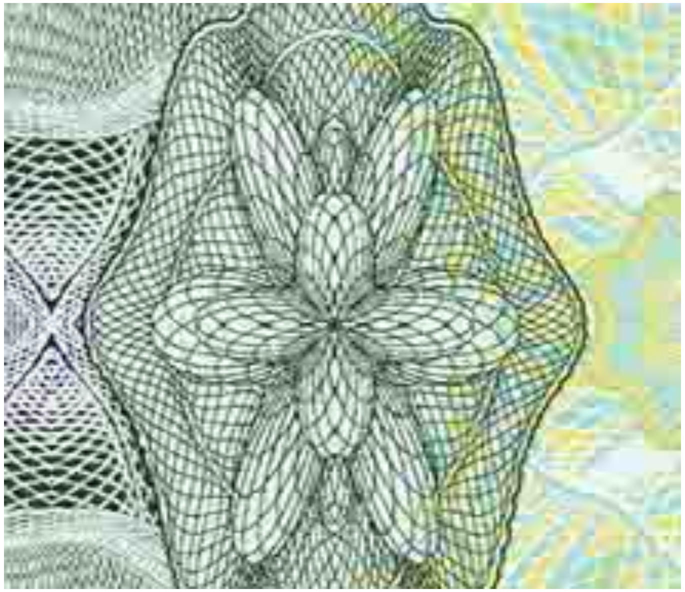
- Graphics solutions characterised by high resolution (20–40 μm) are used to restrict copying or reproduction.

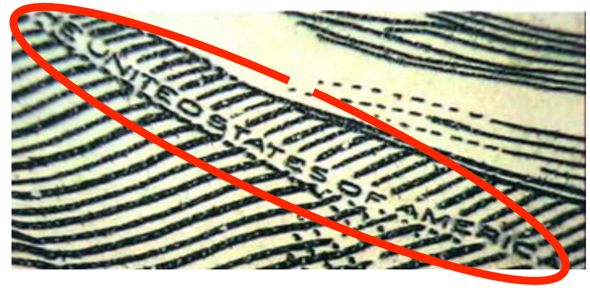
- Special printing equipment, advanced technologies and appropriate properties of materials are required.

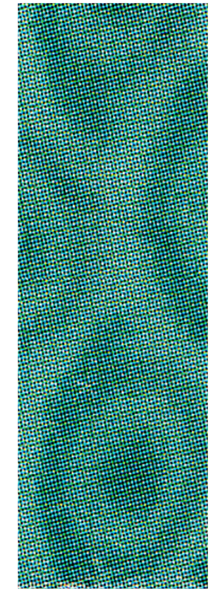
PERSONAL IDENTIFICATION DOCUMENTS

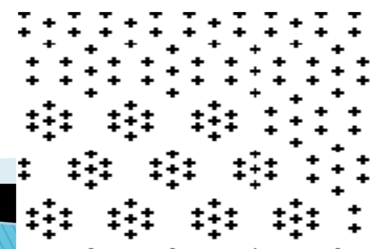
BANKNOTES, SECURITIES, SPECIAL LABELS

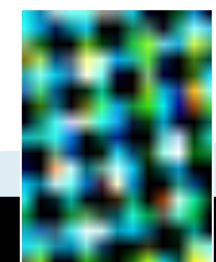
GRAPHIC ELEMENTS OF THE TECHNOLOGICAL SECURITY









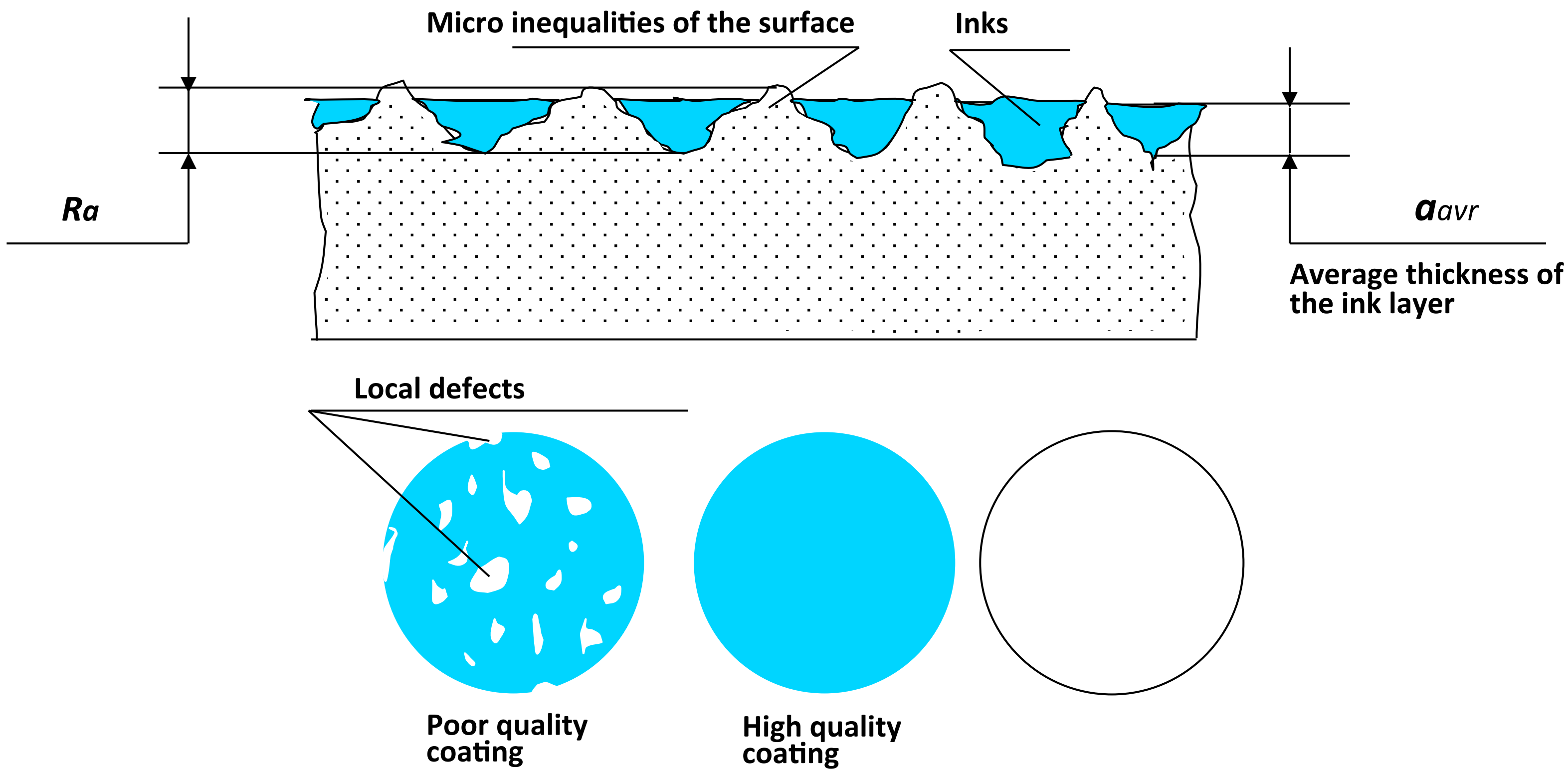


Guilloche elements, micro text, barrier elements, 3D dynamic elements

APPLICATION OF MODERN PHYSICAL RESEARCH METHODS FOR THE TECHNOLOGICAL PROCESS CONTROL OF THE ACCURATE PRINTING

- Offset printing is still the most accurate printing technology.
- Multi-layered structure of printing plate (surface is covered with 0.5–1 μm polymer layer).
- Accuracy of the geometrical dimensions of the printing elements is related to the morphology of the printing plate surface.
- Ink layer thickness *d* applying the offset printing usually ranges within 0.3÷5μm limits.
- Printing high-resolution elements (width b = 25–35 μm), the thickness of the ink layer *d* will be minimal (up to a few hundred nanometres). Distribution of the layer thickness should not exceed $\Delta d \leq 0.05\ d$ limit.

IMPACT OF THE SURFACE MORPHOLOGY ON COATING QUALITY



Average thickness of the ink layer:
- Offset printing – 0,3 – 3 μm;
- Flexography - 1 – 10 μm;
- Gravure- 5 – 80 μm;
- Screen printing 10 -100 μm;

Surface morphology (average height of the inequalities *Ra*):
- Polymer or polymeric coating - 0,09 – 0,12 μm;
- Paper - 0,12 – 0,8 μm;
- Board - 0,8 – 3 μm;

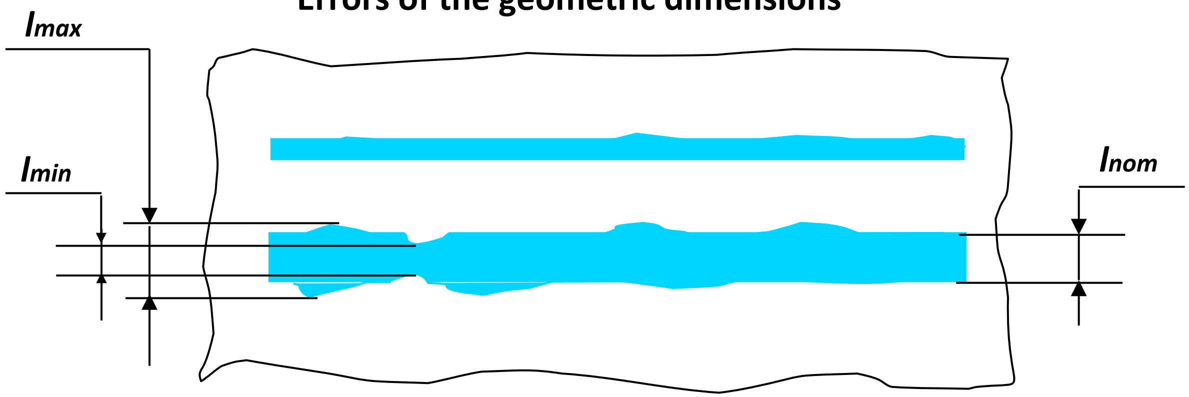
Prerequisite for the high quality coating: $R_a < a_{avr}$

APPLICATION OF MODERN PHYSICAL RESEARCH METHODS FOR THE TECHNOLOGICAL PROCESS CONTROL OF THE ACCURATE PRINTING

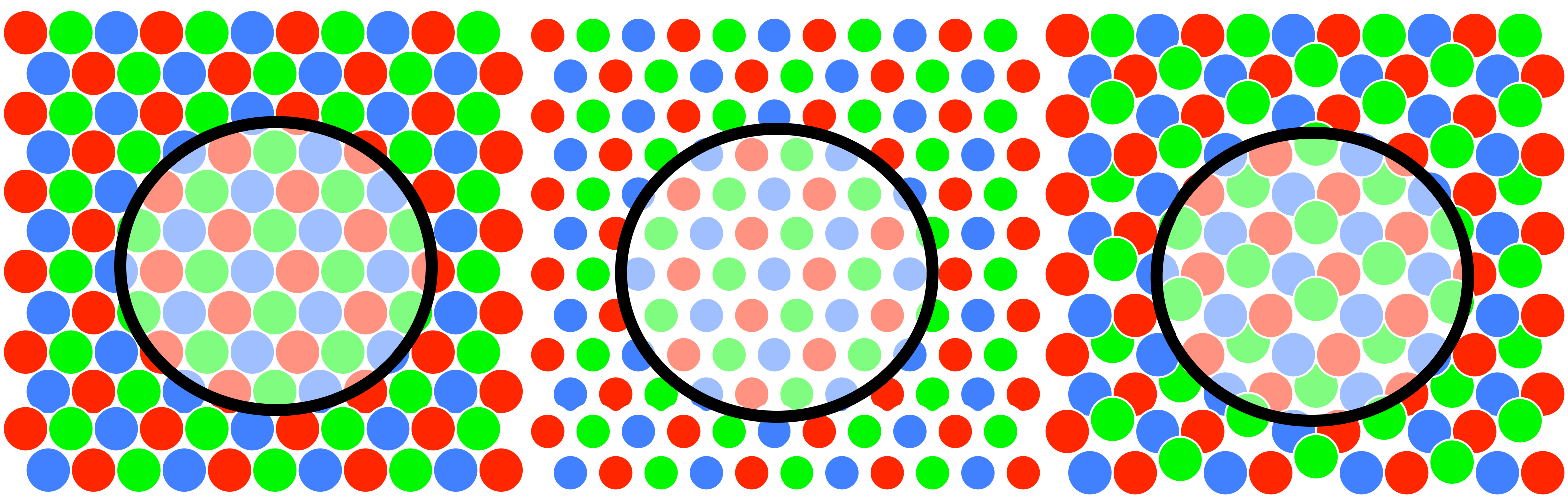
- Formation of the thin ink layer on the high-resolution elements (b = 25–35 μm) is limited by major complex factors:
  - viscosity of the inks and their rheology;
  - accuracy of the geometric dimensions and physical characteristics of the materials of the printing plates;
  - properties of the print materials and morphology of the surface.

ERRORS IN PRINTING

Errors of the geometric dimensions



Change of the colour spectrum due to the geometric errors of the discrete elements

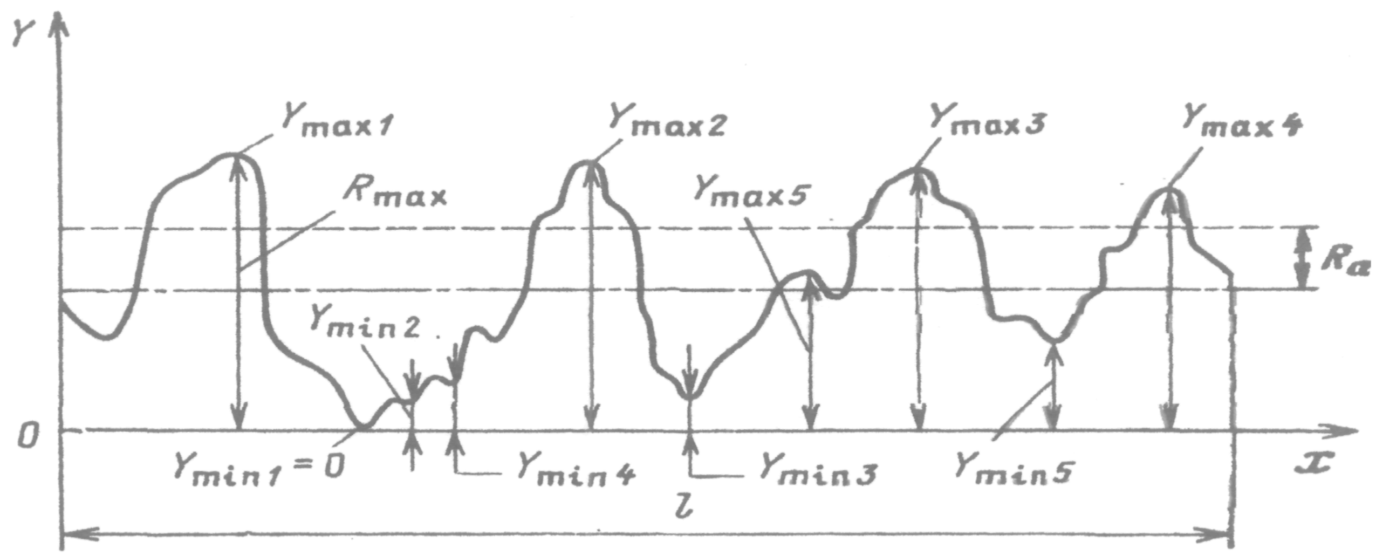


Correct coating | Reduce of the dimension | Errors of overlapping

APPLICATION OF MODERN PHYSICAL RESEARCH METHODS FOR THE TECHNOLOGICAL PROCESS CONTROL OF THE ACCURATE PRINTING

- Accuracy of the geometric elements of the prints is determined by quality of the printing plates.
- Offset printing plates and production technologies currently used:
  - CtP thermal, day-light laser, “violet” technology;
  - Thermal, “violet”, silver halide, chemical, chemistry-free, positive, negative working plates, etc.
  - CtCP – 215-405 nm exposure, conventional plates.
- For each technology appropriate printing plates are used.
- Precision of the discrete elements and quality of the print depends on the characteristics of the surface layer of the printing plate and its physical properties.
- A very important factor to determine quality of the printing plate is its smoothness or morphology.

METROLOGY OF THE SURFACE MORPHOLOGY



1. Arithmetic average of the profile:

$$R_a = \frac{1}{l}\int_0^l |y(x)|dx,$$

or:

$$R_a = \frac{1}{n}\sum_{i=1}^{n} |y_i|$$

2. Height of the microinequalities:

$$R_z = \frac{1}{5}\left(\sum_{i=1}^{5}\left|y_{\max_i}\right| + \sum_{i=1}^{5}\left|y_{\min_i}\right|\right)$$

3. Maximum height of the microinequalities : - *Rmax*

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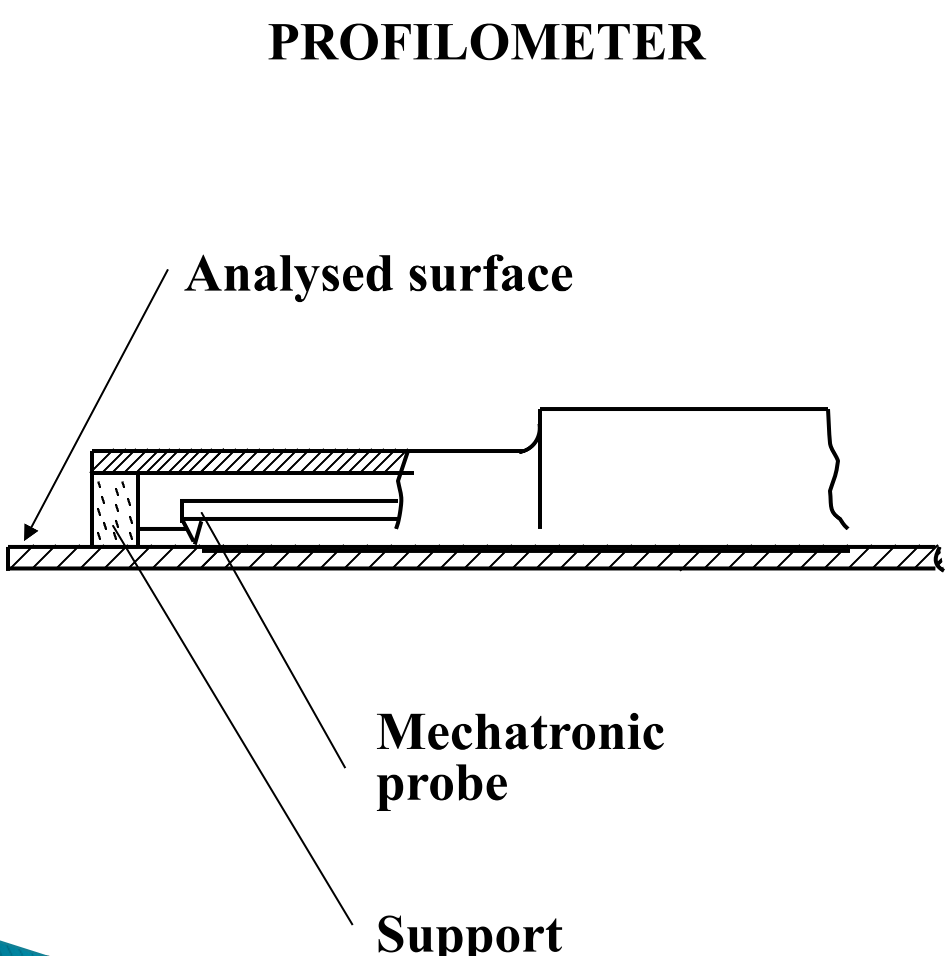
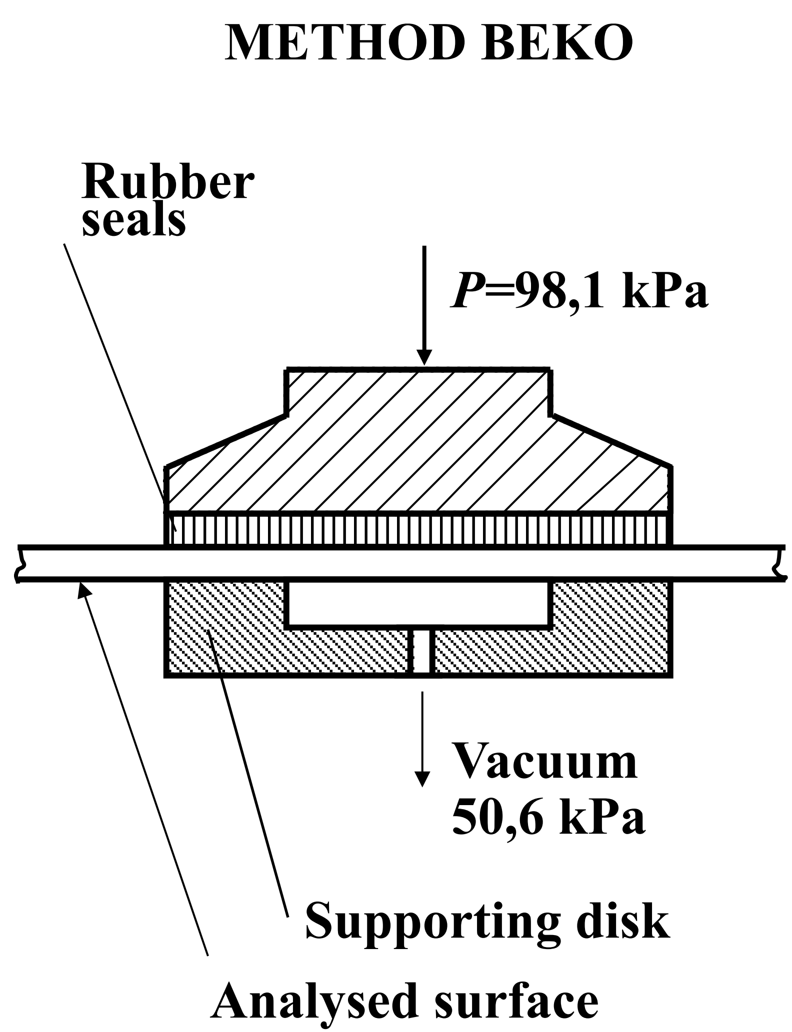
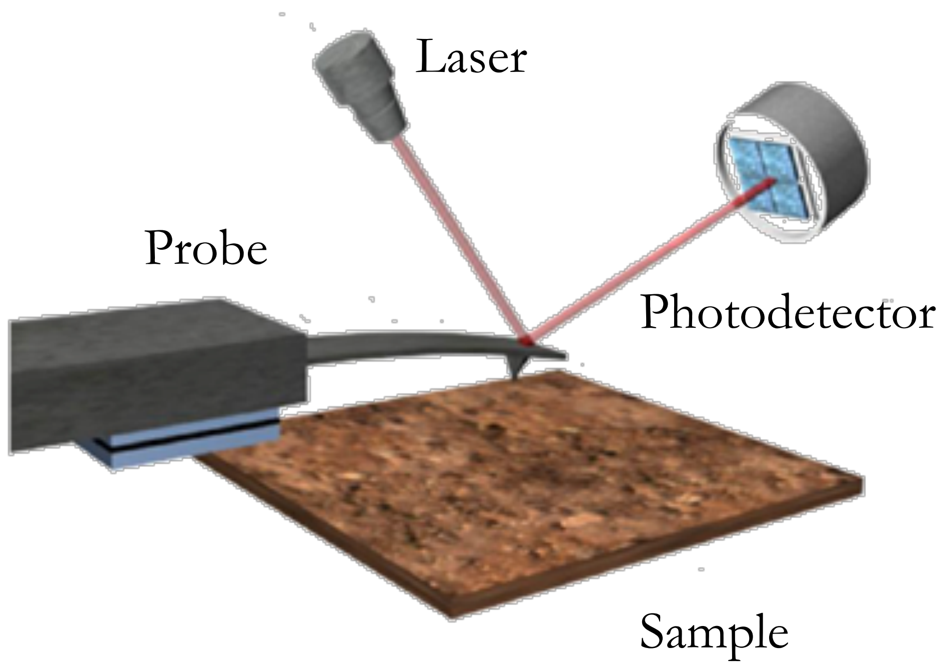
- For a couple of decades, this parameter was measured applying a vacuum change method.
- Recently, profilometres are used to measure changes in the surface morphology within 0.2–1 μm limits.
- Yet, it cannot ensure an accurate analysis, when thickness of the polymer layer on the printing plates is approx. on 0.3–1 μm limits.
- Thus, it becomes necessary to use more accurate methods of physical control which are applied in other areas, e.g. materials science or semiconductor physics.
- For example, an atomic force microscopy detects 10^{-6} mm geometric changes, which in turn, enables to assess extreme values of the surface inequalities, its nature of change and frequency.

MEASUREMENT METHODS OF THE SURFACE MORPHOLOGY





MEASUREMENT METHODS OF THE SURFACE MORPHOLOGY



Atomic force microscope (AFM)

Functions: contact, non-contact

Tasks: surface topography, force curves

Sample analysis and results

AFM (model NT-206) major characteristics:

- z_{max} – 4 μm,
- lateral resolution – 2 nm,
- vertical resolution 0.1–0.2 nm.

Analysed samples:

- FUJI VPS-E offset printing plate for the positive technology $\lambda = 400$ nm;
- AGFA Energy Elite PRO offset printing plate for the positive thermal technology $\lambda = 830$ nm.

Scanned fragments of the AFM printing plate samples and their surface morphology are presented in Fig. 1.

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Sample analysis and results

Scanned fragments of the printing plate samples using AFM:

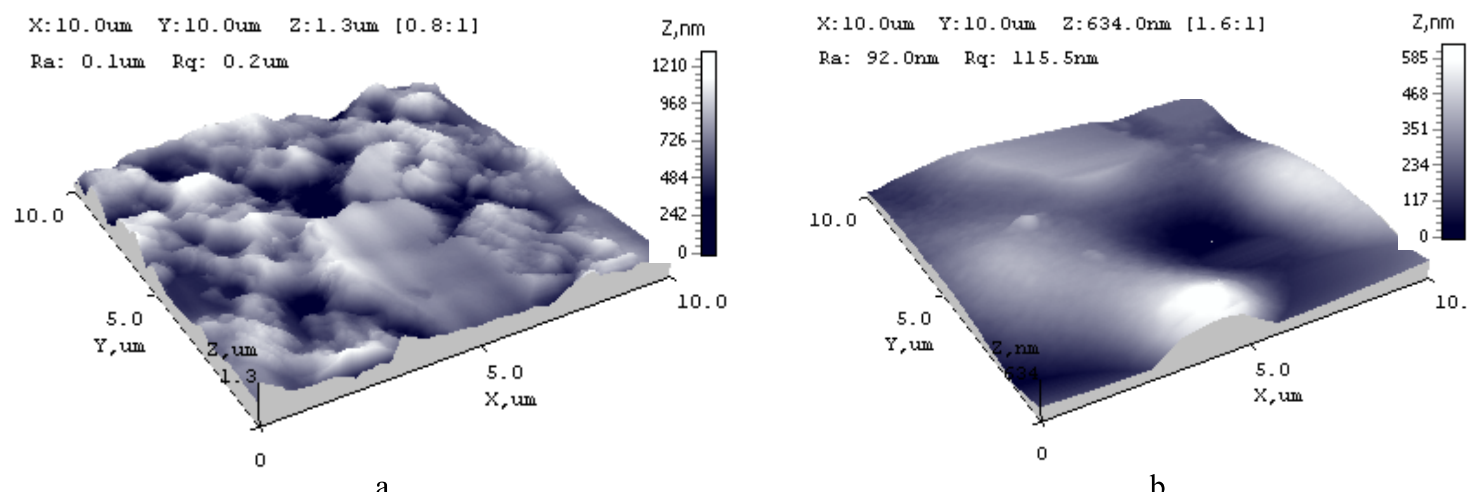

Fig 1. Fragments of the surface morphology: a – FUJI VPS-E, b – AGFA Energy Elite PRO

Different size and nature of the relief micro inequalities of the printing plates:

- Extreme value of 2 opposite surface of the FUJI VPS-E is z_{max} = 1.21 μm;
- Extreme value of 2 opposite surface of the AGFA Energy Elite PRO z_{max} = 0.505 μm.

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Sample analysis and results

- The most widely used generalised size is R_a, an arithmetic mean of the overall height of the surface inequalities. As the results of the sample measurement show:
  - FUJI VPS-E R_a = 0.1 μm,
  - AGFA Energy Elite PRO R_a = 0.09 μm.

- Extreme value of 2 opposite surface:
  - FUJI VPS-E is z_{max} = 1.21 μm;
  - AGFA Energy Elite PRO z_{max} = 0.505 μm.

Measurement results of the printing plates FUJI VPS-E and AGFA Energy Elite PRO surface inequalities show that the discrete roughness values are significantly larger than the thickness of the inks' layer for accurate printing d = 0.2–0.4 μm.

High-resolution prints (and not only) may contain local defects, rough areas on the printed element edge and interruptions of thin line.

! If smoothness of the surface is treated as mathematical average of the extremes R_a, it can be assumed that the surface state is not sufficiently defined.

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Sample analysis and results

Fig. 2 a. FUJI VPS-E
R_a = 0.1 µm
z_{max} = 1.21 µm

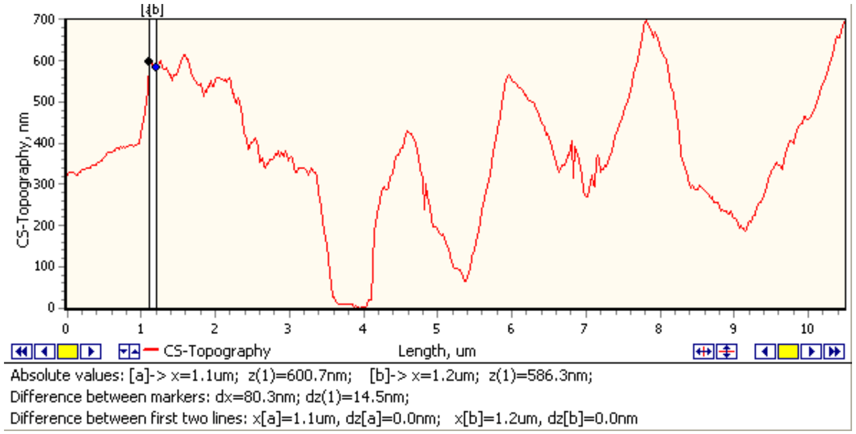
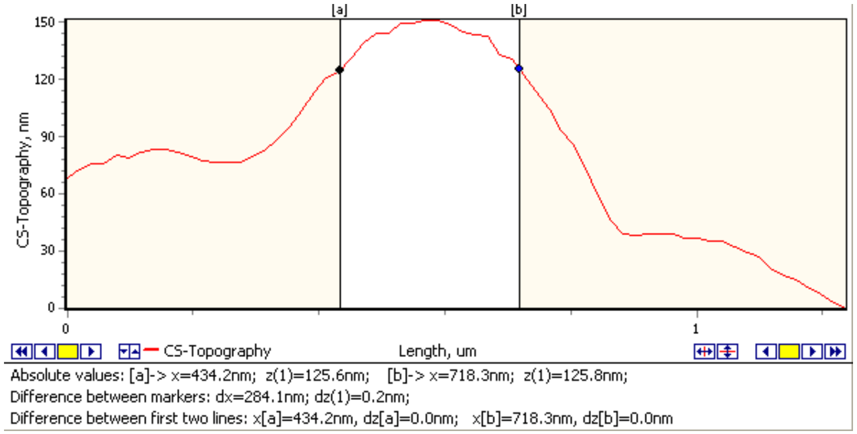


Fig. 2 b. AGFA Energy Elite PRO
R_a = 0.09 µm
z_{max} = 0.505 µm



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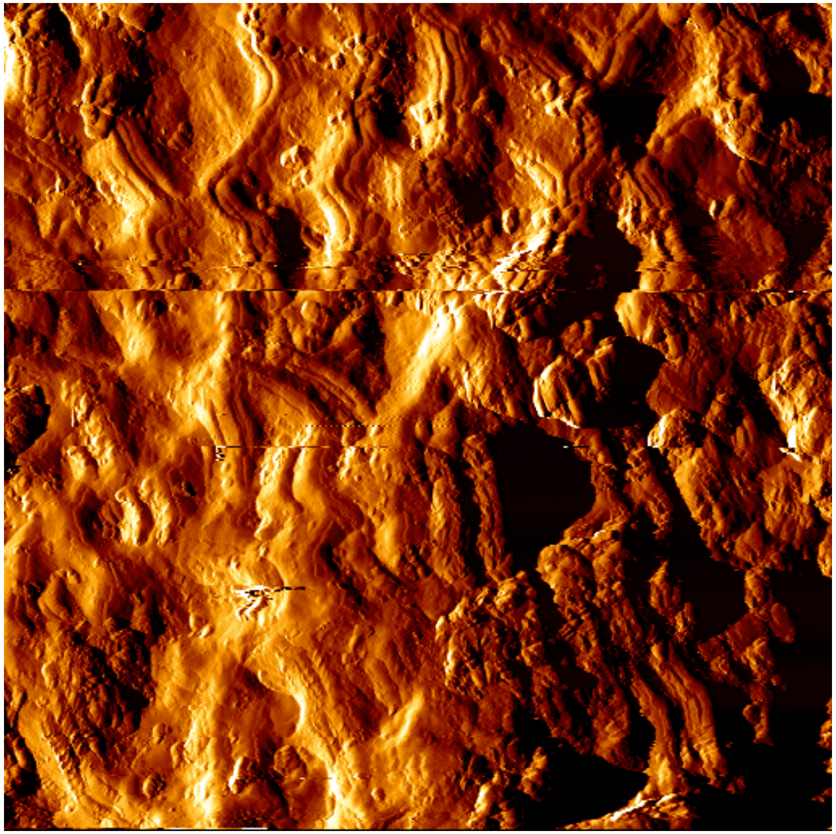
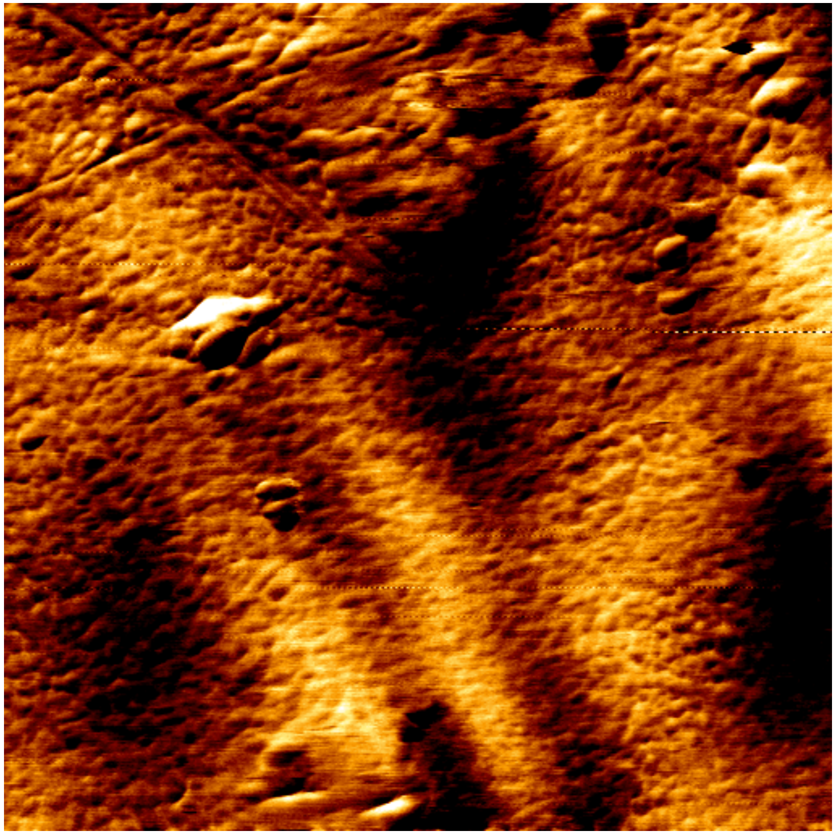
Sample analysis and results



FUJI VPS-E



AGFA Energy Elite PRO

APPLICATION OF MODERN PHYSICAL RESEARCH METHODS FOR THE TECHNOLOGICAL PROCESS CONTROL OF THE ACCURATE PRINTING

Sample analysis and results

- Outcomes of the research show significant differences of the sample surface morphology.
- Frequency rate of the FUJI VPS-E printing plates surface micro inequalities' extremes is greater than in AGFA Energy Elite Pro;
-
- difference in the adjacent extremes' values of the FUJI VPS-E is significantly bigger and reaches 0.4-0.5 μm.
- Meanwhile, the AGFA Energy Elite Pro value is lower (0.15 μm).
- Measurement results using AFM confirm that the generalised evaluation of the micro inequalities' surface height is considered as an arithmetical average, which is inadequate to characterise the concept of the surface smoothness.

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Sample analysis and results

- In the process of ink transfer on the surface of the print and uniformity of the layer thickness, **adhesion force** of the contacting surfaces plays a significant role.
- Liquid ink adhesion force with the surface is proportional to the surface energy.
- AFM method used for the surface analysis enables to evaluate the surface adhesion force F_a.
- The adhesion force is determined by analysing sensitive microprobe retraction/extraction curve slopes and amplitude variations (Fig. 3)

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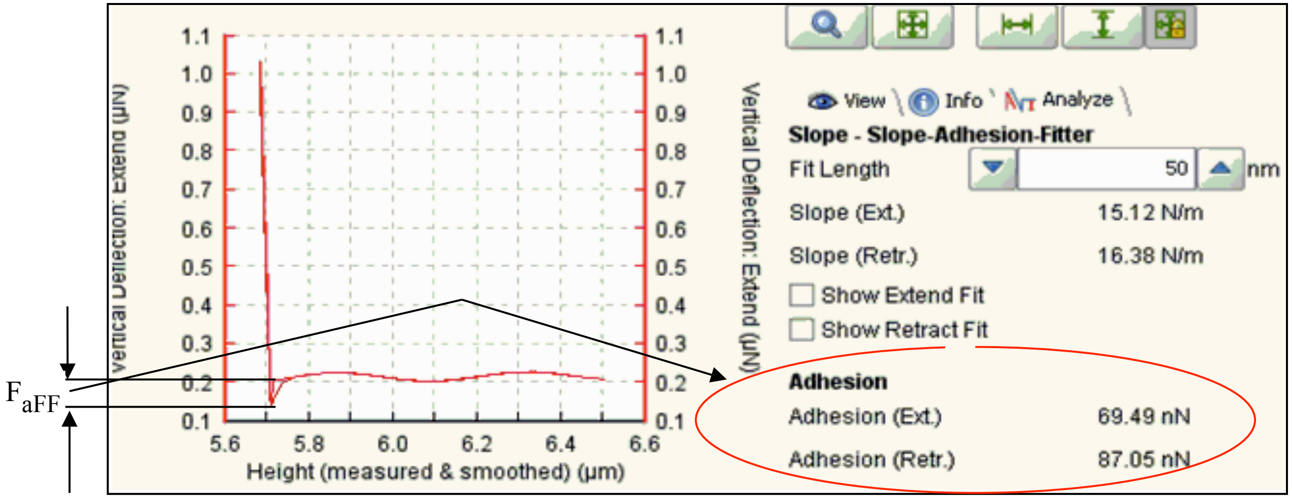
Sample analysis and results



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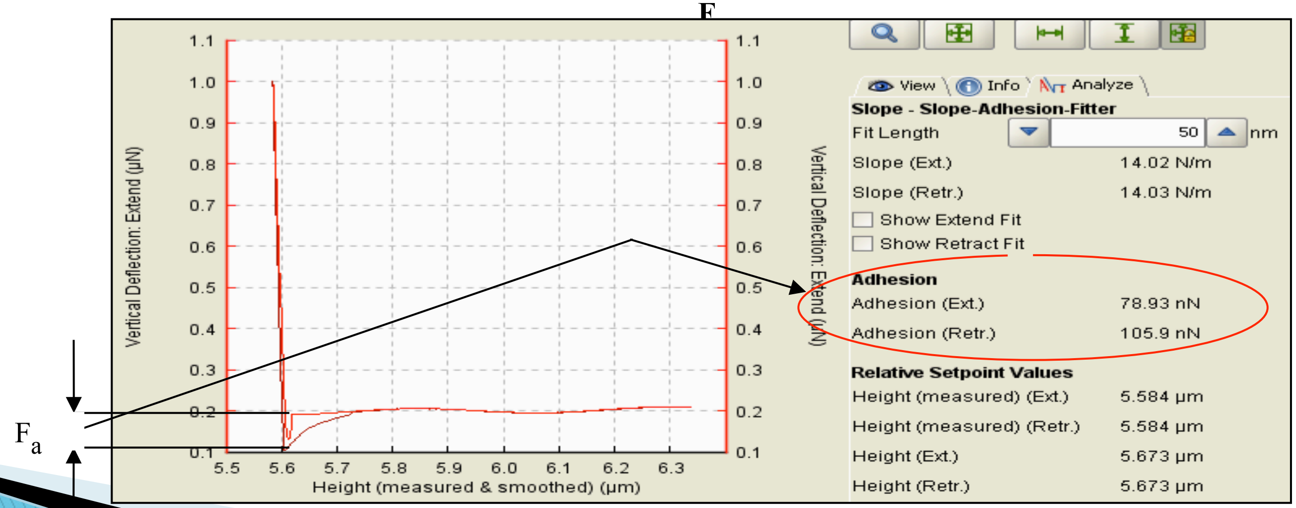

AGFA

APPLICATION OF MODERN PHYSICAL RESEARCH METHODS FOR THE TECHNOLOGICAL PROCESS CONTROL OF THE ACCURATE PRINTING

Sample analysis and results

- Surface **adhesion force** F_a (Fig.3) of the analysed printing plates' surface differs:
  - FUJI VPS $F_a = 69.49$ nN;
  - AGFA Energy Elite PRO $F_a = 78.93$ nN (F_a of the thermal plate is bigger by 11.9 %)
- Absolute measurement value is not sufficient to relate adhesive properties of the printing plate material to surface morphology.
- The adhesion force determines distribution of the printing inks on the surface, thickness of the ink layer and its uniformity, uniformity of the inks separation from the surface, limit capabilities of the discrete elements of minimum geometric dimensions.
- In the offset printing, inks are transferred on several surfaces. The last three pairs of the contacting surfaces determine quality of elements, accuracy, and reproducibility. The surface adhesion of the material of the printing plates should be properly selected to ensure adequate proportion of the inks' thickness for consistent transfer/separation process.

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Sample analysis and results

- Weak adhesion force is determined by low surface energy and lack of hydrophilic properties of the surface and chemical composition of the material.
- Chemical elements have different impact on the surface adhesion. For example, Na increases the surface energy, meanwhile Si, conversely, decreases.
- To analyse qualitative and quantitative chemical elemental composition of the element, method of X-Ray **Photoelectron Spectroscopy** XPS was chosen.
- ESCALAB-250Xi was used.
- FUJI VPS and YP-Q (China) samples of the violet laser technology conventional printing plates were analysed.
- Surface morphology of both samples was measured using AFM NT-206, and as the outcomes of the research demonstrate, the obtained results were similar.
- It means that adhesion of the printing plates surfaces' may be determined by matrix of the element composition and concentration of the chemical admixtures present in the element.

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Sample analysis and results

- Spectroscopy was applied for **Na** and **Si** spectra.
- Results:

Na atomic concentration in both samples is relatively identical approx. 2–3 %;

Si atomic concentration significantly differed (Fig.4 a, b):

- Si concentration in the surface of the plate FUJI VPS is 0.4 %
- Si concentration in the surface of the plate YP-Q is 4.2 %

It is possible to draw a conclusion, that adhesion of the printing plate's FUJI VPS surface should be bigger.

It is confirmed by previous adhesion force measurement using AFM: adhesion force of FUJI VPS printing plate $F_a = 69.49$ nN, of the printing plate YP-Q (China) – $F_a = 51.05$ nN.

Based on correlation of the two analysis methods, it can be claimed that characteristics of the two printing plates, produced by different producers may differ, yet their technologies are the same.

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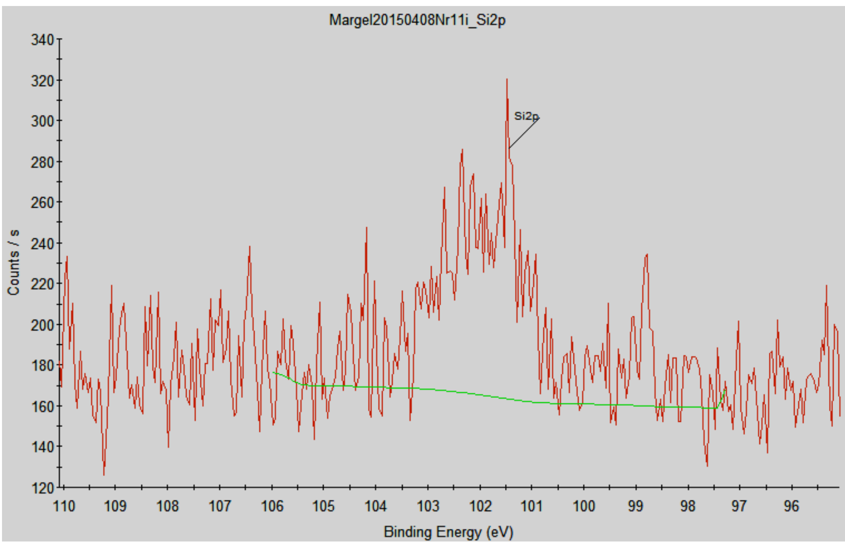
Sample analysis and results



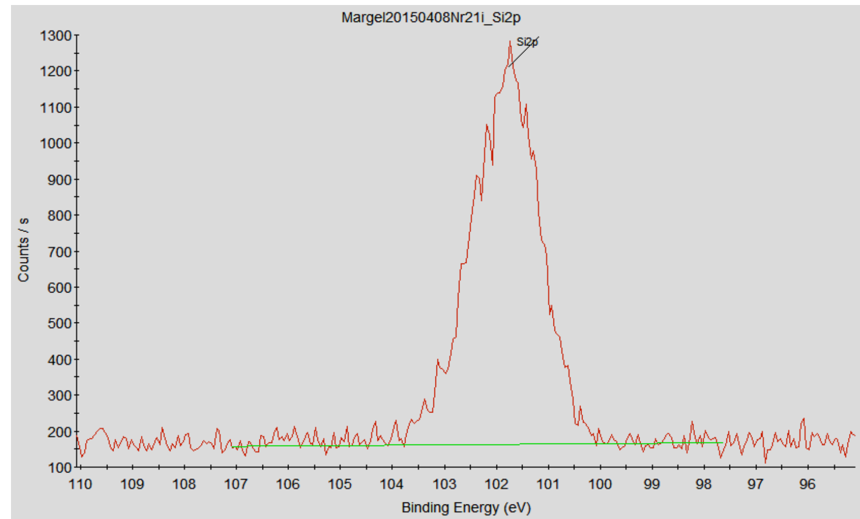


Fig. 4 a. Fuji VPS

Fig. 4 b. YP-Q

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Sample analysis and results

Chemical element	Surface Energy, eV	Atomic concentration, %
Na1s	1071.57	0.2
F1s	688.31	2.8
O1s	532.37	13.8
C1s	284.41	81.9
S2p	168.53	0.7
Si2p	101.44	0.6

FUJI

Chemical element	Surface Energy, eV	Atomic concentration, %
Na1s	1071.18	0.3
F1s	684.89	0.0
O1s	532.03	14.0
C1s	284.32	81.2
S2p	168.74	0.4
Si2p	101.75	4.2

YP-Q

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- CONCLUSIONS
- In the accurate printing, formation of limit resolution of the discrete elements, reproducibility of the element dimensions and uniformity of the ink layer's thickness are determined by physical characteristics of the paper surface/printing plate.

- These factors have a significant influence on formation of elements of 20–40 micron line width and inks' layer thickness of 0.2–0.4 µm. To form elements of such accuracy, the arithmetic average of the inequalities of the surface on which inks are transferred, should be at least twice smaller than the thickness of the formed ink layer.

- Absolute values of the micro relief extremes of the surface and their nature of the spatial distribution determine uniformity of the layer thickness and minimisation of the local defects.

- CONCLUSIONS
- Surface adhesion which depends on the surface interaction with inks, its chemical composition and partially surface morphology plays a vital role in determining accuracy of the element dimension formation and quality of covering the surface with inks, respectively.

- Based on current requirements for the accurate printing and its technologies, regular metrological control tools are not adequate for printing control. Image fragments, individual discrete printing elements of high resolution, graphic prints, geometric reproducibility require modern physical analysis of the surface and chemical composition control methods.

Please, send your questions
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