MATERIALS FOR SECURITY ELEMENTS USED IN PROTECTED DOCUMENTS, OPTICAL EXAMINATION METHODS. A REVIEW.

T. NECSOIU [1], G. BOSTAN[1,2], P. STERIAN[2,3], M. BERTEANU[4]

Abstract. *Each protected document contains a set of security elements, such as paper, inks, stamps, diffractive elements etc., which ensures its protection. It means a complex document protection features, made by special technology and visual features that allow unequivocally establishing authenticity and involves all materials, processes, methods, that allow achieving concrete protective effect, observable, or by using specialized equipment. When talking about physical and chemical methods of protection of the document, we usually refer to optical properties of materials that manifest itself in different regions of the spectrum, the various kinds of luminescence, the ability of absorption, reflection, refraction, diffraction and the magnetic properties of the security elements and pigments. The article briefly analyses representative materials the physical and optical properties of the security elements of the protected documents, characterization methods used and some results of measurements performed.*

Keywords: environment, multicomponent material, fibrous material, material composition, material additives, security elements, protected documents, counterfeits, forensic, document autenticity, ovi inks, colour pigment, watermarks, luminescence, fluorescence, optical methods, spectroscopy, band-pass filters, Bayer demosaicing

1. Introduction

In our activities we are dealing with a variety of documents. Official documents can have security levels. Banknotes, passports. driving licenses, are documents with security features [1].

The protection of documents means the use of variety of features made by specific technology and visual features that allow determining their authenticity [2].

This meaning all materials, processes, methods that allow the concrete effect, visually or by using specialized equipment. In this regard there must be a clear distinction between the elements of protection for the user and for experts. For the user are important elements allowing identification quick and as simple without the use of special equipment, methods and conditions of observation. Watermarked paper is a good example of this. For expertise, in addition to visual characteristics, it is important the confirmation of authenticity using special equipment.

[1]Optoelectronica-2001 SA, Bucharest, Romania.
[2]University "Politehnica" of Bucharest, Academic Center for Optical Engineering and Photonics. Faculty of Applied Sciences, Physics Department, Romania (georgebostan@gmail.com).
[3]Academy of Romanian Scientists, Bucharest, Romania.
[4]University ELIAS Urgency Hospital Romania.

For example, under illumination by infrared radiation can be observed luminescence of specific elements in the visible range.

Only checking the whole set of protective elements may confirm the authenticity of the document.

Discussing about methods of securing documents we consider technological protection, physical-chemical, printing. Technological protection is implemented in the material of the substrate, of the document, generally paper. In the production of paper for documents, are inserted:

– watermarks,

– protection fibre,

– the paper itself is a protective element and has optical properties

– colour pigments,

– holographic images.

Watermark signs are included on paper production stage by varying the thickness of paper.

Imitation (forgery) watermark signs rely on optical density change of paper already made. We distinguish watermarks symbols of two halftones (fig. 1.) or more depending on the complexity of technological prepared special paper.

To study the materials contained in the substrate of the document, some of measures are using, physico-chemical, optical and electronic microscopy, chromatography, spectrophotometry in ultra violet, visible and infrared.

The search for new solutions for document security is still topical. Studies in this area are important because they lead to better security against tampering documents. These problems are studied in specialized centres for the protection of documents. The article briefly analyses representative materials for secured documents, their optical, chemical, properties, methods of detecting counterfeits, optical methods of inspection of documents. In the results, is discussed device diagram for verification of documents, considering the possibility of broadening the functionality, optimization of light sources, efficient use of CMOS camera, studied the interaction of light with materials and quality of recorded images, at the end of the article describe the conclusions.

2. Types of paper

The paper is a capillary-porous material, fibrous (fig. 2.), flexible, the basis of which is the cellulose fibres of vegetable provenance. Many different types of paper are known, of different properties and destination. The papers with various degrees of transparency, from very thin, up to cardboard various thicknesses [3].

The modern paper is a multicomponent material. In order to give the paper special qualities are used, mineral compounds, synthetic dyes.

The fibrous material (fig. 3.) for the paper production is extracted from the wood of conifers, cotton fibres of, synthetic fibres, nylon fibre of synthetic polymers, polyamide. The paper also contains various adhesives, powder of calcium carbonate, gypsum, kaolin, azbestin, silicate of magnesium, etc.

Fig. 1 Watermark is an identifying pattern in paper that appears as various shades

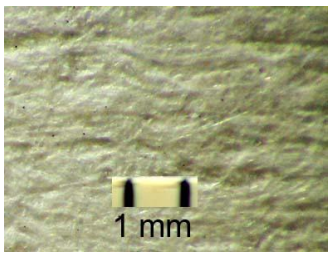

Fig. 2 Paper surface under a microscope

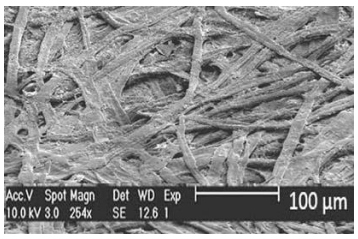

Fig 3 Paper fibers viewed under a microscope

The different types of paper are chemically process, in order to obtain the desired qualities [3]. For example, for bleaching paper, in the paper are introduced white pigments, calcium carbonate, $CaCO_3$ titanium dioxide TiO_2, an artificial pigment, zinc sulphate, $Zn_2(SO_4)_2$, organic compounds absorbing UV radiation of 300 ÷ 400 nm and conversion in 400 ÷ 500 nm, i.e. with the luminescence in the light blue colour, causing the whitening effect of the paper or other desired optical effects. When processing with synthetic substances, cellulose acetate, cellulose nitrate, polyethylene, chlorinated rubber, are obtained waterproof, paper types, vapour resistance, oil resistance. Through the technological procedures are obtained many types of paper: printing paper, electrical insulating paper, paper for filtration, photo paper, cardboard, etc.

The paper document forensics investigation are identify the type of paper, fabrication technology, colour, the thickness, density, weight/(1 m^2), inner structure, layering, security elements contained

3. Optical properties of paper

The paper has important optical properties. Opacity, transparency, light scattering on the surface and in the material environment, luminescence, properties which depend on the material composition of the fibres, thickness, the quantity and the chemical composition of the adhesives. Some optical properties are important through their influence on other properties related to printing, insertion of protective fluorescent fiber [3]. An absolutely white paper will spread on the surface, equally, all spectral components of radiation of the light source in the visible spectrum.

The paper colour is the result of selective wavelength absorption from the spectrum of the source radiation. Higher wave lengths (625 ÷ 759 nm) were red, and lowest (393 ÷ 450 nm) have violet-blue. The colours of the paper that our eyes can see are unabsorbed spectral components and reflected towards the observer.

Printed image quality, their contrast, depends on optical properties of paper. Colour reproduction, in accordance with the IEC, also depends on the optical properties, integral reflection coefficient. Glossy paper is the shiny reflection of light, depends on the quality of the surface, how smooth it is. For specific printing conditions (double-sided) is important opacity of paper, modified by including compounds needed at the stage of production.

The chemical properties are important, for example, anti-corrosion properties, when we inserted metal foils in paper document.

Chemical compounds containing sulphur and sulphates, chlorine can cause darkening of metal surfaces. To avoid such situations, special paper is treated with lead acetate, or zinc acetate. Chemical qualities are important for paper with security features against forgery etc. Microscopic and spectral analysis allows getting important features about the quality of the paper and its applications.

The security paper: as material contains a wide variety of features for authentication purposes [4], it has features that distinguish it from the multitude of existing types of paper. A mix of security features against counterfeiting elements observable at both the surface and intermediate layers.

4. Optically variable colour inks

Colour-shifting inks, ie optically variable colour inks (OVI), reflect different colours of white light incidence, depending on the angle we look at the text area. Our eye will notify a change of colour while the angle of observation is modified. The colour copier or scanner, that records the image at a fixed angle, will record only one colour will lose the information about colour variation depending on the angle of incidence of light.

These colour inks are composed of variable thin film flakes, creating a special blend. Film flakes produce the interference of light reflected from two parallel surfaces, as is shown in (fig. 4.). Light reflected from the two surfaces will interfere constructively or destructively depending on the optical path difference. In particular, we will see different colours depending on film thickness and angle of observation. This thickness is verified in the manufacturing process and cannot be easily reproduced without expensive equipment. The magnitude of the effect depends on the density of optical film flakes, depends on their alignment towards the surface of the paper document. In addition to ink mixture can be added dyes or pigments which can absorb certain wavelengths, having regard the role of optical filters, which can enhance or change colours depending on the angle of observation (fig. 5.).

In different combinations of thickness and stratification of microscopic fragments of thin film, can obtain various colour combinations. Such us: Golden/Green, green/purple, green/blue, blue/green [5,19].

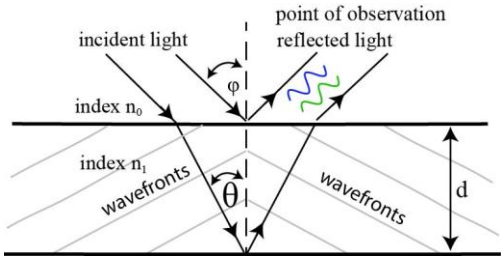

Fig. 4. Thin-film interference.

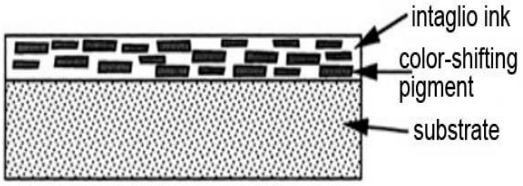

Fig. 5. Pigment ink to achieve colour variation compared to the angle of observation.

Ultrathin film is initially deposited on a planar flexible, substrate, using vacuum sputtering method. Structure absorber / dielectric / reflector / dielectric / absorber is symmetrical as ultrathin film flakes can orient to one side or another. The materials used to obtain the multilayer structure are $Cr/MgF_2/Al/MgF_2/Cr$ or $Cr/SiO_2/Al/SiO_2/Cr$. The thicknesses are: 50 Å, 4000 Å, 900 Å, 4000 Å, 50 Å.

The planar substrate is dissolved and the thin film breaks into small fragments, between 50 and 200 μm diameter, which are stirred by ultrasound to reduce the dimensions between 2 and 20 μm. The average thickness of these fragments is 1 μm. Have a multilayer structure (fig 6.).

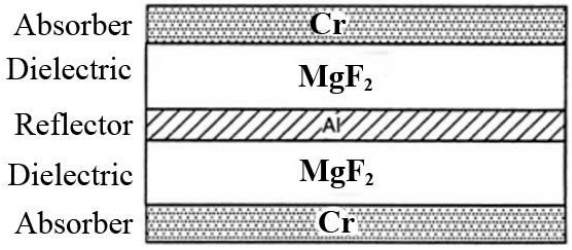

Fig. 6. Multilayer structure for obtaining pigment colour combinations.

Aspect ratio is about 10 to 1. Since the printing ink layer thickness is between 5 and 30 micrometres it helps align parallel to the printed surface. The high technology manufacturing increases the security of this type of inks, surpassing the ability of counterfeiters. Microscopic thin films like those trough which the interference of light is observable, also produce colour variation effect [2, 20-22]. But these films are very sensitive: do not pass the crease test. The small size of the multi-layer film with flakes of the printing ink of variable colours has a significant resistance to mechanical damage of the paper substrate. These elements are already fragmented and dispersed in micron particles in ink, and crumpling does not affect optical performance.

The multilayer film flakes are chemically resistant because they are composed of metallic and dielectric stable material. Moreover, they are incorporated into the mixture ink being protected from chemical exposure. The ink is compatible with intaglio printing and silk screen printing. The effect of colour variation requires the manipulation of angle of observation, from observer, so printed images must have a sufficient surface in order that effect to be real noticeable [5].

Intaglio printing. None of the modern printing methods can reproduce fine lines, which are obtained by intaglio printing process, method known in Germany in the first half of the. XVth century. That is why our money today are printed using this technology, and not by modern and very sophisticated technology.

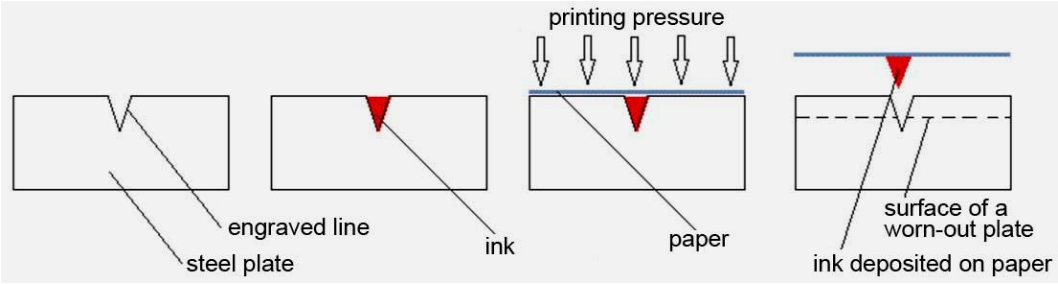

Fig. 7. Intaglio printing process.

Examined with a magnifying glass, a printed line, the pigment of which appears as it would be out of paper surface, comes out in relief (small triangle, fig. 7.). If so, then we can see main characteristics of intaglio print, which indicates us that pattern is genuine; any reproduction will give a blurry print, different from the original, will have no relief, nor contrast of the original [6].

5. Optical methods of documents control

Spectroscopy and spectroscopic measurement methods are in constant development. Spectroscopy methods applied in researching and producing colour pigments, chemical analysis, quality control, pharmaceutical testing, non-invasive medical investigations, monitoring plant growth, testing light-emitting devices and equipment control, pollution control, environmental and forensic investigations

The advantage of optical spectroscopy is that they are non-destructive and provides the ability to monitor the subject studied, without physical contact with it, so spectroscopy is a very developed technological process for [7-10].

Photometry is the measurement of optical radiation as perceived by the human eye. Standard IEC 1931 defined a colour-mapping function called the standard (colourimetric) observer, to represent an average human's chromatic response within a 2° arc inside the fovea (fig. 8) is an attempt to describe colour perception by the human eye, using three colour curves.

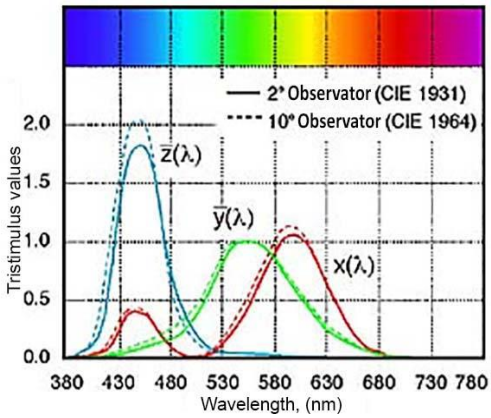

Fig. 8. Tristimulus values.

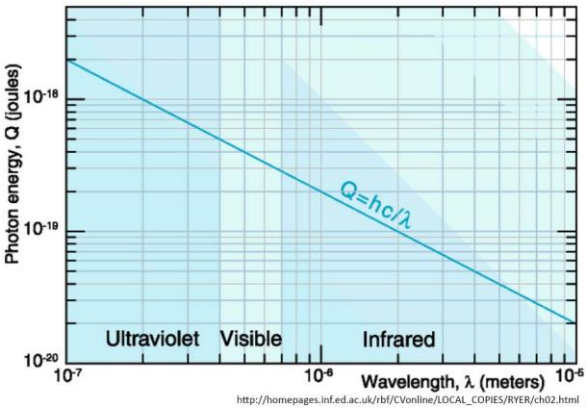

Fig. 9. Photon energy vs. wavelength, in accordance with Planck's equation.

The power of the radiation flux, watt is a fundamental unit of light power energy, is defined as the energy of one joule (J) per second; it is a function that depends on the number of photons and the wavelength.

Each photon carries energy described by Planck's equation:

$$Q = hc/\lambda$$

where:

Q is the photon energy (joules), h is Planck's constant (6.623×10^{-34} J·s), c is the speed of light in the vacuum (2.998×10^{8} m·s^{-1}), and λ is the wavelength of the radiation (m).

All the amount of light energy are distributed spectral, spatial, or temporal [9, 10].

As shown in the (fig. 9.) shorter wavelengths, from ultraviolet light have more energy per photon than in the infrared [9].

Photometry is confined to defining the appropriate optical radiation and measurements of spectral sensitivity of the human eye.

Relations between the photometric and radiometric quantities, and are joined by the spectral sensitivity factor $V(\lambda)$ of the human eye.

Device for controlling authenticity of protected documents. Description of operating principles and technical aspects of expanding device functionality, verification of original documents by optical methods.

The device is designed checking identity documents, and other documents protective elements. It has an enclosure in which is placed face up, document examined.

From the distance of approx. 240 mm is situated CMOS camera that displays on your computer screen, document image in real time (fig. 10).

The camera can zoom into different parts of the document to examine areas of interest. Chamber of the device has a complex lighting system that helps the camera to view areas of interest on the surface of the document.

The optical scheme of light sources. Light sources ensure a controlled flow of light, to avoid the appearance of scattered rays, unwanted reflections, what creates unwanted shadows on image affects image sharpness, contrast. Sources of light are mounted in a closed box.

It has several light sources for various types of lighting which differentiates it, a) by the emission spectrum: visible, ultraviolet, infrared, against certain bulbs are placed optical band filters to highlight various aspects of the document image. The spectral characteristic of bulbs ensure efficient lighting of document that contain elements of different colours; b) by the type of lighting, oblique, coaxial, transmission. The reflection from paper of document is diffuse, for plastic laminated documents, lacquered with glossy surfaces different angle of illumination is selected, to obtain better diffuse reflectance. In the case of metallic elements, highly reflective, it recommends lighting polarized light, so that the rays that give shine to be rejected and reflections in scattered light to be accepted. The appliance is equipped with special software that processes the acquired images recorded by the camera. In front of the camera lens is located two turrets with optical filters, used to filter reflections from areas under examination of the document. The combination of optical filters can be: passing down, high pass, band pass, for different spectral ranges. Some of the filters can be removed from the optical scheme, replacing the current lamps with LEDs with necessary emission spectrum. The lighting system is equipped with UV (ultraviolet), lamps for viewing fluorescent fibres protection, inserted in paper of document. The document to be examined is placed on a matte glass plate which has lighting bulbs underneath, lighting by transmission for semi-transparent sheets

Camera lens must have a sufficient optical zoom to view the Microprint, $0,1 \div 0,2$ mm, a technical problem that requires optimization, by finding solutions to technological upgrade; the lighting scheme is controlled by computer software. The optical system of the device is presented in figure (fig. 11).

The device is composed of a camera with 5 megapixel CMOS sensor, connected to the PC contains various light sources that provide illumination efficiency, bandwidth optical filters.

In the paper, multiple images, were recorded and examined, explore ways to highlight the microtext from the background, that almost blends in certain specific lighting conditions (fig. 12-14), the presence of some spectral components which make it difficult to record with a digital camera; methods of improvement through the study of reflection spectra of paper, before processing with the help of specialized software, it is necessary that the optical system can record images of sufficient quality.

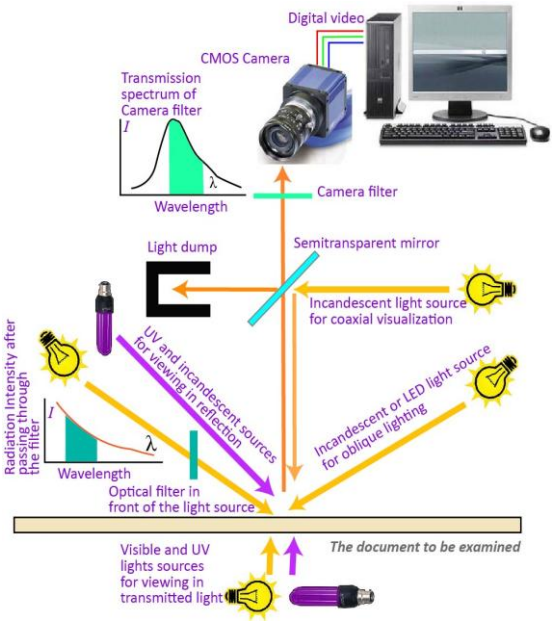

Fig. 10. Device schema for documents authenticity verification.

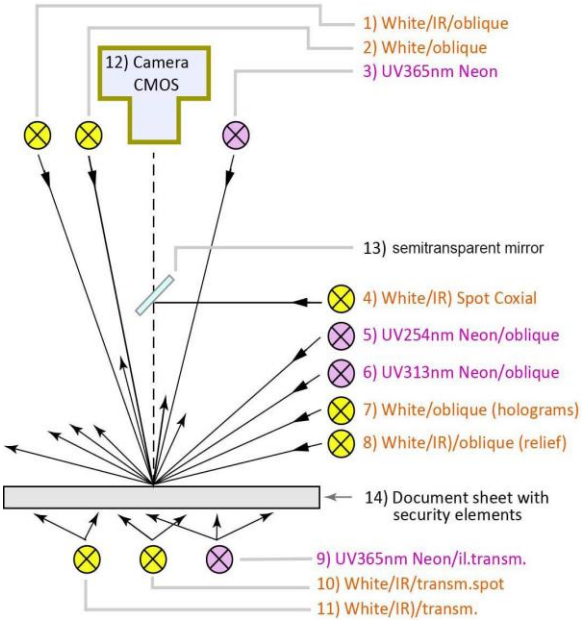

Fig. 11. The optical scheme of light sources.

Selective absorption in the visible spectrum is the way dyes to show their colour that we see. If the light that illuminates a blue object, does not contained blue light, the object will appear black to the observer.

Result, the light that illuminates the subject should contain spectral components that dye to absorb, reflect or diffuse and develop the dye colour or colour of printing pigment.

Light scattering is another component of formation colour tones.

After the selective absorption of light some of the rays are scattered by pigments. At the same time the scattering of light contributes to opacity [16].

Manipulating source emission spectrum of light we can control the reflection and image quality. To increase the contrast of the recorded images need proper selection of lighting sources.

The camera sensor uses Bayer demosaicing algorithm, for interpolation and processing recorded image, does not provide authentic data about colour, so as shown in fig. 18.

Because colour coordinates depend not only on the reflection spectrum of the object, but the spectral properties of the illuminant, colorimetric perception suffering from metamerism, objects of the same colour may appear different colour when illuminated by another source.

6. Results

Interaction between light, inks and paper.

Low contrast images are the result of the lighting sources with improper emission spectrum. Spectrum of lighting source should contain spectral components that will be better reflected at items on the document to be examined [11,17], and the background to reflect how much less.

Microscopic image recorded, (fig. 12), is presented for consideration a document fragment of low contrast, which contains micro printing 0.1 mm, recorded with a CMOS camera.

The document contains elements that are difficult to view, because they are on a background that has shades of close colours, as a result have low contrast image and sharpness deteriorates due to incidents light scattering in the paper fibrous substrate (fig. 13), which in some adverse conditions may increase the loss of contrast.

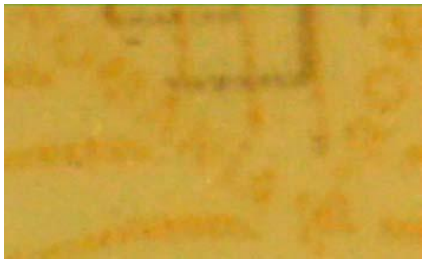

Fig. 12. Low contrast image.

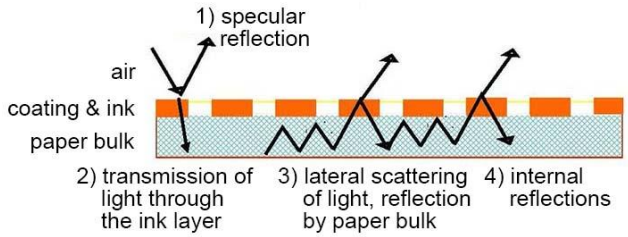

Fig. 13. Interaction between light, inks and paper.

Some radiation from the emission spectrum of the light source can interact with the background, generating a weak luminescence of the fibres of the paper substrate (fig. 12), multiple internal reflections in the paper substrate medium [12,18], in printing pigments and other effects of light scattering (fig. 13).

Before talking about the quality of the lens, the camera lens, the optical resolution (lines per mm), it is necessary to analyse the phenomenon of diffusion of light rays, how substrate colour is change depending of change in emission spectrum of the lamp (fig. 14).

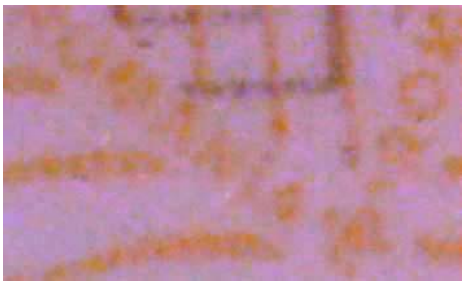

Fig. 14. Lighting conditions modified for fig 12.

For the estimation of influence, it is necessary to modify optical band of radiation source with the pass filters and watch under a microscope, contrast modification for each optical filter.

It is important to have adjustments for the angle of incidence of the light flow. Image from fig. 12, has a very narrow palette of colours, (small differences between shades), the figure 15 shows the colour palette of image from fig. 12.

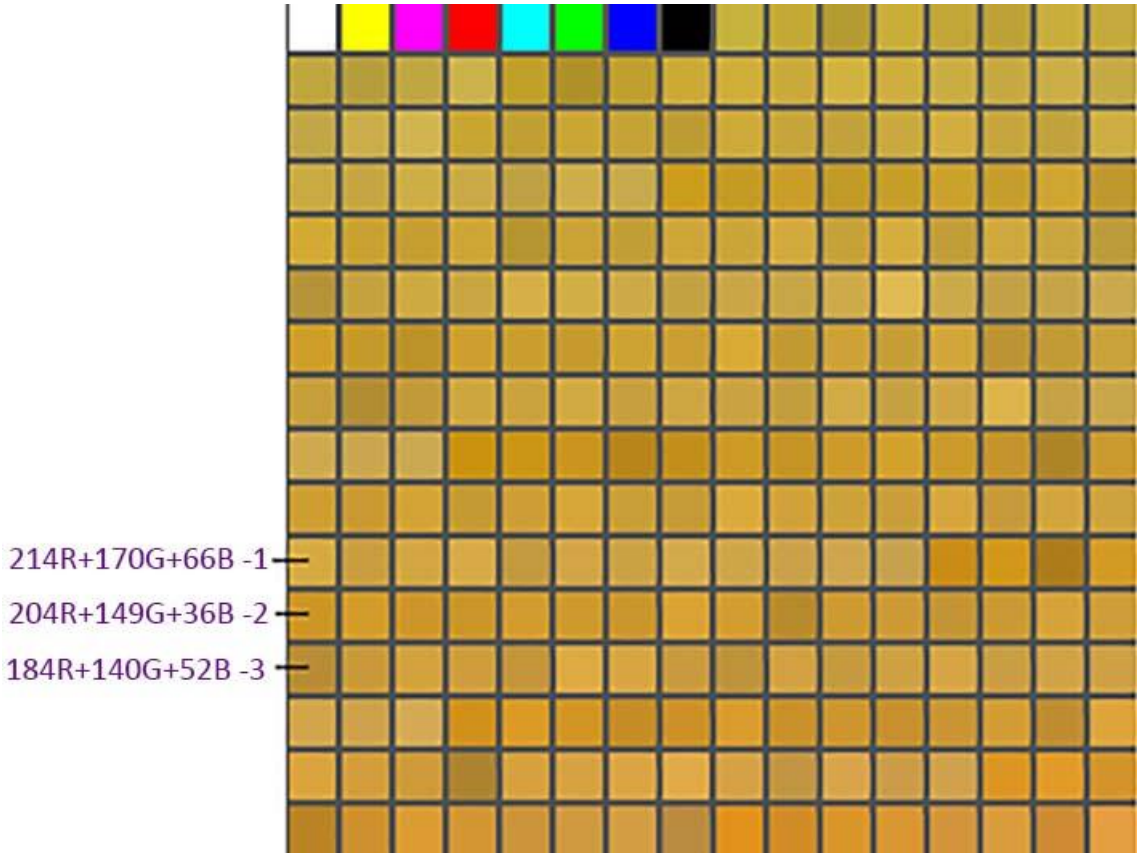

Fig. 15. A limited colour palette of image in fig. 12.

For example:

colours 1, 2 and 3 are very close to the human eye, but have different RGB components.

To achieve a good contrast is necessary to have adequate lighting.

To select the correct light source, you need to estimate the reflection spectrum of the surface to be examined.

In fig. 16 shows the emission spectrum from an orange region of the document.

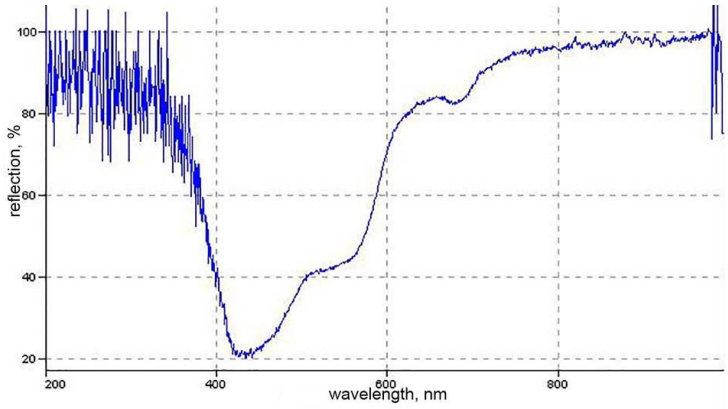

Fig. 16. The reflection spectrum of orange pigment.

Often it is counting on the magical qualities of the CMOS camera, which does not always unravel, that in the situation examined here. In conclusion, the camera must be helped through a proper illumination. Taking into account the discussed above, about the lighting source and her spectrum the emission spectrum, about the diffusion of the light in the environment of the paper and reduce the contrast, the observations of the other authors [11,23], we can say that it is recommended to manipulate the light source, than to filter out diffuse reflection that reaches the camera, in certain situations, as described, optical band-pass filter should be placed in front of the bulb, not in front of the camera.

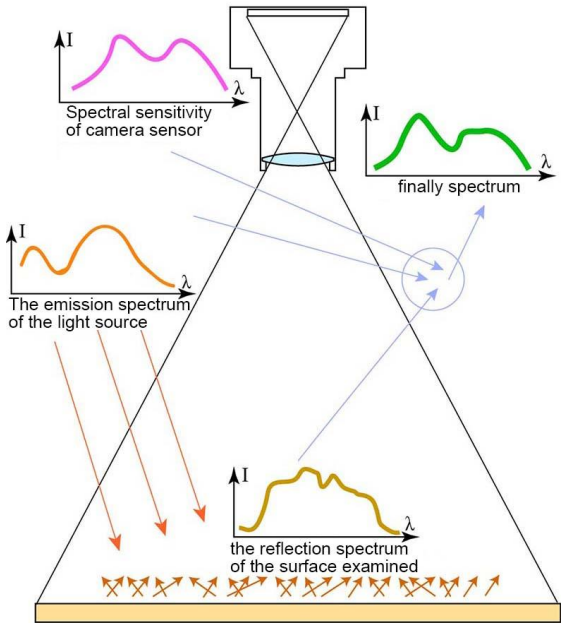

Fig. 17. The superposition of the spectral characteristics.

It is true spectrum of optical radiation that reaches the sensor is a sum of light source spectrum, the reflection spectrum of the paper document and the spectrum sensitivity of the camcorder, but it does matter the order in which you add up these terms, since the optical path toward the camera, optical diffusion phenomena occur and fluorescence, uncontrolled in the fibres of the paper (fig. 17), in certain circumstances, of course, because here are some concrete cases, examines (fig. 12) was registered with a camera of latest technology, but due to inadequate enlightenment was obtained a low contrast, it is a special case, which is being examined.

At the same time with the evolution of technology, a new feature of the device is implemented: spectroscopic analysis of ink signatures and stamps. Some equipment manufacturers, shows the technical specifications of the machine, a new function for colorimetric measurements using CMOS camera and linear interference filter placed in front of the camera. To understand the functioning, it is necessary to remember how colours are register by optical sensor with Bayer filter aid [13, 14].

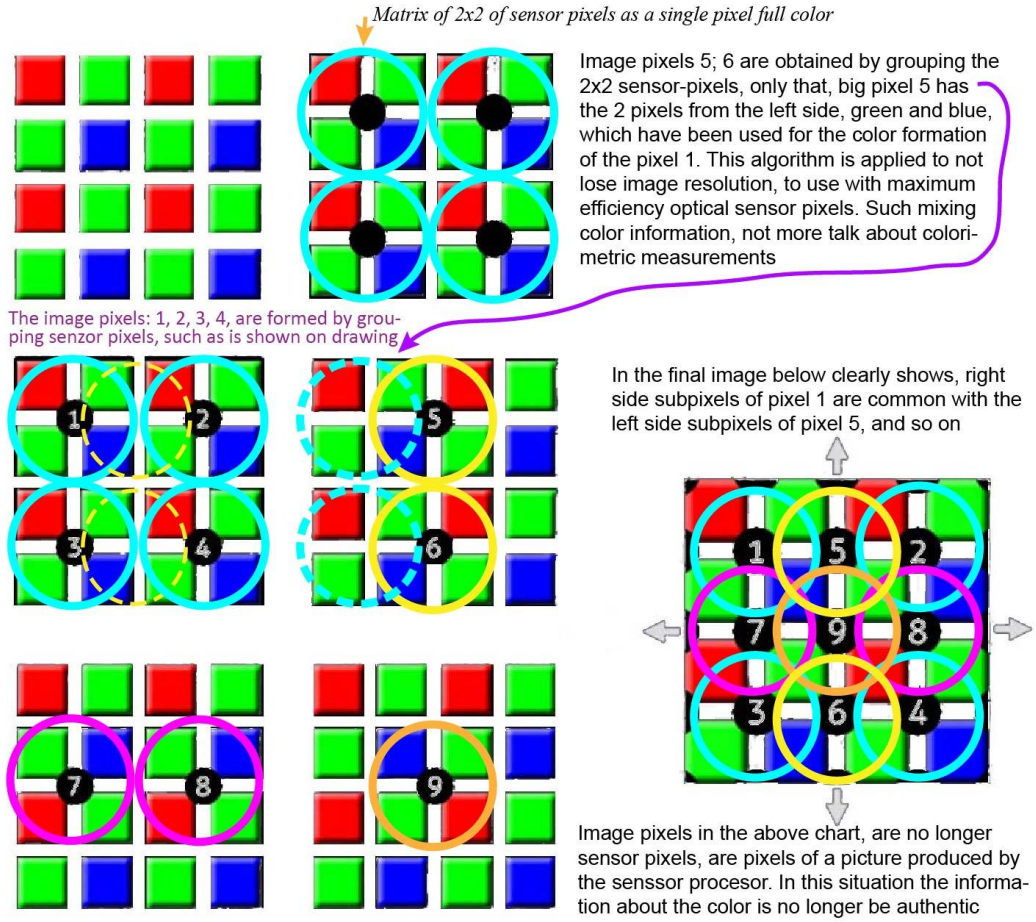

Fig. 18. Bayer demosaicing algorithm.

Bayer demosaicing, is a transfer algorithm of Bayer matrix, containing data about the three RGB primary colours in the final image with complete data about colour for each pixel separately [15,23]. To understand, let's examine a matrix of 2×2 pixels as a single pixel full colour (fig. 18). If camera would treat a 2×2 pixel arrays as a single pixel full colour, sensor resolution would halve, both horizontally and vertically. For neighbouring pixels colour not register directly but, is calculated. The camera calculates the colour using the overlapping matrices, so the image resolution increase, compared with 2×2 matrices which are presented as a single pixel full colour.

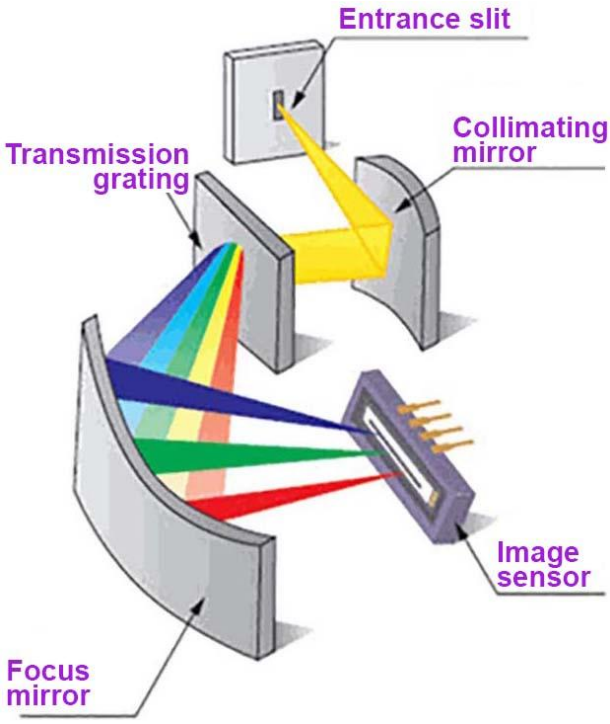

Fig. 19. Linear optical sensor array for spectrometry.

Sensors for spectrometers are linear array of photosensitive pixels, connected in a well-planned optical scheme, did not have to face the Bayer filter, on the photosensitive cells falls monochromatic light (fig. 19). Unlike the photo camera, spectrometer decomposes into monochromatic rays light that are reflected from the area analysed.

From the recorded test images (fig. 12, 14), results that the type of lighting is very important for getting a good contrast, especially if they needed highlighted areas of the image colours very close to those of the background. The presented results will help to optimize the operation of the equipment, the widening capacity to distinguish close shades of colour Contrast examination methods by recording reflectance spectrum, proposed in the work will allow perfecting device.

7. Conclusion

The article discusses the physical and optical properties of the materials of the security elements of the security documents, characterization methods used and some results of measurements performed.

The camera sensor uses Bayer demosaicing algorithm, for interpolation and processing recorded image, does not provide authentic data about colour, so as shown.

Spectra that are seen by the human eye as different can be seen by the video camera and displayed as identical or nearly identical.

R E F E R E N C E S

[1] Rudolf L. van Renesse, *A Review of Holograms and other Microstructures as Security Features*, Formerly with TNO Institute of Applied Physics. Delft, the Netherlands: since **2002** Van Renesse Consulting, The Hague, The Netherlands.

[2] Peter Bamfield, Consultant. Chromic Phenomena *The Technological Application of Colour Chemistr*, The Royal Society of Chemistry **2001**.

[3] Hubbe et al. (**2008**) *"Paper's Appearance: A Review"* BioResources **3**(**2**), 627-665.

[4] Raymond L. Garner *Creating security documents on the MECCA 2000 System*, Amgraf, Inc., September 17, **2000**.

[5] COUNTERFEIT DETERRENT FEATURES FOR THE NEXT GENERATION CURRENCY DESIGN. COMMITTEE ON NEXT-GENERATION CURRENCY DESIGN. NATIONAL MATERIALS ADVISORY BOARD. Commission on Engineering and Technical Systems. National Research Council. National Academy Press, **1993**.

[6] Terminology Page. http://www.martin**2001**.com/terminology/terminology.html.

[7] 7.Christopher R. Jonson, *The visualization handbook*, **2005**, Elsevier Inc.

[8] Iordache, D. -A.; et al., "Complex Computer Simulations, Numerical Artifacts, and Numerical Phenomena", International Journal of Computers. Communications & Control Volume: 5, Issue: 5 Pages: 744-754, Published: DEC **2010**.

[9] Iliescu, F. S.; et al., *Continuous Separation of White Blood Cell from Blood in a Microfluidic Device*, University Politehnica of Bucharest, Scientific Bulletin – Series: A-Applied Mathematics and Physics Volume 71, Issue 4, pages: 21-30, Published: **2009**.

[10] Sterian, A. R**.,** *Amplificatoare optice*, Printech Publishing House, Bucharest, 336 p., (ISBN 973-718-434-3, 978-973-718-434-4), **2006**.

[11] Jun Jiang and Jinwei Gu, *Recovering spectral reflectance under commonly available lighting condition*, Rochester Institute of Technology, 54 Lomb Memorial Drive, Rochester, NY, 14623.

[12] Roger David Hersch *Spectral reflectance prediction models for the characterization & control of colour printers* Ecole polytechnique Fédérale de Lausanne (EPFL) Switzerland.

[13] Rajeev Ramanath, Wesley E. Snyder, Youngjun Yoo, and Mark S. Drew, *Colour Image Processing Pipeline*, IEEE Signal processing magazine, January **2005**.

[14] Douglas A. Kerr, *Colourimetric characterization of digital camera sensors*, Issue 1, October 18, **2015**.

[15] BAYER demosaicing, http://www.cambridgeincolour.com/tutorials/camera-sensors.htm.

[16] *Scattering Absorbtion Opacity*, https://www.sabic-ip.com/cxp/jsp/user/LearnAboutColour/ColourBasicsDetail/scatter_opacity_transparency_translucency.jsp.

[17] L.Fara, V. Iancu, M. R. Mitroi, E. Nistor, *Bazele fizice ale nanotehnologiilor. Aplicații și perspective*, ISBN 978-973-8323-42-1, București, Editura Punct, **2007**.

[18] Andrei D. Petrescu, et al., *Solitons Propagation in Optical Fibers Computer Experiments for Students Training*, Computational Science and its Applications – ICCSA 2007, Volume 4705 of the series Lecture Notes in Computer Science, pp 450-461, **2007**.

[19] Ninulescu, V; Sterian, AR, *Dynamics of a two-level medium under the action of short optical pulses*, Computational Science and its Applications - ICCSA 2005, PT 3 Book Series: Lecture Notes in Computer Science, Volume: 3482, Pages: 635-642 Published: **2005**.

[20] Manaila-Maximean, D. and Red, C., **2004**, *Influence of Polarizing electric field on electrical and optical properties of PDLC films*, Molecular Crystals and Liquid Crystals, 413 (1), pp. 9-19.

[21] Rosu, C; et al., Influence of Polarizing Electric Fields on the Electrical and Optical Properties of Polymer-Clay Composite System, Modern Physics Letters B, Volume: 24, Issue: 1, Pages: 65-73, Published: Jan. **2010**.

[22] Rogojan, Rodica, et al. *Spectral behavior and nonlinear optical properties of aluminophosphate semiconductor-doped glasses*, 11th International School on Quantum Electronics: Laser Physics and Applications. International Society for Optics and Photonics, **2001**.

[23] Spulber, C., *Some contributions to the image analysis in ambient perturbations by using an integrated video sensors system*, Annals of the Academy of Romanian Scientists Series on Science and Technology of Information , Volume 8, Number 1, pp. 47-55; **2015**.