

## NEAR INFRARED SPECTROSCOPY OF COLORANTS IN SECURITY DESIGN OF POSTAGE STAMPS

### *NEAR INFRARED SPEKTROSKOPIJA PIGMENATA BOJILA U SIGURNOSNOM DIZAJNU POŠTANSKIH MARAKA*

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#### ABSTRACT

In honor of the 350th anniversary of the University of Zagreb, a commemorative postage stamp is issued to which our new security printing design method with NIR dual image called INFRAREDESIGN® is applied. This paper describes spectrography of light absorption in visible and near infrared spectral region for the colorants on this postage stamp. The description includes spectra of colorants as well as spectra of their separated components: cyan, magenta, yellow and key (black). Digital, experimental printing is a predecessor of a large circulation printing. There is a slight difference between colorant recipes (for the same color) prepared for digital printing and those for offset printing. IRD, applied in security of postage stamps, implies coloring that differently manifests itself in visible spectrum and in near infrared spectrum. Equal color twins with different colorant composition are introduced in "IRD numismatics" technology. To meet the requirements of public tender for the postage stamp design, the design concept was executed by digital printing. In printing of securities there are two levels of execution, performed in two steps.

Large circulation stamps are issued into the philatelist world by the method of offset printing. Both stages in the postage stamp production have the same colorants. Therefore, two groups of twins of security recipes for colorants are prepared in order to achieve the infrared security effect with respect to the requirements of both public tender documentation and large circulation for numismatics.

Development of IRD technology allowed me to extend graphic preparation method in security printing of postage stamps under the name "VZ-PM separation", which is a special type of Gray Component Replacement - GCR method.

**Keywords:** *Security graphics, NIR spectroscopy, computer graphics, IRD numismatics, INFRAREDESIGN®*

#### SAŽETAK

Povodom 350 godina Sveučilišta u Zagrebu, izdana je prigodna poštanska marka na kojoj je primjenjena naša nova zaštitna tiskarska, dizajnerska, metoda s NIR dualnom slikom pod nazivom INFRAREDESIGN®. U ovom članku se objavljuje spektrografija apsorpcije svjetla za vizualno i blisko infracrveno područje za bojila na toj poštanskoj marci. Prikaz obuhvaća spektre bojila i spektre njihovih izdvojenih komponente: cijan, magenta, žuta i crna. Digitalni, pokusni tisak je prethodnica tisku visokih naklada. Recepture bojila (za istu boju) pripremljene za digitalni tisak i za offset se malo razlikuju. IRD u primjeni zaštite poštanskih maraka podrazumijeva bojanje koje će se manifestirati različito u vizualnom spektru i u bliskom infracrvenom spektru. U tehnologiju „IRD numizmatika“ uvodim blizance jednakih boja, ali različitog sastava bojila. Za potrebe javnog natječaja izrade poštanske marke, prijedlog dizajna se izveo digitalnim tiskom. Sigurnosni tisak vrijednosnice ima dvije razine izvedbe; u dva koraka. U filatelistički svijet izdaje se marka u visokoj nakladi metodom offsetnog tisaka. Oba stupnja izrade poštanske marke imaju jednake boje.

Zbog toga se pripremaju dvije grupe blizanaca sigurnosnih receptura bojila kako bi se postigao efekt infracrvene zaštite; i u razini natječajne dokumentacije kao i u razini tiska visoke naklade za numizmatičke potrebe. Razvojem IRD tehnologije proširila sam grafičku pripremu u sigurnosnom tisaku poštanskih maraka pod nazivom „VZ-PM separacija“, a koja je specijalni oblik Gray Component Replacement - GCR metode.

**Ključne riječi:** *Sigurnosna grafika, NIR spectroscopy, computer graphic, IRD numizmatika, INFRAREDESIGN®*

## 1. INTRODUCTION

### 1. UVOD

Postage stamp, along with many other roles it assumes, is one of the facilitators and channels of communication through which a country expresses its identity and creates its good image. Applying innovative technique of controlled dual image in visible and infrared spectrum to the postage stamp production is an example that promotes Croatian Post stamp issues, which represent the Republic of Croatia as a unique country in the world, being especially interesting for philatelists worldwide.

Although postage stamps are almost 200 years old, they are still up-to-date and particularly valuable graphic product. Postage stamp, as a medium, has broad visual aspects related to events, famous sights, phenomena, and occasions in social environment. One of those aspects is innovative application of infrared printing that enables “an image within an image“, which has been applied to four issues of postage stamps of the Republic of Croatia.

Postage stamp is a security which I designed using V and Z colorant twins. Z colorant group includes colors for designing graphics that can also be recognized by infrared camera [1]. On the other hand, V colorants are used to design the graphics which infrared camera cannot identify. The term “twins of colors and colorants“ is introduced as a sub-group of VZ dual colorants [2].

Those are two or more equal colorants that differ from each other according to their response to infrared spectral region. Z colorants absorb light in two spectra: in near infrared area (800 to 1000 nm) and in visible spectral region (within the range from 400 to 700nm) [3]. The pigments are added the Z parameter as the numeric value of light absorption at 1000nm [4].

IR graphics was first introduced into our banknotes about thirty years ago. The difference in relation to IRD method is in the domain of computerization [5]. There are two particular features that appear on banknotes (e.g. on Kuna and Euro banknotes) when NIR counterfeit banknote detection is implemented. All graphic elements can be seen by the naked eye. Z camera does not show a considerable part of the banknote [6].

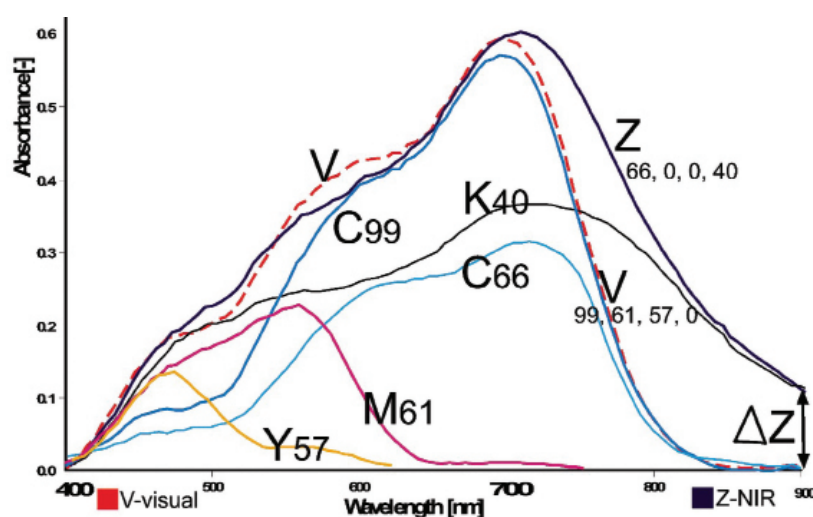
The first group of graphic solution, which cannot be seen by the Z camera, is executed by the so-called V colorants which do not absorb Z band wavelength. The other part of the banknote is colored with the Z colorants, so that the graphics is visible by both the naked eye and NIR camera. So far, hidden, invisible graphics has not been applied to banknotes [7]. Hidden graphics, which is applied in my design of postage stamps, is a novelty in our IRD printing technology.

## 2. SPECTROSCOPY OF COLOR TWINS IN POSTAGE STAMP DESIGN

### 2. SPEKTROSKOPIJA BLIZANACA BOJA U DIZAJNU POŠTANSKIH MARAKA

Color equality is measured in  $\Delta E$  measurement size by relations described by the authors Glogar and Parac-Osterman, which refer only to the visible spectral region [8]. IRD procedure used in printing implies colorant composition with carbon black [9]. Colorant twins applied in IRD include given Z values at 1000 nm.

After obtaining equality within the range from 400 to 700nm, absorption light graph shows abrupt separation, although our eye perceives light up to 780nm.



*Figure 1 Spectrography of colorant twins on the postage stamp "S350": components and twins*

*Slika 1 Spektrografije za blizanca bojila na poštanskoj marci „S350“: komponente i blizanci*

The range from 700 to 800nm is denoted as Z1. ZRGB camera still shows both V and Z graphics. Z2 range is also introduced to achieve light spectrum in which V and Z images in ZRGB camera are different, separated and selected. The article published in 2017 [10] describes domains of certain printing inks which take only their specific narrow space.

Yellow pigment has absorption maximum at 460nm when width ranges from 400 to 520 nm; Magenta has the range from 420 to 630nm with absorption maximum at 550nm; Cyan from 500 to 780nm with absorption maximum at 700 nm. Carbon black covers visible and infrared spectrum with maximum absorbance at 730nm and typical "hump"(hump on the back) at 550nm. The term S "colorant" is introduced, which is manifested in all hues of gray tone.

S colorant is a mixture of C, M and Y. As none of C, M, Y pigments absorb light in the Z2 spectral region, S colorant is a gray twin of the Z gray color which consists of carbon black and white pigment. S colorant has a hump at the same place (550nm) as the carbon black colorant. Up to 50% gray hue coverage, S and K colorants equally absorb light within the range from 400 to 700nm. It is the similarity of spectral shape of S and K colorants and the dissimilarity beyond 700nm that initiated the application of GCR method for VZ separation as well as the research into the twin systems of colors and colorants.

This paper presents light absorption graph for colorant twins (design concepts) that can be found on the postage stamps I designed.

It is a series of colorants on the stamps for experimental printing. Table 1 includes numeric data of the twins for digital printers. In the C,M,Y,K process color system, planned invisibility of hidden information is achieved for the given printing technique by "VZ" separation method which is a special type of Gray Component Replacement - GCR method.

Digital RGB image is separated by the VZ procedure in the CMYK system of color arrangement with beforehand given information for the K channel [11].

Researches into the colorants for offset printing for large circulation in IRD technology was first developed for newspaper printing and for production of photo monographies in the field of fine arts. [12]. For each specific IRD use, the colorant twins recipes were prepared, the same was done for multiplying postage securities – stamps.

Colorant twins are prepared for two printing techniques: digital and offset, i.e., those technologies to be applied to the design concept of postage stamp that will be submitted for the public tender (Fig.1). In RGB, definition the colors are: 0, 100, 150 (28). The values of recipe of C, M, Y, K components of twins for experimental digital printing are as follows:

V: C 99%, M 61%, Y 57% K 0% ;

Z: C 66%, M 0%, Y 0%, K 40% (Fig. 1).

"Infrared group" of researchers have developed several mathematical models of VZ separation [13].

All those relations are far from academic learning about prepress conversion of RGB into CMYK, by the traditional GCR procedures and colorsetting. IRD requires high-level equality between the colorant twins ( $\Delta E$  minimization) in visible spectrum for the planned printing technique and colorsetting.

This paper puts emphasize on the twins and the twin spectrography with 40% participation of carbon black colorant. The colorants with added carbon color components are carriers of hidden IR information on postage stamps.

### 3. POSTAGE STAMPS OF THE REPUBLIC OF CROATIA PERFORMED BY IRD

#### 3. REALIZIRANE MARKE REPUBLIKE HRVATSKE S IRD DIZAJNOM

##### 3.1. THE FIRST POSTAGE STAMP CARRIED OUT BY IRD TECHNOLOGY

##### 3.1. PRVA MARKA S IRD TEHNOLOGIJOM

On 1 July, 2013, Croatian Post put into circulation a commemorative postage stamp and a postage stamp block on the occasion of the accession of the Republic of Croatia to the European Union. For this particular event, a special issue was prepared which, by the technique and printing, was the unique in the world. The motif on the stamp, denominated 3,10 Kunas in the so-called Croatian stamp sheet, shows the European Union - the Republic of Croatia flag pair, while the stamps in the block of stamps, denominated 20 Kunas, show the motif of Croatia on the European map. Croatian Post issued, as the first day cover (FDC), two stamped envelopes and a commemorative album. The first day cover postmark has been in use in the Post Office in Jurišićeva str. 13, 10101 Zagreb.

In its stamp issues, Croatian Post first “built in” the scientific innovation INFRAREDESIGN (IRD), which implies a design of two interdependent images on the same surface [2009 IRPh].

At INPEX, the leading world exposition of innovations and new products, this innovation was awarded a gold medal and a special award for the best European innovation. This is also the first postage stamp in the European Union for which the new technology enables presentation of double images.

One image is visible to the naked eye in the normal circumstances, while the second is visible in near infrared spectral area i.e., with infrared glasses or infrared camera. On the printed sheet of 25 stamps in 30 fields, under infrared light, in the background of the stamp, we can see Croatian coat of arms and five stars of the EU flag, while the first two stanzas of Croatian national anthem can be seen in the block of stamps. On 1 July, 2013, Croatia became the 28th star on the EU flag, and for that occasion Croatian Post issued this really extraordinary postage stamp for numerous philatelists.

<https://www.posta.hr/pristupanje-hrvatske-euroskoj-uniji/456>

##### 3.2. MINERALS AND ROCKS, PREHNITE (24/10/ 2014)

##### 3.2. MINERALI I STIJENE, PREHNIT (24. 10. 2014)

The other stamps I designed applying IRD technology included the motif of green-schist (Mt. Medvednica) 600:ZAG; 1028:MP1, and prehnite (Komiža, the island of Vis) 600:ZAG; 10027:MP1.

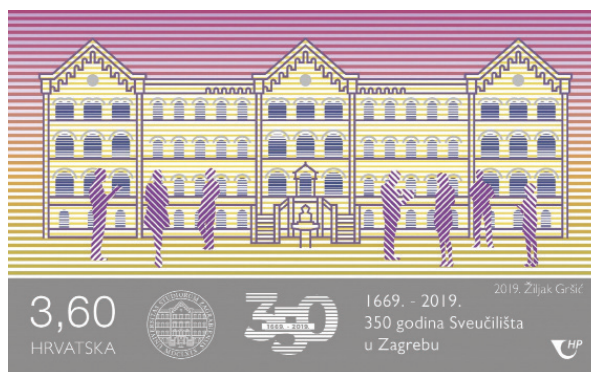


Figure 2 “Postage stamp 350 years of the University of Zagreb”

Slika 2 „Marka 350 godina Sveučilišta u Zagrebu”

In the background of the block, under the motif of green-schist, in the infrared light, we can see the parish church of Majka Božja Sljemenska Kraljica Hrvata at Mnt. Medvednica, and the coastline of the island of Vis under the prehnite motif [15].

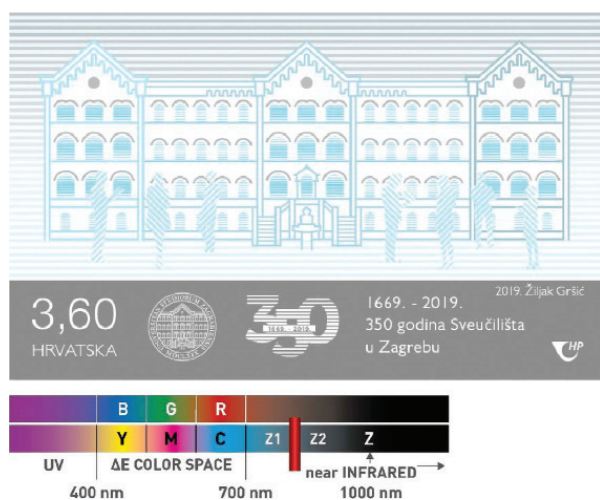
<https://www.posta.hr/hr/pregled-postanskih-maraka/195?m=53515>

### 3.3. POSTAGE STAMP ISSUED ON THE OCCASION OF THE 1000TH STAMP OF THE REPUBLIC OF CROATIA

#### 3.3. POŠTANSKA MARKA POVODOM TISUČITE MARKE REPUBLIKE HRVATSKE

“One thousand stamps“, was the reason to make a decision for issuing a special stamp. Hundreds of designers with numerous amazing ideas and masterpieces, many of which had received international awards, applied to the “thousand stamps“ public tender.

“Denomination: 3,1 HRK; Design: Jana Žiljak Vujić, graphic designer, Zagreb; Size: 35,50 x 35,50 mm; Paper: white. 102, gummed; Perforation: comb, 14; Printing multicolor offset + infrared technique“. Issue date: 27 April, 2015. Circulation: 300,000.



<http://jana.ziljak.hr/S350.mp4>  
<http://jana.ziljak.hr/S350.swf>

**Figure 3** Animation of “Stamp350“ with blocked light spectrum from 400 to 1000nm

**Slika 3** Animacija „Marke350“ s blokadama svjetlosti od 400 do 1000 nm

Motif: A thousand fields – symbols of postage stamps. The stamp was issued in a 9-stamp sheet; Croatian Post also issued commemorative first day of issue cover (FDC) as well as commemorative postcard. On the background of the stamp, under infrared light, the visible text reads: “1000 stamps of Croatian Post“. Computer graphic solution is described in the textbook “Sigurnosna grafika“ on the pp.157,165- marka 1000 ISBN 978-953-7048-33-4, eng: address:[16]

### 3.4. POSTAGE STAMP ISSUED IN HONOR OF THE 350TH ANNIVERSARY OF THE UNIVERSITY OF ZAGREB

#### 3.4. IZDANJE MARKE POVODOM 350 GODINA SVEUČILIŠTA U ZAGREBU

Designing a stamp is a challenging and demanding task. The goal is to achieve as good harmony and visual impression as possible on a confined space. This paper first presents spectroscopy of stamp colorant, particularly on the example of the stamp which marked the 350th anniversary of the University of Zagreb (on 30 October, 2019).

Recognizable building of the University of Zagreb (Rectorate) is presented in visible spectrum by vector graphics where the visualization of students and their professors standing in front of the building adds dynamic to the image. Designer elements on the stamp include data such as denomination, the year of issue, visual identity of the 350th anniversary of University of Zagreb, Croatian Post P logo and the authoress's name.

This paper describes the stamp as a proposal, as a design concept and technological solution including visible and infrared spectrum. Postage stamp is a security, so the numeric values of the colorant twins (for the large circulation in offset printing) by the IRD method are not released in this open-access article.

The stamp “S350“ is a video example of the approach to learning about spectroscopy in the V and Z area. The stamp is recorded by PAG Projektina video camera which has 24 filters within the range from 240 to 1000 nm.

Photographies are joined for the video presentation with the option of stopping at the desired light frequency, i.e., studying the results of the color blockage (RGB) and printing colors (CMYK).

The stamp design is adjusted to the textile printing. For the occasion, a dress was made which differently manifests itself in visible and near infrared light. The photo is taken by ZRGB camera (Figure 4). Z camera does not have its own source of NIR radiation, so the NIR component of sunlight is used (Figure 4). In the camera, filters are replaced for visible and NIR spectral area. Such Z camera [6] records NIR radiation, which is manifested as a quantity of absorbed light at 1000nm.



*Figure 4 Dress designed for V and Z daylight wavelength.*

*Slika 4 Haljina sa dizajnom za V i Z valno područje dnevnog svjetla*

## 4. CONCLUSION

### 4. ZAKLJUČAK

For the postage stamp project, I worked out the area of twins for continuous values of  $L^*a^*b$  in colorimetric system, which are used to define numeric values of light and colors. This paper presents the color which is created as V and Z twins. The graphic values of light absorption of the colorant components as well the mixture used to execute printing are given, too.

The stamp S350 is viewed in continuous stages recorded in 24 blockages of light. Presenting the stamp is extended with photography in various light blockages in visible and near infrared spectral region. In designing the stamp, our original high security system was planned and introduced under the name "INFRAREDESIGN". Our security technology applied in the domain of postage stamp printing is extended to the printing technology used in dying of textile. The IRD image of the stamp is transferred to a dress, as its unique solution. Our intention was to mark the 350 years of the University of Zagreb with an innovation developed in this country.

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### 5. REFERENCE

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