# INFLUENCE OF MATERIAL COMPOSITION OF BLENDED YARNS CONTAINING PHOTOLUMINESCENT PP AND PA6 FIBRES ON THEIR COLOUR EFFICIENCY

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***Abstract:*** *World`s leading companies in all industrial fields try to protect effectively their sophisticated products against counterfeiting. One of affordable and cost-effective access to originality protection of textile and clothing products is application of modified fibres containing photoluminescent pigments, which besides colour change emit also light under UV lamp. The contribution focuses on preparation of twisted yarns based on standard unmodified and modified polypropylene and polyamide filaments. The polypropylene and polyamide fibres incorporate organic photoluminescent pigment with a concentration of 0.01 wt.% and 0.10 wt.% in the fibre. Degree of efficiency of the photoluminescent pigment has been evaluated objectively on packages of blended yarns by change of colour expression defined by means of b* colour coordinate in the CIE LAB colour space and by optical expression of photoexcitation under UV lamp.*

***Keywords:*** *Photoluminescency, photoluminescent PP fibres, photoluminescent PA6 fibres, blended yarns, change of colour expression.*

## 1 INTRODUCTION

Criminal activities in the field of intellectual property have significant economic consequences. It deprives legitimate companies of incomes and public administration of taxes. The counterfeit goods can have, besides the economic losses, also significant influence on health and safety of the consumers as well as adverse consequences for the environment. Slovakia loses millions of Eur due to falsification every year. The counterfeit and pirated goods are usually made by anonymous subjects which do not respect requirements for the protection of human health, safety and quality and do not provide any assistance, guarantee or instructions for use after purchase of the goods. Luxury products, clothing and accessories are traditionally the most popular categories of fake products (and belong among the cases disclosed the most frequently). Manufacture of fake clothing is growing in the frame of EU every year; the organized criminal groups affix false trademarks on imported, unbranded clothing. This way they reduce a risk of discovery of the clothing during transport [1].

An affordable and cost-effective access to protection of originality of products is application of photoluminescent dyestuffs and pigments, which besides colour change emit also light under UV lamp. Phenomenons involving absorption of energy and subsequent light emission are classified generally as luminescence. There are several kinds of luminescence depending on way of excitation. Photoluminescent dyestuffs and pigments, available in organic as well as inorganic form, are particularly interesting for the purpose of protecting product originality. Protection of originality of textile materials can be assured by luminous colour expression of the modified polymer fibres under UV light, whose intensity grows with increasing content of the photoluminescent dyestuff in the modified polymer fibres. Unmodified polymer fibres do not show any luminous colour expression under UV light [2].

The contribution focuses on solution how to protect originality of textile products using blended yarns with different content of modified polypropylene (PP) and polyamide (PA6) filaments containing 0.01 wt.% and 0.10 wt.% of special protective photoluminescent (FL) organic pigment in the fibre.

## 2 EXPERIMENTAL PART

### *2.1 Materials used*

Standard unmodified PP (**PPš**) and PA6 (**PAš**) friction textured filaments and modified PP and PA6 friction textured filaments have been used to prepare the blended yarns:

- PP fibre containing blue organic photoluminescent pigment (PP FLV) with concentration of 0.01 wt.% (**PP FLV** $_{(0.01)}$) and 0.10 wt.% (**PP FLV** $_{(0.10)}$) in the fibre;
- PA6 fibre containing blue organic photoluminescent pigment (PA FLV) with concentration of 0.01 wt.% (**PA FLV** $_{(0.01)}$) and 0.10 wt.% (**PA FLV** $_{(0.10)}$) in the fibre.

PP and PA6 fibres were of the same linear density 180 dtex.

**Table 1** Composition of the blended yarns containing PP FLV incorporating 0.01 wt.% of FL pigment in the fibre

| Designation of the blended yarn | Composition of the blended yarn | | Percentage of PP FLV in the blended yarn [%] |
|---|---|---|---|
| | Quantity of PP FLV in the yarn | Quantity of PPš fibres in the yarn | |
| A-$PP_{š}$ | 0 | 4 | 0 |
| B-$PP_{(0.01)}$ | 1 | 3 | 25 |
| C-$PP_{(0.01)}$ | 2 | 2 | 50 |
| D-$PP_{(0.01)}$ | 3 | 1 | 75 |
| E-$PP_{(0.01)}$ | 4 | 0 | 100 |

**Table 2** Composition of the blended yarns containing PP FLV incorporating 0.10 wt.% of FL pigment in the fibre

| Designation of the blended yarn | Composition of the blended yarn | | Percentage of PP FLV in the blended yarn [%] |
|---|---|---|---|
| | Quantity of PP FLV in the yarn | Quantity of PPš fibres in the yarn | |
| A-$PP_{š}$ | 0 | 4 | 0 |
| B-$PP_{(0.10)}$ | 1 | 3 | 25 |
| C-$PP_{(0.10)}$ | 2 | 2 | 50 |
| D-$PP_{(0.10)}$ | 3 | 1 | 75 |
| E-$PP_{(0.10)}$ | 4 | 0 | 100 |

**Table 3** Composition of the blended yarns containing PA FLV incorporating 0.01 wt.% of FL pigment in the fibre

| Designation of the blended yarn | Composition of the blended yarn | | Percentage of PA FLV in the blended yarn [%] |
|---|---|---|---|
| | Quantity of PA FLV in the yarn | Quantity of PAš fibres in the yarn | |
| A-$PA_{š}$ | 0 | 4 | 0 |
| B-$PA_{(0.01)}$ | 1 | 3 | 25 |
| C-$PA_{(0.01)}$ | 2 | 2 | 50 |
| D-$PA_{(0.01)}$ | 3 | 1 | 75 |
| E-$PA_{(0.01)}$ | 4 | 0 | 100 |

**Table 4** Composition of the blended yarns containing PA FLV incorporating 0.10 wt.% of FL pigment in the fibre

| Designation of the blended yarn | Composition of the blended yarn | | Percentage of PA FLV in the blended yarn [%] |
|---|---|---|---|
| | Quantity of PA FLV in the yarn | Quantity of PAš fibres in the yarn | |
| A-$PA_{š}$ | 0 | 4 | 0 |
| B-$PA_{(0.10)}$ | 1 | 3 | 25 |
| C-$PA_{(0.10)}$ | 2 | 2 | 50 |
| D-$PA_{(0.10)}$ | 3 | 1 | 75 |
| E-$PA_{(0.10)}$ | 4 | 0 | 100 |

### *2.2 Technology of preparation of the blended yarns*

The blended yarns have been prepared using twisting technology on the multipurpose twisting device DirecTwist2B. The twisting has been performed under the same technological conditions of manufacture, i.e. winding speed 6.66 m/min., drum revolutions 1 350 rev/min, quantity of twists 150 twists/m, twist direction Z.

Each blended yarn consisted of 4 filaments. Composition of the blended yarns is given in the Tables 1-4.

Each blended yarn has been wound on a dark mat in two layers. The color expression of the blue FL pigment has been evaluated on the prepared samples.

### *2.3 Evaluation of efficiency of the colour expression*

Colour expression of the FL pigment has been evaluated in two ways:

1) objectively by a change of colour expression defined by means of b* colour coordinate in the CIE LAB colour space (Figure 1) using ULTRASCAN XE device according to the standard STN ISO 105-J03. The b* colour coordinate defines shades between yellow and blue colour. Shift of the b* coordinate to the positive values (+b*) causes colour transition to the field which comes up to the yellow colour spectrum. Shift of the b* coordinate to the negative values (-b*) causes colour transition to the field which comes up to the blue colour spectrum. The lower (more negative) b* value is measured the stronger intensity of emission is observed [3].

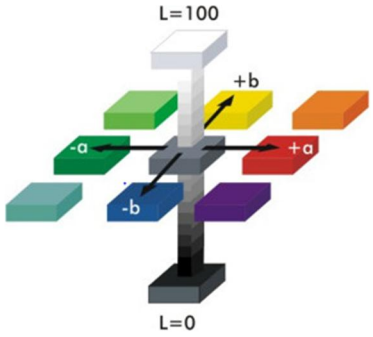


**Figure 1** Colour space CIE LAB

2) by optical expression of photoexcitation using device Fluotest with UV lamp enabling to demonstrate luminescent effects of the materials in the range of short-wave and long-wave ultraviolet (UV) radiation. Ultraviolet radiation is inter alia an approved method to identify presence or absence of substances (e.g. photoluminescent pigments, optical brighteners) for the purpose of distinction of material differences which cannot be distinguished in the visible light. The blended yarns wound on a dark mat have been exposed to filtered UV radiation in the region of electromagnetic radiation (Figure 2) for long-wave radiation (UV-A region) and intensity of emission of FL blue organic pigments has been assessed visually.

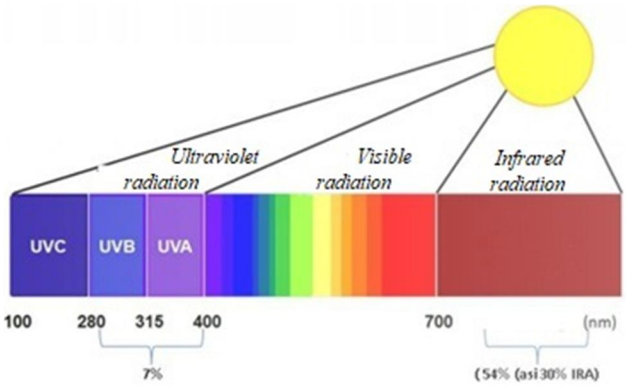


**Figure 2** Electromagnetic spectrum

## 3 RESULTS AND DISCUSSION

PP blended yarns have white colour in the daylight and neither material composition of the yarn nor concentration of FL pigment in the fibre is distinguishable with naked eye of an observer (Figure 3).

Optical excitation in a form of blue light emission, enabling distinct identification of the blended yarns containing PP FLV has been observed on PP blended yarns with naked eye using UV lamp (Figures 4 and 5).

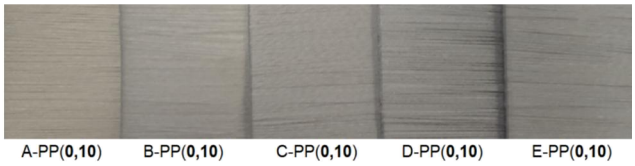


**Figure 3** PP blended yarns with different content of PP FLV containing 0.10 wt.% of FL pigment in the fibre in the daylight

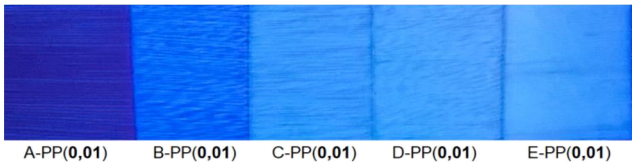


**Figure 4** PP blended yarns incorporating PP FLV containing 0.01 wt.% of FL pigment in the fibre after exposition to long-wave UV radiation in the device Fluotest

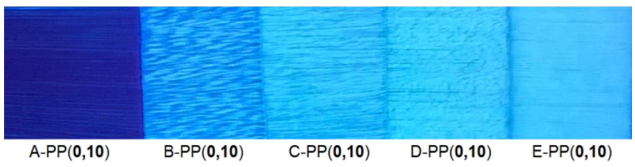


**Figure 5** PP blended yarns incorporating PP FLV containing 0.10 wt.% of FL pigment in the fibre after exposition to long-wave UV radiation in the device Fluotest

All PP blended yarns emit bright pale blue colour whose intensity increases with increasing share of PP FLV in the yarn. Yarns prepared from standard PP fibres (designation of the yarns A) have deep dark blue colour. Blue light emitted by the yarn prepared from 100% PP FLV is brighter and its depth and brightness moves with increasing share of the standard unmodified PP fibre to the yarn prepared from 100% unmodified standard PP fibre. From a viewpoint of concentration of FL pigment in PP fibre we can state that the blended yarns prepared from PP FLV containing 0.10 wt.% of FL pigment in the fibre emit brighter blue light that the yarns prepared from PP FLV containing 0.01 wt.% of FL pigment in the fibre, what confirm also results of measurement of b* colour coordinate (Figure 6).The blended yarns incorporating PP FLV containing 0.10 wt.% of FL pigment in the fibre have by about 60% higher intensity of blue light emission than blended yarns containing 0.01 wt.% of FL pigment in the fibre. Efficiency of FL pigments can be expressed also by means of colour difference between a yarn prepared from standard PP fibre and/or yarn prepared from modified PP FLV and blended yarns with different content of PP FLV. Provided that a yarn prepared from 100 wt.% of standard PP fibre (designation of the yarn A) will show emission intensity 0% and a yarn prepared from 100 wt.% of PP FLV (designation of the yarn E)

will show emission intensity of blue light on a level of 100%, then decrease and/or increase of emission intensity of blue light in the blended yarns (designation of the blended yarns B – D) can be expressed also as percentage. Emission intensity of blue light of the blended yarns prepared from PP FLV containing 0.01 wt.% and/or. 0.10 wt.% of FL pigment in the fibre is, in comparison with a yarn prepared from 100 % modified PP FLV containing 0.01 wt.% and/or 0.10 wt.% of FL pigment in the fibre, on a level of:

- 51% and/or. 60% at 25% of PP FLV in the blended yarn (designation of the blended yarn B),
- 77% and/or. 83% at 50% of PP FLV in the blended yarn (designation of the blended yarn C),
- 95% and/or. 94% at 75% of PP FLV in the blended yarn (designation of the blended yarn D).

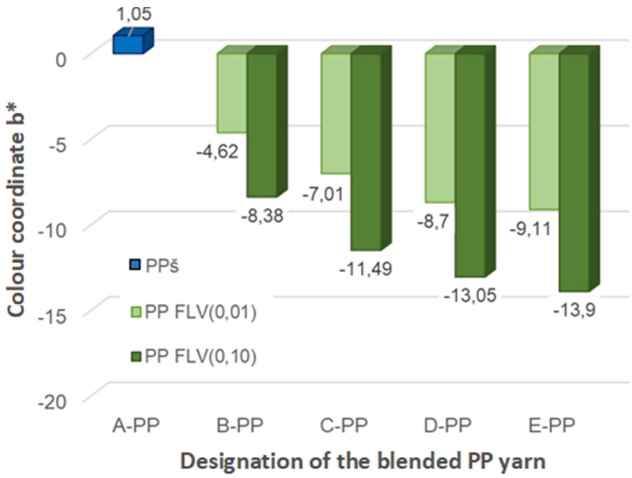


**Figure 6** Influence of material composition of PP blended yarns on a change of b* colour coordinate

PA blended yarns, as well as PP blended yarns, have white colour in the daylight and neither the share of PA FLV in the blended yarn nor the concentration of FL pigment in PA FLV is distinguishable by the naked eye of an observer (Figure 7).

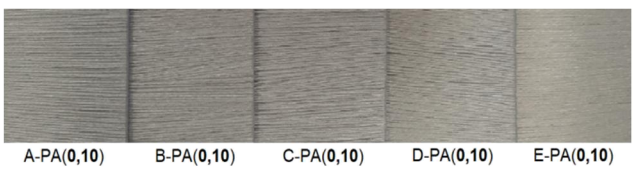


**Figure 7** PA6 blended yarns with different content of PA FLV containing 0.10 wt.% of FL pigment in the fibre in the daylight

PA blended yarns emit in the region of long-wave UV radiation blue light of various depth and brightness, whose intensity depends on content of PA FLV in the blended yarn (Figures 8 and 9).

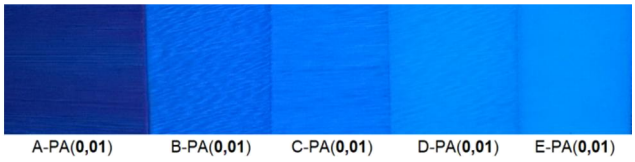


**Figure 8** PA6 blended yarns incorporating PA FLV containing 0.01 wt.% of FL pigment in the fibre after exposition to long-wave UV radiation in the device Fluotest

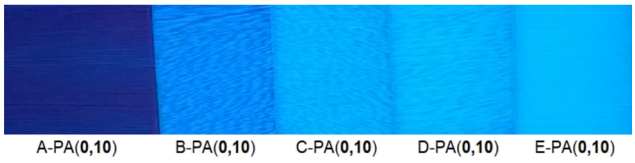


**Figure 9** PA6 blended yarns incorporating PA FLV containing 0.10 wt.% of FL pigment in the fibre after exposition to long-wave UV radiation in the device Fluotest

From a viewpoint of concentration of FL pigment in PA fibre we can state that the blended yarns prepared from PA FLV containing 0.10 wt.% of FL pigment in the fibre emit brighter blue light than the yarns prepared from PA FLV containing 0.01 wt.% of FL pigment in the fibre, what confirm also results of measurement of b* colour coordinate (Figure 10).

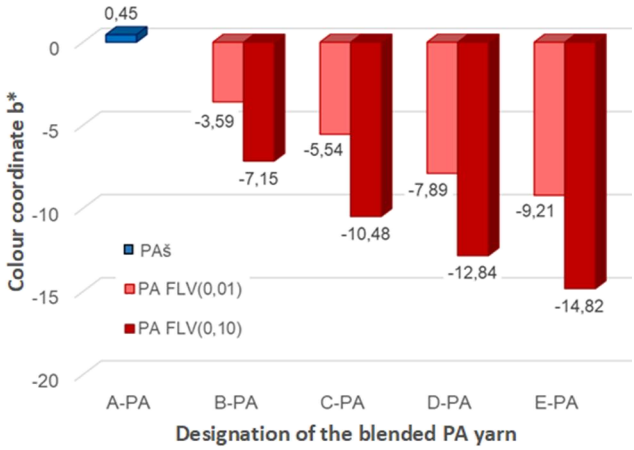


**Figure 10** Influence of material composition of PA6 blended yarns on a change of b* colour coordinate

Emission intensity of blue light of the blended yarns prepared from PA FLV containing 0.01 wt.% and/or 0.10 wt.% of FL pigment in the fibre is, in comparison with a yarn prepared from 100% modified PA FLV containing 0.01 wt.% and/or. 0.10 wt.% of FL pigment in the fibre on a level of:

- 39% and/or 48% at 25% PA FLV in the blended yarn (designation of the blended yarn B),
- 60% and/or 71% at 50% PA FLV in the blended yarn (designation of the blended yarn C),
- 86% and/or 87% at 75% PA FLV in the blended yarn (designation of the blended yarn D).

Figures 6 and 10 demonstrated clearly that emission intensity of blue light with PP and PA6 blended yarns with the same concentration of FL pigment in the fibre is comparable and content of FLV in the blended yarn has influence on emission intensity of blue light.

## 4 CONCLUSION

Polypropylene and polyamide fibres are widely used in the assortment of textile and clothing products and their application depends on intended use of the final products. Photoluminescent fibres, whose added value is their simple identification at specific wavelength out of region of visible radiation, can be prepared by modification of PP and PA6 fibres using special additives, e.g. photoluminescent organic pigments applied to mass of the polymer system. The photoluminescent fibres incorporated in a form of protective elements in the assortment of textile and clothing products are able to ensure effectively authenticity and originality of products and reduce risk of falsification. Photoluminescent pigments belong among rather expensive materials, increasing price of the modified PP and PA6 fibres. One of the solutions in the field of textile workability is optimization of rate of the photoluminescent fibres in the yarn construction while ensuring sufficient excitation of colour light at a specific wavelength. On the base of achieved results it is possible to state that for identification of the photoluminescent PP and PA6 fibre in the blended yarns concentration of 0.01 wt.% of blue photoluminescent organic pigment in PP and/or PA6 fibre and 25% content of photoluminescent PP and/or PA6 fibre in the blended yarn is sufficient. In comparison with a yarn made of 100% PP FLV emission intensity of blue light of the blended yarn containing 25% of PP FLV is on a level of about 50% and emission intensity of blue light of the blended yarn containing 25% of PA FLV is on a level of about 40%. The achieved emission intensity of blue light of the above-mentioned blended yarns is sufficient for human perception to distinguish blue colour under long wavelength UV radiation.

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