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Magdalena NOWACZYK-ORGANISTA

PROTECTION OF BIRCH AND WALNUT WOOD COLOUR FROM THE EFFECT OF EXPOSURE TO LIGHT USING ULTRA-FINE ZINC WHITE

The research was carried out using methods of accelerated ageing tests consisting in exposure of birch and walnut wood surface to xenon lamp light. It was proved that the use of ultra-fine zinc white in lacquer made it possible to obtain furniture elements of high lightfastness.

Keywords: wood, nanoparticles of zinc oxide (ZnO), colour change, lightfastness

Introduction

Because of its decorative and functional qualities wood is commonly used in the furniture industry. Finishing of its surface by lacquering brings out the pattern and colour of wood, and at the same time it improves aesthetic and decorative qualities. The colour of wood depends on chemical composition, age and origin of the tree. Wood exposed to external factors such as, for instance, humidity, temperature, biotic factors or light, undergoes ageing processes and as a result of these processes it loses not only mechanical strength but also its aesthetic qualities [Kataoka et al. 2006; Dziurzyński et al. 1988; Fumiro et al. 1996].

In order to extend durability of furniture in use, wood is subjected to finishing, for example with clear lacquers. However, this process does not protect wood against photochemical reactions of wood composites [Paprzycki et al. 1994]. One method of protection of wooden furniture colour durability is adding UV radiation absorbers to lacquer composition. The existing agents which limit colour change may be generally classified as organic absorbers, inorganic absorbers, and stabilizers of UV radiation. Depending on chemical structures and types of substituents, organic absorbers change their properties; however the maximum of UV light absorption is within the range of 280-350 nm. Traditionally used inorganic compounds demonstrate absorption of UV radiation and

Magdalena NOWACZYK-ORGANISTA, Wood Technology Institute, Poznań, Poland
e-mail: M_Nowaczyk@itd.poznan.pl

visible light; however they cause partial coverage (matting) of the base surface. Thanks to nanotechnology inorganic compounds may be so prepared that the lacquer coating produced with the share of these compounds does not cover the base and at the same time protects wood surface against ultraviolet light and part of visible light.

In the field of improvement of resistance to atmospheric factors, including light, such applications of nanomaterials as the following inorganic compounds are mentioned: titanium oxides, zinc oxides, cerium oxides, and iron oxides [Boehm 2005]. As UV absorbers, the nanoparticles of inorganic compounds are especially important for these lacquer products, in which organic absorbers demonstrate a strong trend towards migration and sublimation which decreases their effectiveness as regards light protectiveness [Knowles 2006]. Particles of the size equal to half of the wave length of light getting to their surface have the highest refraction coefficient. In the visible range the highest refraction coefficient characterises particles of the size within the range of 200-385 nm, and in the case of ultraviolet – particles whose size ranges from 140 to 200 nm. In the case where the size of particles is smaller than half of the wave length the substance will not effectively reflect the light [Główczyk-Zubek, Gabrylewicz 2001].

Own research of the author indicates that the use of the same light protective agent, as an addition to lacquer, protects particular wood species to various degrees as regards the effect of exposure to light. It also happens that a finished surface instead of improving its lightfastness reduces it. A similar phenomenon, i.e. improvement or reduction of lightfastness, was observed in the case of wood subjected to extraction of secondary wood components [Nowaczyk et al. 2004].

Aim and scope of the research

The aim of the research was to determine the effect of modification of wood (impregnation) and water-based lacquer with ultra-fine zinc white on colour durability of birch and walnut veneer exposed to light.

The scope of the research encompassed determination of the influence of:

- wave length of light getting to the surface of birch and walnut wood on colour change,
- share of nanoparticles of zinc oxide added to lacquer on the reduction of colour change of wood finished surface caused by light,
- wood impregnation with water dispersions of zinc oxide on colour change caused by light.

Test methodology

Materials used in the tests

Birch and walnut veneers were used in the tests. The wood species selection criterion was different resistance to light of the wave length of 270–800 nm (UV-VIS) and 400–800 nm (VIS). Table 1 presents characteristic of the veneers.

Table 1. Characteristic of the veneers
Tabela 1. Charakterystyka oklein

Characteristic of veneers *Charakterystyka oklein*		Wood species *Gatunek drewna*	
		Birch *Brzoza*	Walnut *Orzech*
Colour coordinates*) *Współrzędne barwy*)*	L	83,43	54,09
	a	4,9	7,2
	b	15,5	13,1
Moisture content of wood *Wilgotność drewna*		6,2	5,6
Veneer thickness [mm] *Grubość okleiny [mm]*		0,6	0,6

*) Average value from 20 measurement points.
**) Wartość średnia z 20 punktów pomiarowych.*

Table 2. Physical and chemical properties of the lacquer product
Tabela 2. Właściwości fizyko-chemiczne wyrobu lakierowego

Tested property *Badana właściwość*	Unit *Jednostka*	Lacquer *Lakier*
Density *Gęstość*	g/cm^3	1,04
Content of film making substances *Zawartość ciał błonotwórczych*	%	32
Viscosity in 23°C *Lepkość w 23°C*	s	25–30
Gloss at 60° *Połysk przy 60°*	%	28–32
Drying time in 70°C *Czas suszenia w 70°C*	min	10–15
Diluent *Rozcieńczalnik*	–	Water *Woda*
pH	–	8,1

A lacquer characterised by high resistance to light was used so as to show the influence of nanoparticles of ultra-fine zinc white on the improvement of resistance to light of finished wood elements. The second criterion for lacquer product selection was its low toxicity. Amongst products offered on the market the above-mentioned requirement was fulfilled by water-based lacquer produced on the base of acrylic dispersion by one of leading producers of lacquer products. Physical and chemical properties of the lacquer are presented in table 2, whilst properties of nanoparticles of zinc oxide (ZnO) are shown in table 3.

Table 3. Physical and chemical properties of zinc oxide*)
Tabela 3. Właściwości fizyko-chemiczne tlenku cynku*)

Properties *Właściwości*	Symbol of zinc oxide (ZnO) *Symbol tlenku cynku (ZnO)*		
	Nano 20	Nano 40	Nano 60
Appearance *Wygląd*	White water dispersion *Biała dyspersja wodna*		
Particle size [nm] *Rozmiar cząstki [nm]*	20	40	60
Content of ZnO [%] *Zawartość ZnO [%]*	40	40	50
Density [g/cm3] *Gęstość [g/cm3]*	1,59	1.59	1,72
pH	7	7	7

*) Data from the producer.
**) Dane producenta.*

Radiation filters

In order to determine the influence of electromagnetic wave length on wood colour change during exposure to xenon lamp light of the wave length of 270–800 nm the surfaces of birch and walnut veneers were covered with optical filters A–F. Fig. 1 presents characteristic of transmittance of xenon lamp light through filters B–F. According to the data of the producer of the SUNTEST apparatus, filter A (quartz glass) lets through the radiation of the wave length of 270–800 nm; however shape and dimensions of the filter made it impossible to make transmittance spectrum.

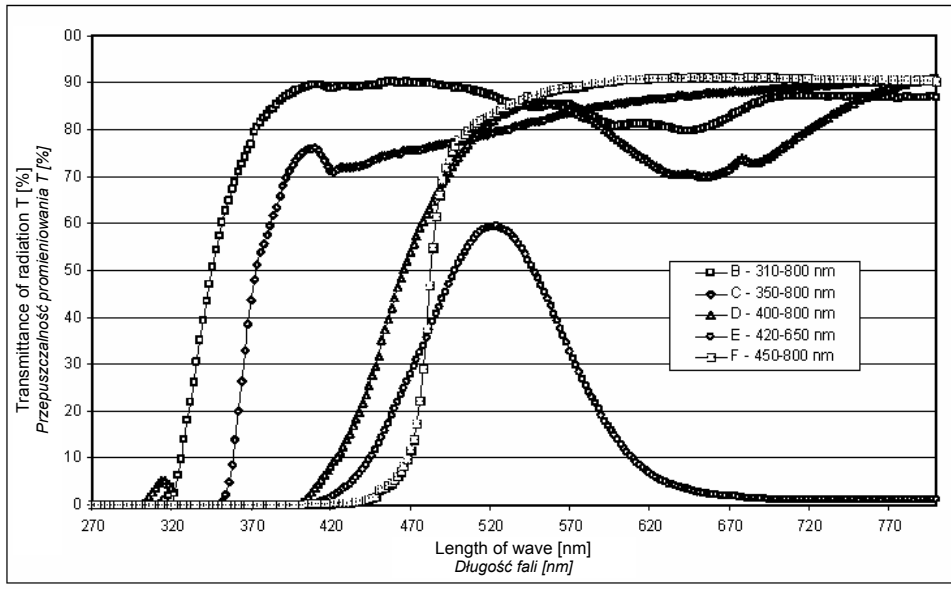

Fig. 1. Transmittance of xenon lamp light through glass filters B–F (own research)
Rys. 1. Przepuszczalność światła lampy ksenonowej przez filtry szklane B–F (badania własne)

Preparation of samples for testing

Modification – impregnation of wood with water dispersion containing nanoparticles of zinc oxide

Veneer samples of the dimensions of $(50 \times 50 \times 0.6)$ mm in the amount of around 20 g were placed in beakers of the volume of 600 ml. Then the samples were poured over with 500 ml of a dispersion of commercial zinc oxide preparations (ZnO) dilute in distilled water in the following proportions: 2.5 : 97.5 ml (Nano 20 and Nano 40 preparations) and 2:98 ml (Nano 60 preparation). Impregnation of wood was conducted in vacuum drier (7 mbar) for 30 minutes. After impregnation the samples were protected from the access of light and dried in the temperature of 23 ±°C.

Lacquer coatings on quartz plates

220 g/m^2 of 9 lacquer compositions was applied on the surface of quartz plates of the dimensions of $30 \times 50 \times 3$ mm. The applied systems were the following: EM lacquer without ZnO, EM lacquer + 2%, 4% and 6% share of Nano 20, Nano 40 and Nano 60 zinc oxide preparations. So prepared samples were dried in the temperature of 23 ± 2 °C. The thicknesses of created coatings were within the range of 69–71 μm. Characteristic of transmittance of light of the wave length of 270–800 nm through the created lacquer coatings is presented in fig. 2.

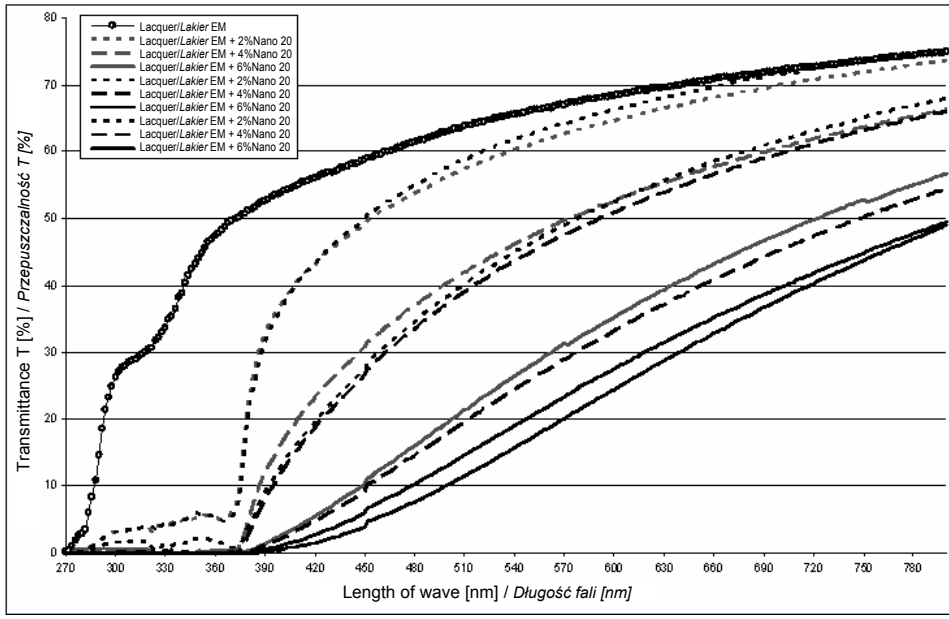

Fig. 2. Transmittance of radiation through lacquer coatings without and with different shares of zinc white (3820, 3840 and 3860) on quartz plates
Rys. 2. Przepuszczalność promieniowania przez powłoki lakierowe bez udziału oraz z różnym udziałem bieli cynkowej (3820, 3840 oraz 3860) na płytkach kwarcowych

The transmittance of radiation through lacquer systems containing ultra-fine zinc white was determined using a UV VIS – Spekol 1500 spectrophotometer, by AnalitykJena. Determinations of transmittance were recorded every 1 nm for the wave range of 270–500 nm and every 5 nm for the wave length of 500–800 nm.

Lacquer coatings on natural veneers

10 samples of the dimensions of ($90 \times 500 \times 12$) mm were cut out from particleboards covered with birch veneer, and 10 samples of the dimensions of ($90 \times 500 \times 12$) mm were cut out from particleboards covered with walnut veneer. Then around 44 g/m^2 of EM lacquer without ultra-fine zinc white (ZnO) was applied on the samples using a sponge. On so prepared base one layer of each of different lacquer-absorber compositions was applied using an aperture applicator (aperture of 240 μm). In this way 10 variants of coatings on each of the wood species were obtained. The thicknesses of particular finishing types are presented in table 4.

Table 4.Characteristic of the surface of tested furniture elements
Tabela 4.Charakterystyka powierzchni badanych elementów meblowych

Veneer type *Rodzaj okleiny*	Layers of lacquer coating *Warstwy powłoki lakierowej*		Thickness of lacquer coating [µm] *Grubość pokrycia lakierowego [µm]*		
	1	2	Min.	Max.	Average *Średnia*
Birch *Brzoza*	EM lacquer without ZnO *Lakier EM bez udziału ZnO*	EM lacquer without ZnO *Lakier EM bez udziału ZnO*	56	57	56
		EM lacquer + 2% Nano 20 *Lakier EM + 2% Nano 20*	55	58	57
		EM lacquer + 4% Nano 20 *Lakier EM + 4% Nano 20*	54	58	56
		EM lacquer + 6% Nano 20 *Lakier EM + 6% Nano 20*	56	61	58
		EM lacquer + 2% Nano 40 *Lakier EM + 2% Nano 40*	73	75	74
		EM lacquer + 4% Nano 40 *Lakier EM + 4% Nano 40*	72	77	74
		Lakier EM + 6% Nano 40 *EM lacquer + 6% Nano 40*	74	76	75
		EM lacquer + 2% Nano 60 *Lakier EM + 2% Nano 60*	75	79	77
		EM lacquer + 4% Nano 60 *Lakier EM + 4% Nano 60*	76	80	78
		EM lacquer + 6% Nano 60 *Lakier EM + 6% Nano 60*	74	77	75
Walnut *Orzech*	EM lacquer without ZnO *Lakier EM bez udziału ZnO*	EM lacquer without ZnO *Lakier EM bez udziału ZnO*	61	64	62
		EM lacquer + 2% Nano 20 *Lakier EM + 2% Nano 20*	67	70	68
		EM lacquer + 4% Nano 20 *Lakier EM + 4% Nano 20*	65	68	66
		EM lacquer + 6% Nano 20 *Lakier EM + 6% Nano 20*	62	67	65
		EM lacquer + 2% Nano 40 *Lakier EM + 2% Nano 40*	58	62	61
		EM lacquer + 4% Nano 40 *Lakier EM + 4% Nano 40*	57	65	61
		EM lacquer + 6% Nano 40 *Lakier EM + 6% Nano 40*	67	72	69
		EM lacquer + 2% Nano 60 *Lakier EM + 2% Nano 60*	70	74	72
		EM lacquer + 4% Nano 60 *Lakier EM + 4% Nano 60*	63	68	65
		EM lacquer + 6% Nano 60 *Lakier EM + 6% Nano 60*	64	67	65

Thickness of lacquer coatings was determined using a QuintSonic PRO ultrasound thickness gauge, by ElektroPhysik.

Tests of surface resistance to light

Surface resistance to light was tested according to EN 15187:2005. Test duration, which is a measure of material resistance to light, was determined based on the change of colour between light exposed and not light exposed part of the sixth standard of the blue woollen fabric at 4 degree of grey scale contrast whose numerical value in the LAB system is $\Delta E = 1.7 \pm 0.3$ [PN-EN 20105-A02:1996; PN-EN ISO-105-J03:2000].

Irradiation was conducted in a SUNTEST CPS apparatus, by Heraeus, equipped with a xenon lamp covered with quartz filter letting through light of the wave length of 270–800 nm.

The colour of tested surfaces before and after irradiation was measured using an ELREPHO 2000 spectrophotometer, and colour coordinates were recorded in the CIE Lab system.

Colour change was calculated acc. to the following formula [PN-ISO 105-B02:2006]:

$$\Delta E = \sqrt{(\Delta L)^2 + (\Delta a)^2 + (\Delta b)^2} \tag{1}$$

where: ΔE – colour difference,
L – colour achromatic coordinate (lightness); $L = 100$ indicates approximation of a given colour to white, and $L = 0$ to black,
a, b – colour chromatic coordinates; (+ a) indicates red colour, (– a) indicates green colour, (+ b) indicates yellow colour, (– b) indicates blue colour.

The measurement of colour coordinates L*, a*, b* of veneers before and after irradiation was done in the same, accurately marked places (fig. 3).

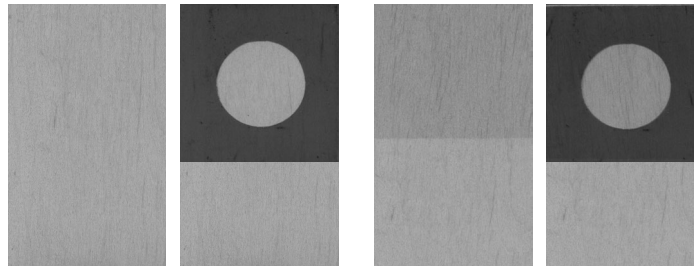

Fig. 3. The method for measurement of veneer colour coordinates before and after irradiation
Rys. 3. Sposób pomiaru współrzędnych barwy oklein przed i po naświetlaniu

Test results

The impact of wave length of electromagnetic radiation getting to wood surface on colour change (ΔE) after irradiation

Fig. 4 and 5 present colour change (ΔE) of surface of birch and walnut veneers after 45 h of exposure to radiation of the wave length of 270-800 nm, 310–800 nm, 350–800 nm, 400–800 nm, 420–650 nm, and 450–800 nm (A–F filters – fig. 2) .

The change of birch veneer colour is determined mainly by ultraviolet light. ΔE of surface exposed to light of the wave length of 270-800 nm and 310–800 nm was 14.83 and 10.31, respectively. Blocking of 270–350 nm radiation by application of filter C (fig. 1) brought about rapid reduction of wood colour change to the value of ΔE = 3.5. The change of birch surface colour caused by visible light (400–800 nm) was relatively insignificant and, depending on applied filters (D–F), ranged from 2.19 to 2.52.

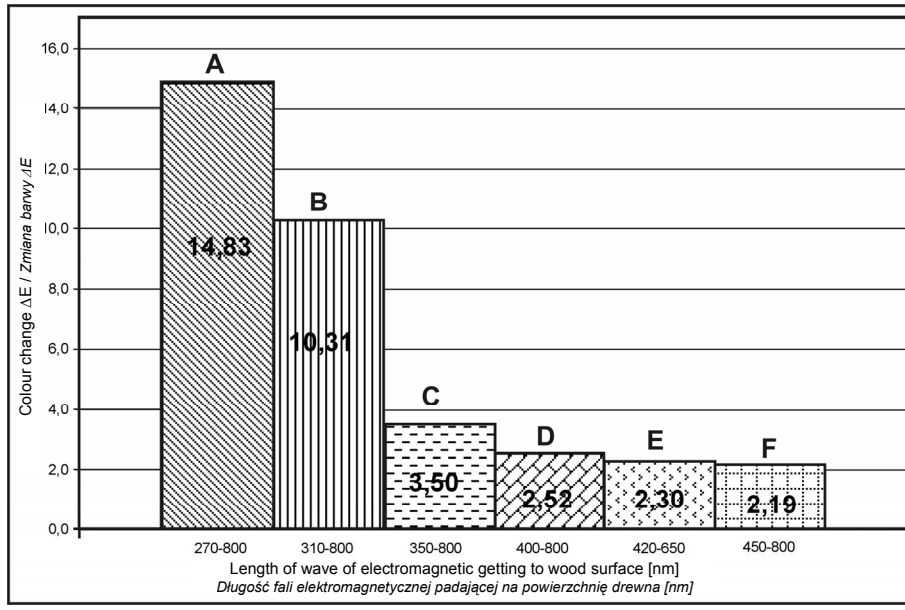

Fig. 4. Colour change ΔE of birch veneer covered with filters A–F after 45 h of exposure to light of the wave length of 270–800 nm

Rys. 4. Zmiana barwy ΔE okleiny brzozowej osłoniętej filtrami A–F po 45 h działania światła o długości fal 270–800 nm

In the case of walnut wood, it was observed that the range of ultraviolet light and the range of visible light are responsible for photochemical reactions accompanied by colour effects. The colour change caused by (UV-VIS) radiation 270–800 nm and 310–800 nm was 6.79 and 8.41. Unlike in the case of birch wood, blocking of 270–350 nm radiation did not cause considerable reduction of wood colour change. ΔE of walnut veneer exposed to light of the wave length of 350–800 nm (filter C) was 7.0. As a result of exposure to visible light VIS (400–800 nm) the surface colour change was 5.24 (filter D) and 3.93 (filter F – 450–800 nm). An insignificant value of ΔE caused by radiation of the wave length of 420–650 nm (filter E) may stem from either lower transmittance of this light range to wood surface by filter E (fig. 1) or photochemical reactions consisting in, for instance, disintegration of colour chromophore groups present in wood.

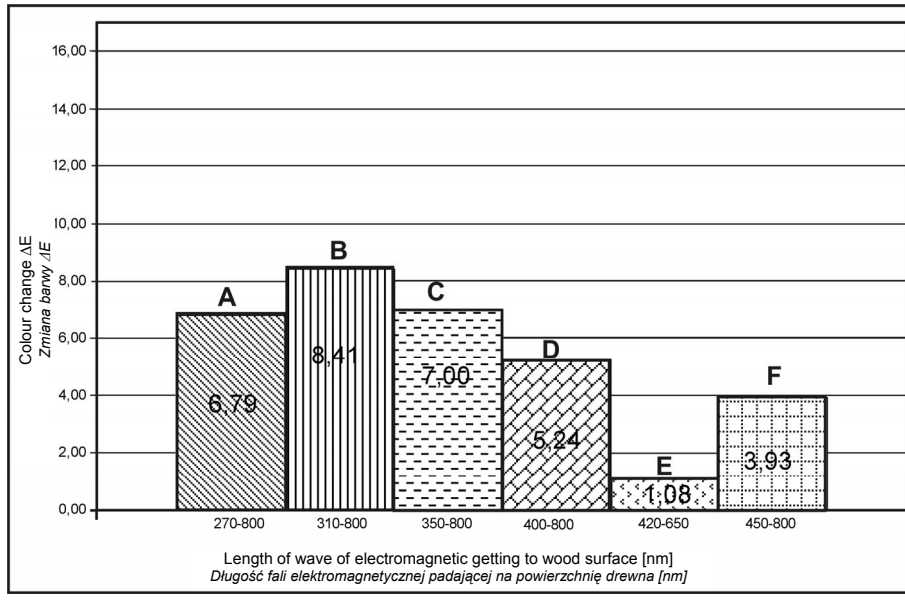

Fig. 5. Colour change ΔE of walnut veneer covered with filters A–F after 45 h of exposure to light of the wave length of 270–800 nm

Rys. 5. Zmiana barwy ΔE okleiny orzechowej osłoniętej filtrami A–F po 45 h działania światła o długości fal 270–800 nm

The influence of wood impregnation with water dispersion of nanoparticles of zinc oxides on colour change caused by irradiation

Two processes resulted simultaneously from wood impregnation. The first one was partial removal of components soluble in cold water. The second was introduction of nanoparticles of zinc oxide (ZnO) into wood structure. From fig. 6 and 7 it follows that leaching of extraction substances during wood impregnation with distilled water only had the least impact on wood colour change. The change of birch colour was 1.06, whilst of walnut colour 2.12. Removal of extraction substances and simultaneous introduction of zinc oxide nanoparticles of the size of 20 nm, 40 nm, and 60 nm into wood caused much greater changes of wood colour in comparison with not impregnated wood. Depending on the size of zinc white nanoparticles introduced into wood, the change of birch colour ranged from 3.27 to 4.87, whereas ΔE of walnut was in the range of 6.99–10.78. These changes were caused mainly by the colour component "L" (tables 5–6). The impregnation of wood resulted in lightening of wood surface which might contributed to improvement of colour durability of modified wood compared to not modified wood. The improvement of colour durability (smaller change of ΔE after 45 h of exposure to light – fig. 8 and 9) was caused by the fact that lightener wood surface reflected visible light to a greater extent. Therefore in the case of walnut wood (sensitive to visible light) impregnation of wood resulted in much better protective effect compared to birch wood. The change of colour of walnut impregnated with zinc oxide was in the range of 4.22–4.95, whilst ΔE of not impregnated wood was 7.52. In the case of birch veneer characterised by much smaller sensitivity to VIS light the difference between ΔE values for impregnated and not impregnated wood was around unity. In the case of both veneers, it was observed that extraction of secondary wood components with cold water had a negative impact.

Table 5. Change of colour coordinates of birch surface after impregnation
Tabela 5. Zmiana współrzędnych barwy powierzchni brzozowej po nasycaniu

Change of colour coordinates L*,a* and b* of birch wood after impregnation *Zmiana współrzędnych barwy L*,a*,b* drewna brzozy po nasycaniu*	Wood impregnation with *Nasycanie drewna*			
	Water *Wodą*	Nano 20	Nano 40	Nano 60
ΔL	–0,47	–2,98	–4,48	–2,96
Δa	0,3	0,6	1,8	0,6
Δb	–0,9	–1,2	–0,6	–1,6
ΔE	1,06	3,27	4,87	3,42

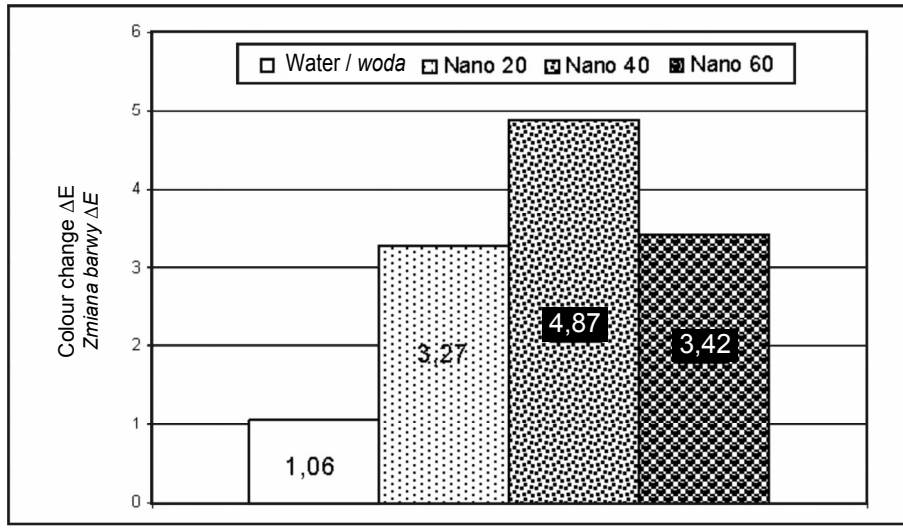

Fig. 6. Colour change ΔE of birch veneer after impregnation with distilled water and water dispersion of Nano 20, Nano 40, and Nano 60 preparations
Rys. 6. Zmiana barwy ΔE okleiny brzozowej po nasycaniu wodą destylowaną oraz wodną dyspersją preparatów Nano 20, Nano 40 i Nano 60

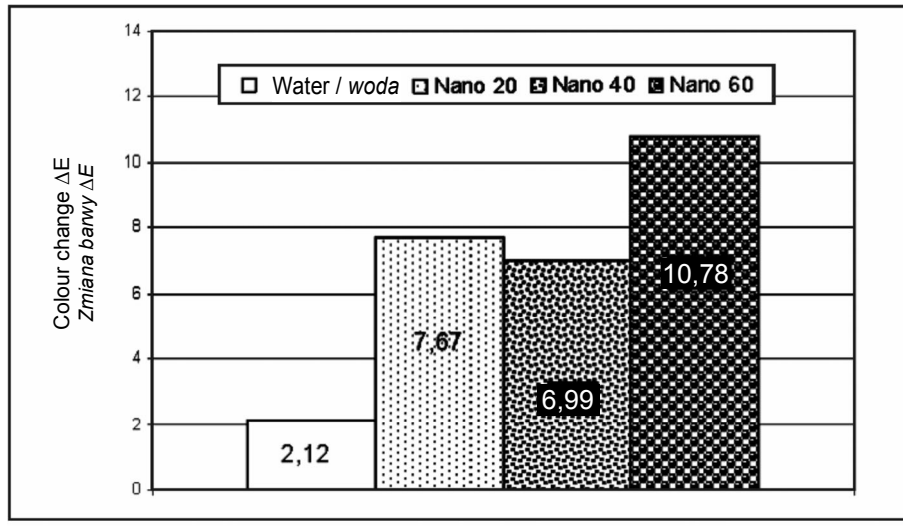

Fig. 7. Colour change ΔE of walnut veneer after impregnation with distilled water and water dispersion of Nano 20, Nano 40, and Nano 60 preparations
Rys. 7. Zmiana barwy ΔE okleiny orzechowej po nasycaniu wodą destylowaną oraz wodną dyspersją preparatów Nano 20, Nano 40 i Nano 60

Table 6. Change of colour coordinates of walnut surface after impregnation
Tabela 6. Zmiana współrzędnych barwy powierzchni orzechowej po nasycaniu

Change of colour coordinates L*,a*,and b* of walnut wood after impregnation *Zmiana współrzędnych barwy L*,a*,b* drewna orzecha po nasycaniu*	Wood impregnation with *Nasycanie drewna*			
	Water *Wodą*	Nano 20	Nano 40	Nano 60
ΔL	–0,93	–6,96	–6,51	–10,26
Δa	–0,1	0,4	0,5	1,4
Δb	–1,9	3,2	2,5	3
ΔE	2,12	6,07	6,99	10,78

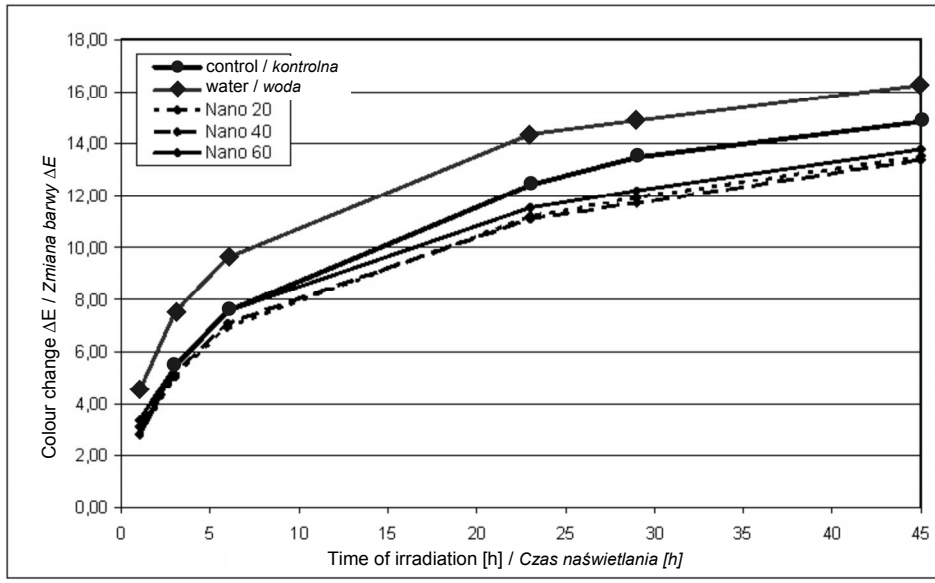

Fig. 8. Distribution of colour change (ΔE) during irradiation with light of the wave length of 270–800 nm of birch veneer impregnated with distilled water and water dispersion of zinc whites of the particles' size of 20 nm, 40 nm, and 60 nm
Rys. 8. Przebieg zmian barwy (ΔE) w czasie naświetlania światłem o długości fal 270–800 nm okleiny brzozowej nasyconej wodą destylowaną oraz wodną dyspersją bieli cynkowych o rozmiarach cząstek 20 nm, 40 nm oraz 60 nm

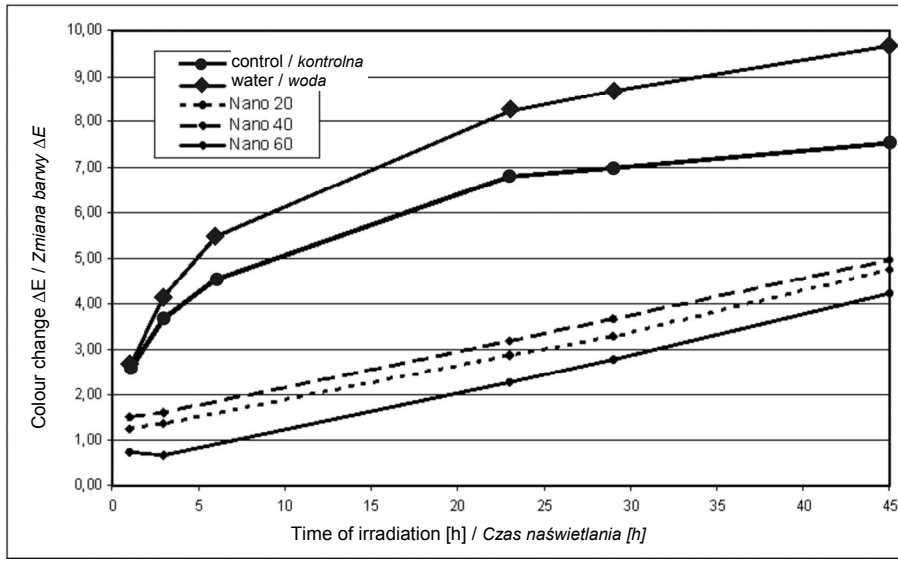

Fig. 9. Distribution of colour change (ΔE) during irradiation with light of the wave length of 270–800 nm of walnut veneer impregnated with distilled water and water dispersion of zinc whites of the particles' size of 20 nm, 40 nm, and 60 nm
Rys. 9. Przebieg zmian barwy (ΔE) w czasie naświetlania światłem o długości fal 270–800 nm okleiny orzechowej nasycaneej wodą destylowaną oraz wodną dyspersją bieli cynkowych o rozmiarach cząstek 20 nm, 40 nm oraz 60 nm

The influence of nanoparticles of zinc oxides in lacquer on colour durability of finished wooden elements

Birch veneer

Fig. 10 and 11 present change of colour (ΔE) of birch veneer finished with EM lacquer without the addition of zinc white (oxide) and with different percentage shares of ZnO nanoparticles of the particle size of 20 nm, 40 nm, and 60 nm, caused by xenon lamp light of the wave length of 270–800 nm.

From fig. 10 and 11 it follows that the best effect of birch wood protection against light was obtained for lacquer systems with a 4% share of zinc whites (Nano 20, Nano 40, and Nano 60). The change of colour of these lacquer systems during the whole exposure period (45 h) did not exceed the value of $\Delta E \leq 1.7 \pm 0.3$. These systems block UV radiation in the wave range of 270–380 nm (fig. 2). From a practical point of view, the lacquer coating with the share of white of the smallest size of particles is the best system protecting wood colour against the effect of exposure to light amongst these 3 variants of finishing. At the same time this coating ensures the best exposition of wood pattern (without the effect of matting).

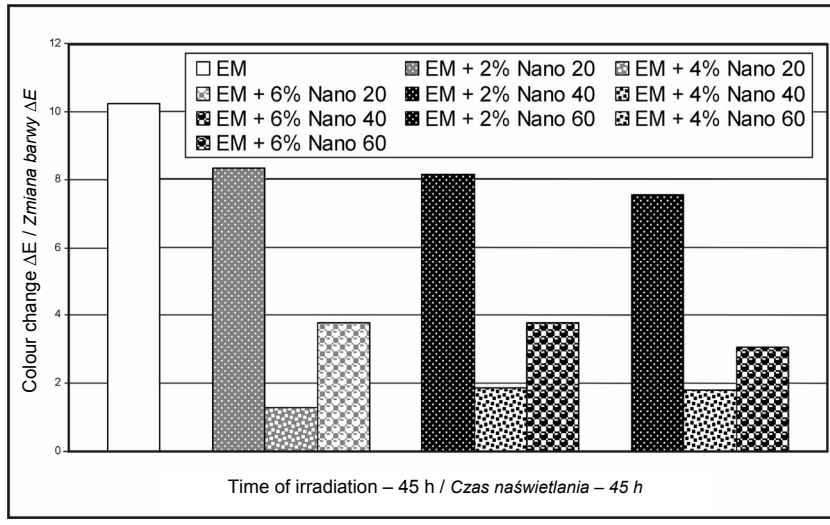

Fig. 10. Colour change of birch veneer finished with EM lacquer without the share and with different shares of Nano 20, Nano 40, and Nano 60 zinc whites after 45 h of exposure to light of the wave length of 270–800 nm

Rys.10. Zmiana barwy okleiny brzozowej uszlachetnionej lakierem EM bez udziału oraz z różnym udziałem bieli cynkowych Nano 20, Nano 40 oraz Nano 60, po 45 h naświetlania światłem o długości fal 270–800 nm

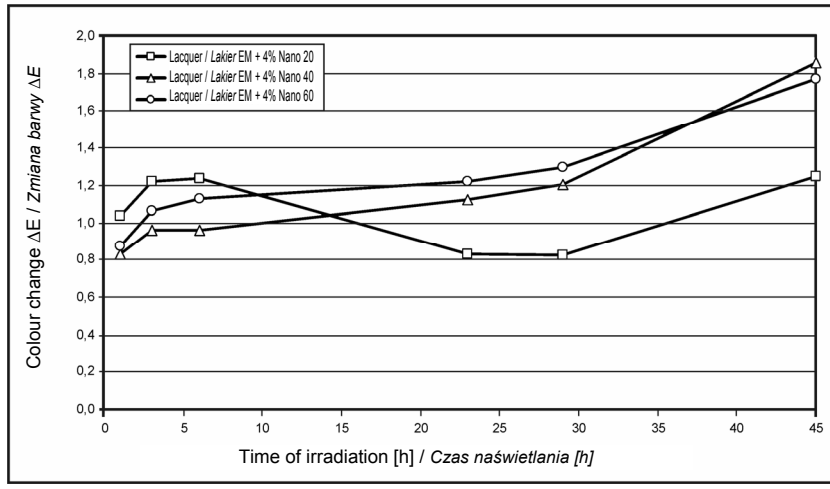

Fig. 11. Distribution of colour change (ΔE) during irradiation with light of the wave length of 270–800 nm of birch veneer finished with EM lacquer with a 4% share of zinc whites of the particles' size of 20 nm, 40 nm, and 60 nm

Rys. 11. Przebieg zmian barwy (ΔE) w czasie naświetlania światłem o długości fal 270–800 nm okleiny brzozowej wykończonej lakierem EM z 4% udziałem bieli cynkowych o rozmiarach cząstek 20 nm, 40 nm oraz 60 nm

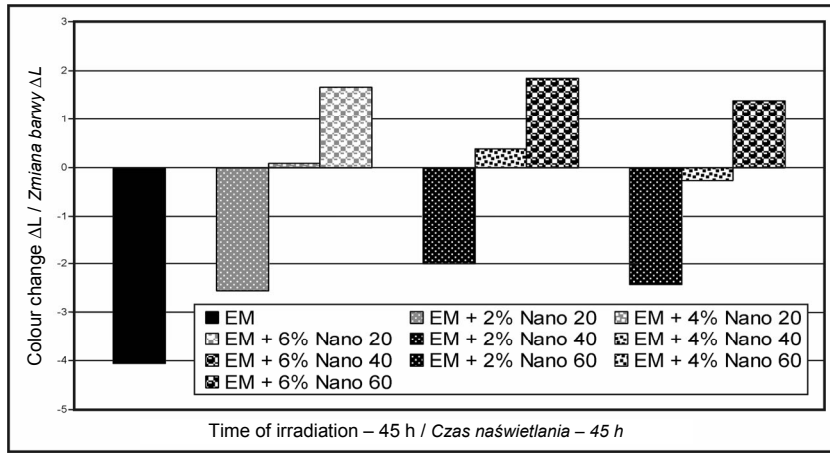

Fig. 12. Change of the lightness coordinate (ΔL) of birch wood finished with EM lacquer without the share and with different percentage shares of Nano 20, Nano 40, and Nano 60 zinc whites after 45 h of irradiation with light of the wave length of 270–800 nm

Rys.12. Zmiana współrzędnej jasności (ΔL) drewna brzozy uszlachetnionego lakierem EM bez udziału oraz z różnym procentowym udziałem bieli cynkowych Nano 20, Nano 40 oraz Nano 60, po 45 h naświetlania światłem o długości fal 270–800 nm

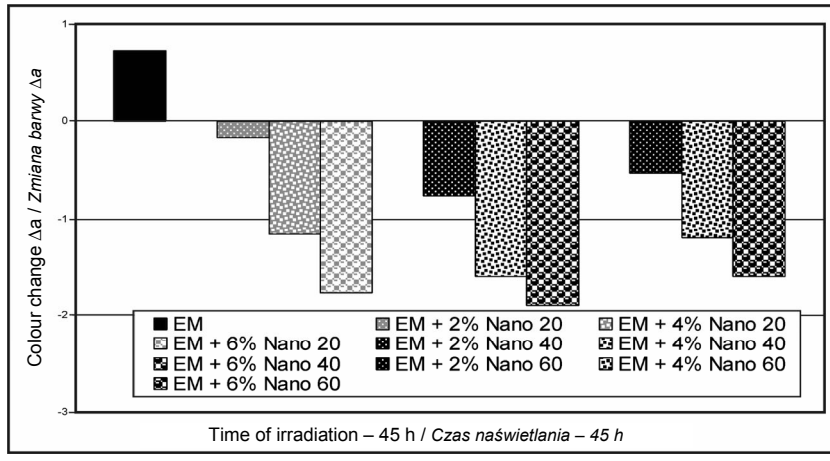

Fig. 13. Change of the chromatic coordinate (Δa) of birch wood finished with EM lacquer without the share and with different percentage shares of Nano 20, Nano 40, and Nano 60 zinc whites after 45 h of irradiation with light of the wave length of 270–800 nm

Rys.13. Zmiana współrzędnej chromatycznej (Δa) drewna brzozy uszlachetnionego lakierem EM bez udziału oraz z różnym procentowym udziałem bieli cynkowych Nano 20, Nano 40 oraz Nano 60, po 45 h naświetlania światłem o długości fal 270–800 nm

Lacquer coatings with a 2% share of zinc whites protected wood colour against the effect of irradiation to a small degree. The change of colour of wood finished with EM lacquer without the addition of zinc white was 10.2, whilst ΔE of wood protected with the lacquer with a 2% share of zinc whites used in the tests was 8.3 (ZnO-Nano20), 8.2 (Nano 40), and 7.6 (Nano 60). The lack of appropriate protection of wood colour against the effect of exposure to light ($\Delta E > 1.7 \pm 0.3$) stems from the fact that these coatings let through radiation of the wave range of 280–370 nm (fig. 2) which causes photochemical reactions of birch wood, which reactions bring about the greatest colour effects (fig. 4).

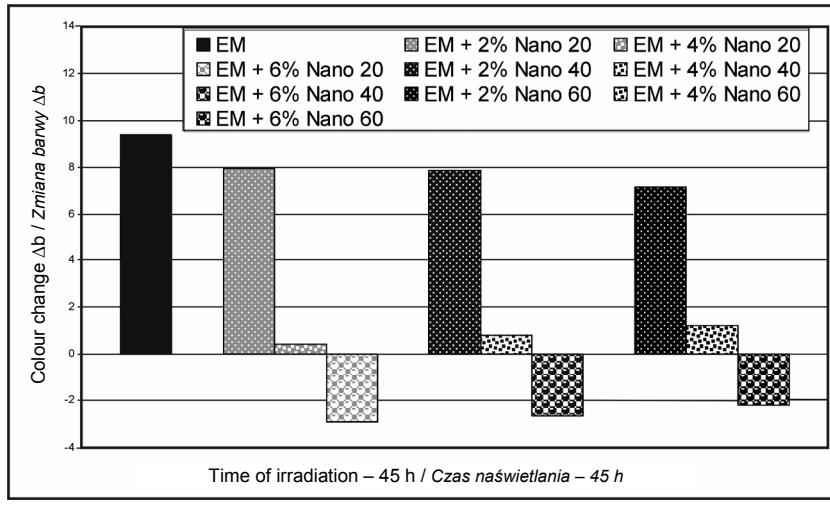

Fig. 14. Change of the chromatic coordinate (Δb) of birch wood finished with EM lacquer without the share and with different percentage shares of Nano 20, Nano 40, and Nano 60 zinc whites after 45 h of irradiation with light of the wave length of 270–800 nm

Rys.14. Zmiana współrzędnej chromatycznej (Δb) drewna brzozy uszlachetnionego lakierem EM bez udziału oraz z różnym procentowym udziałem bieli cynkowych Nano 20, Nano 40 oraz Nano 60, po 45 h naświetlania światłem o długości fal 270–800 nm

The change of colour of birch finished with EM lacquer with a 6% share of zinc whites is approximately 2 times greater in comparison with the change of colour of wood finished with the lacquer with a 4% share of ZnO. The analysis of colour coordinates "L", "a" and "b" (fig. 12–14) indicates that the addition of zinc whites at the amount of 6% to EM lacquer caused change in the direction of changes of finished wood surface colour components. As a result of exposure to UV-VIS (270–800 nm) radiation wood surface became darker (–ΔL), more red (+Δa), and more yellow (+ Δb). Limitation of the influence of UV radiation by

adding 2% of ZnO to EM lacquer caused reduction of coordinate "b" changes, whereas blocking of UV radiation (270–380 nm) by using a 6% share of ZnO caused the situation, where, as a result of irradiation, birch surface became lighter (ΔL), les red and less yellow. It may mean that UV light causes photochemical reactions in birch wood during which colour chromophore systems are created, whereas visible light is responsible for disintegration of chromophore systems present in wood. An appropriately selected share of the absorber allow establishment of such a wood-lacquer-absorber system, in which changes of wood colour caused by UV and VIS radiation are balanced, i.e. change of colour of the whole system will not exceed the assumed value of $\Delta E = 1.7 \pm 0.3$.

Walnut veneer

Fig. 15 presents the change of colour (ΔE) of walnut veneer finished with EM lacquer without an addition of zinc white and with different percentage shares of zinc white. The change was caused by xenon lamp light of the wave length of 270–800 nm.

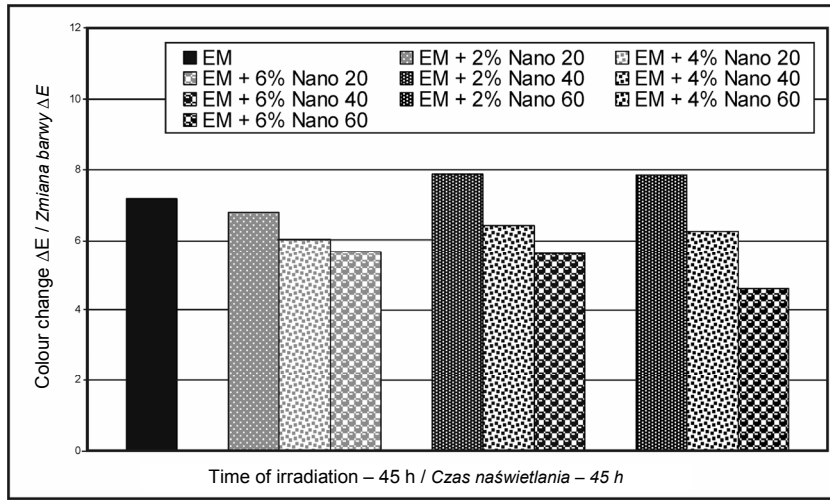

Fig. 15. Colour change of walnut veneer finished with EM lacquer without the share and with different shares of Nanobyk 3820, Nanobyk 3840, and Nanobyk 3860 zinc whites after 45 h of irradiation with light of the wave length of 270–800 nm

Rys. 15. Zmiana barwy okleiny orzechowej uszlachetnionej lakierem EM bez udziału oraz z różnym udziałem bieli cynkowych Nanobyk 3820, Nanobyk 3840 oraz Nanobyk 3860, po 45 h naświetlania światłem o długości fal 270–800 nm

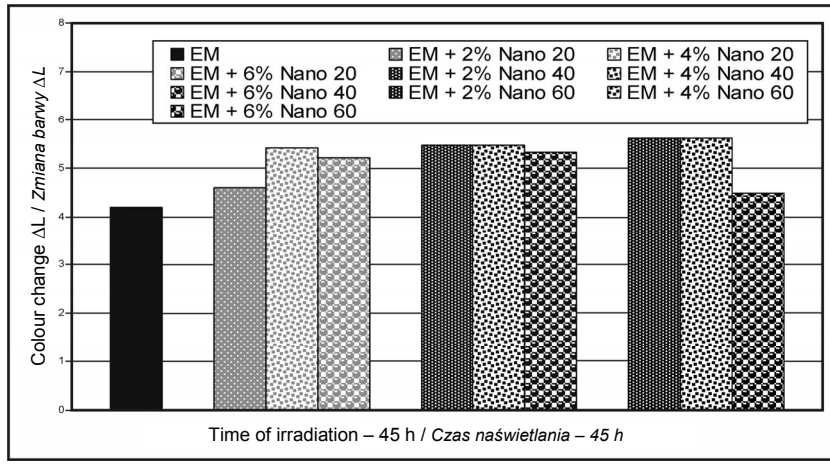

Fig. 16. Change of the lightness coordinate (ΔL) of walnut wood finished with EM lacquer without the share and with different percentage shares of Nano 20, Nano 40, and Nano 60 zinc whites after 45 h of irradiation with light of the wave length of 270–800 nm

Rys.16. Zmiana współrzędnej jasności (ΔL) drewna orzecha uszlachetnionego lakierem EM bez udziału oraz z różnym procentowym udziałem bieli cynkowych Nano 20, Nano 40 oraz Nano 60, po 45 h naświetlania światłem o długości fal 270–800 nm

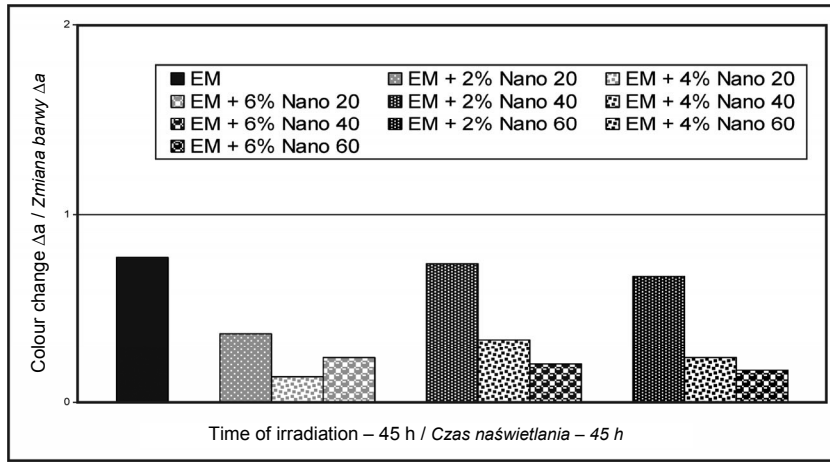

Fig. 17. Change of the chromatic coordinate (Δa) of walnut wood finished with EM lacquer without the share and with different percentage shares of Nano 20, Nano 40, and Nano 60 zinc whites after 45 h of irradiation with light of the wave length of 270–800 nm

Rys.17. Zmiana współrzędnej chromatycznej (Δa) drewna orzecha uszlachetnionego lakierem EM bez udziału oraz z różnym procentowym udziałem bieli cynkowych Nano 20, Nano 40 oraz Nano 60, po 45 h naświetlania światłem o długości fal 270–800 nm

The change of the colour of walnut veneer surface finished with EM lacquer decreases as the share of zinc white increases. However, none of the applied systems, differing by size and percentage share of zinc white in lacquer, sufficiently protected wood colour against the effect of exposure to light ($\Delta E > 1,7 \pm 0,3$).

The analysis of the changes of coordinates L*, a*, b* (fig. 16–18) of walnut indicates that, unlike in the case of birch veneer, all colour coordinates changed in the same direction, independently of the wave length of light getting to the base – wood.

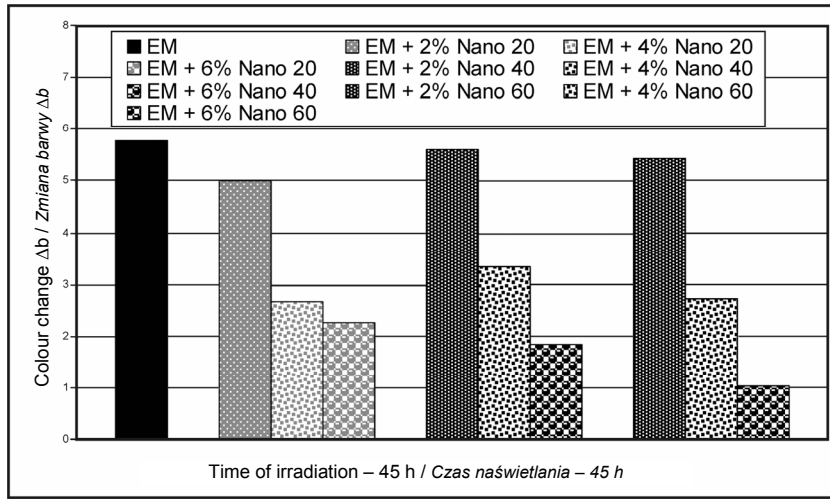

Fig. 18. Change of the chromatic coordinate (Δb) of walnut wood finished with EM lacquer without the share and with different percentage shares of Nano 20, Nano 40, and Nano 60 zinc whites after 45 h of irradiation with light of the wave length of 270–800 nm

Rys.18. Zmiana współrzędnej chromatycznej (Δb) drewna orzecha uszlachetnionego lakierem EM bez udziału oraz z różnym procentowym udziałem bieli cynkowych Nano 20, Nano 40 oraz Nano 60, po 45 h naświetlania światłem o długości fal 270–800 nm

As a result of exposure to light the surface of walnut finished with various systems of lacquer coatings became lighter (ΔL), more yellow (+ Δb), and less red (+ Δa). The changes of chromatic coordinate "a" were very small (below unity), which was the reason for eliminating them from further analysis of test results. None of the lacquer systems reduced changes of the lightness coordinate, whereas the value of Δb decreased as the percentage share of zinc white in lacquer increased.

Conclusions

On the basis of conducted research it may be stated that:

1. The change of birch wood colour is caused mainly by ultra-violet light (UV), whereas the change of walnut wood colour is caused by UV light and visible light (VIS).
2. Modification of wood, consisting in introduction of zinc oxide nanoparticles into the structure of wood, may constitute an initial process of protection of wood against the effect of irradiation.
3. An appropriately selected share of zinc white in lacquer allows obtaining of stable in time protection of wood colour from the effect of irradiation. In the case of birch wood such system is constituted by acrylic lacquer EM with a 4% share of zinc white whose particles' size is 20 nm.
4. None of the applied lacquer systems, differing by the particle size and share of zinc whites, protected walnut wood from the effect of exposure to light. Such situation was caused by the lack of effective protection of wood components responsible for changes of the lightness coordinate ΔL.

References

Boehm P. [2005]: Applications for cerium oxide nanoparticles in coatings: protect your wood for 10 years. Surface Coatings International Part A: Coating Journal [88] A09: 359–362

Dziurzyński A. , Prądzyński W., Rypacek V. [1988]: *Notes on colour changes in wood decayed by coriolus versicolor fungus.* Folia Forestalia Polonica. Seria B [19]

Fumiro K. Hideo O. i inni [1996]: Photodiscoloration of western hemlok (Tsugaheterophylla) sapwood II. Surfaces of constituents causing photodiccoloration. Mukuzai Gakkaishi [3]: 301–307

Główczyk-Zubek J. , Gabrylewicz A. [2001]: Ditlenek tytanu – własności i zastosowanie w kosmetykach. Wiadomości Polskiego Towarzystwa Kosmetologicznego [3–4]: 54–59

Kataoka Y., Kiguchi M. Williams R. Evans P [2006]: The effects of wavelength on photodegradation depth profiles in Japanese Cedar (Cryptomeria Japonica D.Don) earlywood. Fith International Woodcoating Congress "Enhancing Service Life", paper 9

Knowles T. [2006]: The new toolbox. Nanotechnology in paints and coatings. Europ. Coatings J. [3]: 16–18

Nowaczyk M., Krzoska-Adamczak Z., Oleszek T. [2004]: Poznanie czynników powodujących zmianę barwy drewna pod wpływem światła oraz opracowanie metody zapobiegania tym zmianom. (Maszynopis). Instytut Technologii Drewna, Poznań

Paprzycki O. Banaszak A. Rajczowski J. [1994]: Wpływ promieniowania słonecznego na zmiany barwy lakierowanych powierzchni mebli. Przem Drzew. [8]: 1–4

EN 15187: 2005 Furniture – Assessment of the effect of light exposure
PN-EN 20105-A02 (PN-ISO 105-A02):1996 Tekstylia – Badania odporności wybarwień – Szara skala do oceny zmiany barwy
PN-EN ISO 105-J03: 2000 Tekstylia – Badania odporności wybarwień – Obliczanie różnic barwy
PN-ISO 105-B02:2006 Tekstylia – Badania odporności wybarwień – Odporność wybarwień na światło sztuczne: Test płowienia w świetle łukowej lampy ksenonowej

Opis techniczny lakieru EM
Opis techniczny bieli cynkowych t

OCHRONA BARWY DREWNA BRZOZY I ORZECHA PRZED DZIAŁANIEM ŚWIATŁA ZA POMOCĄ MIKROTONIZOWANEJ BIELI CYNKOWEJ

Streszczenie

W celu wyeksponowania walorów estetycznych oraz użytkowych, drewno poddaje się uszlachetnianiu na przykład za pomocą lakierów transparentnych. Proces ten jednakże nie zabezpiecza przed fotochemicznymi reakcjami składników drewna. Wśród zastosowań nanomateriałów z zakresu poprawy odporności na działanie warunków atmosferycznych, w tym również światła, wymieniane są związki nieorganiczne, obejmujące między innymi takie związki jak tlenki cynku, tytanu, ceru oraz żelaza.

Celem badań było określenie wpływu nanocząstek bieli cynkowej na poprawę trwałości barwy okleiny brzozowej oraz orzechowej eksponowanych na działanie światła. Zakres badań obejmował ustalenie wpływu nasycania drewna wodną dyspersją tlenku cynku (ZnO) oraz zabezpieczania drewna za pomocą lakieru wodorozcieńczalnego z dodatkiem tlenku cynku na zmianę barwy pod wpływem światła. W pracy zastosowano handlowe preparaty bieli cynkowych w postaci wodnych dyspersji, charakteryzujących różną wielkością cząstek (20 nm, 40 nm oraz 60 nm). Badania prowadzono metodą przyśpieszonych testów starzeniowych, polegających na naświetlaniu powierzchni drewna światłem lampy ksenonowej o długości fal 270–800 nm, imitującej światło słoneczne w warunkach zewnętrznych.

Na postawie przeprowadzonych badań stwierdzono, że zmiana barwy nieuszlachetnionej okleiny brzozowej w głównej mierze determinowana jest działaniem światła ultrafioletowego, natomiast na zmianę barwy drewna orzecha wpływa zarówno światło ultrafioletowe (UV), jak również światło widzialne (VIS). Najlepszy efekt ochrony barwy drewna brzozy przed działaniem światła uzyskano dla układów lakierowych z 4% udziałem bieli cynkowych (Nano 20, Nano 40, Nano 60), w których w całym czasie naświetlania (45h) zmiana barwy nie przekroczyła wartości $\Delta E \leq 1,7 \pm 0,3$. Były to układy odcinające promieniowanie UV w zakresie fal 270–380 nm. Powłoki lakierowe z 2% oraz 6% udziałem bieli cynkowych nie zabezpieczyły barwy brzozy przed działaniem światła.

W przypadku drewna orzecha, żaden z zastosowanych układów: drewno-lakier-absorber nie zabezpieczył barwy drewna w zamierzonym stopniu. W miarę wzrostu procentowego udziału bieli cynkowej stwierdzono istotne ograniczenie zmiany współrzędnej chromatycznej „b". Nieznaczna poprawa zmiany wartości współrzędnej ΔL wskazuje, że w celu poprawy odporności drewna orzecha na działanie światła, należy rozważyć zastosowanie innych związków absorbujących promieniowanie UV-VIS.

Słowa kluczowe: drewno, nanocząstki tlenku cynku (ZnO), zmiana barwy, odporność na światło