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Full Length Research Paper

A nano-technological product: An innovative varnish type for wooden surfaces

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In this study, "nanolacke ultraviolet (UV) varnish," developed by a Turkish dyeing and varnish company and widely accepted as a 21st century technology, has been compared to other conventional varnish types that are widely used in the industry in order to compare the dry film resistance properties of the varnishes. In this study, cellulosic, polyurethane, polyester, synthetic, and nanolacke ultraviolet varnishes were applied to beech (*Fagus orientalis L.*) and oak (*Quercus robur L.*) wood samples that had been prepared according to industry standards. Then, specular gloss, pencil hardness (scratch resistance) and surface resistance to cold liquids of these layers were determined according to the ASTM D 523-89, ASTM D 3363-00, and TS 3584 EN 12720 standards, respectively. The results of this study demonstrated that the nanolacke UV varnish had dry film resistance properties of gloss, scratch resistance and surface resistance to cold liquids that were superior to these same properties for the conventional varnishes.

Key words: Wood, varnish, nanotechnology, coatings.

INTRODUCTION

Wood is an organic material that has been used by humanity from the early ages. Over time, people have also learned how to produce many other materials from wood. Although some have argued that wood has decreased in importance due to the development of synthetic and polymeric materials, wood is often preferred over these products and the amount of wood used per person has continued to increase all over the world. The main reason for this is that the wood has a unique group of properties that no other material has. At the present time, it is almost impossible for anybody to live without wood and wooden products.

Along with the superior properties of wood, there are some undesirable properties, including its susceptibility to damage by fungus and beetles due to its organic structure, its change in its size depending on its moisture content and temperature due to its hygroscopic property and its flammability. In order to overcome these disadvantages of wooden materials, protective covers, such as dye and varnish, are applied to them. After the application of surface treatments performed according to Industry standards, the technical, aesthetic and economical values of wood increases.

The long-term durability of varnishes applied to wooden surfaces with respect to mechanical effects, such as friction, abrasion and impact, and to chemical effects, such as the effects of acids, alkalis, alcohols and detergents, depends on the resistance of the varnish layers to these effects. Varnished wooden surfaces are exposed to various effects, depending on the environments in which they are used. Therefore, in order to prevent economic losses, the use of varnish types that supply optimum efficiency according to the usage area is required.

However, some of the properties of varnishes applied as a means of protection are either partially known or misunderstood. As a result of the mistakes made in choosing the type of varnish to use, the protective material may lose its protective properties because it does not have the desired strength and durability, and large economic losses may be incurred. The provision of a long lifespan for the furniture and maximum profit are highly dependent on the proper use and quality of the protective material (dye or varnish). Various varnishes

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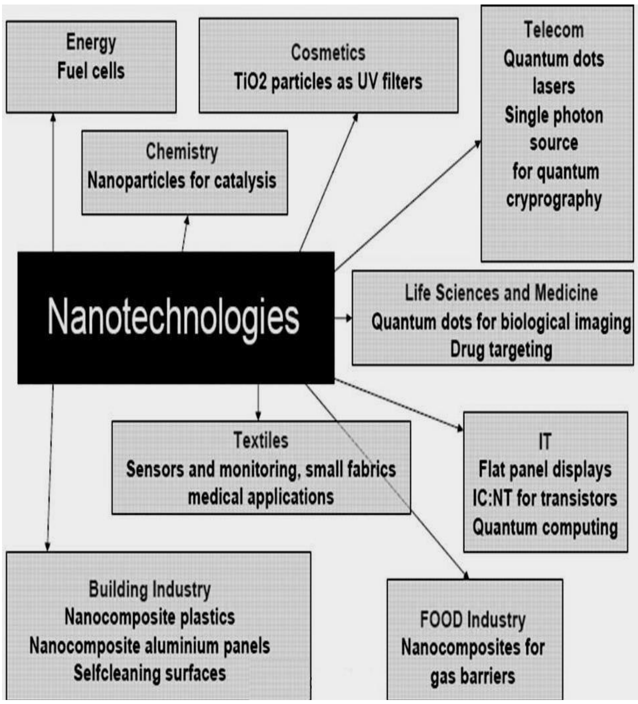

Figure 1. Industrial nanotechnology applications.

and varnish systems for use on wood surfaces have been developed over time as a result of quality demands and environmental protection consciousness. The nanotechnology product varnishes discussed herein are the newest area of development in this field.

The properties of materials are totally different at nanoscale than they are at macro-scales and some new, special, and useful properties are available at the nanoscale. The building of materials at atomic and molecular scales provides stronger and lighter materials than the materials produced by conventional methods. These materials have brought revolutionary innovations to many current industrial processes with their low error rates and unique strengths. Nano-tubes, fibers and coating materials provide the development of new manufacturing methods and techniques (Nanotechnology strategy group, 2004).

Nanotechnology has a huge number and variety of applications across many different sectors. Some Industrial applications of nanotechnology can be seen in Figure 1. Demir, (2007).

Yalinkilic et al. (1999) studied the outdoor performance of polyurethane varnish and an alkyd-based synthetic varnish applied to chromium-copper-boron (CCB)-impregnated Scots pine (*Pinus sylvestris* L.) and chestnut (*Castanea sativa* Mill.) wood. They noted that CCB impregnation successfully stabilized the surface colour of varnish-coated panels and that polyurethane varnish provided a harder surface and improved glossiness with superficial cleaning than synthetic varnish. Thus, the use of the combination of impregnated preservatives and surface coating is suggested for outdoor protection of wood panels.

Faucheu et al. (2006) studied polyvinylidene fluoride (PVDF) coatings after 10 years of exposure in Florida. They found that the main cause of gloss change was related to formation of micron-scale pits rather than the emergence of pigment particles at the coating surface. Surface roughness also affected the gloss characteristics.

Budakci and Atar (2001) conducted a research related to the effects of bleaching of Scots pine (*P. sylvestris* L.) wood exposed to outdoor conditions. It was found that exposure to outdoor conditions can significantly decrease the hardness and glossiness values. However, these values can be increased by using bleaching materials, so it was suggested that bleaching materials could be used for the restoration of wooden materials exposed to outdoor conditions.

According to a previous study (Kaygin and Akgun, 2008), nanolacke UV varnish performed better than conventional varnish types in terms of dry film resistance properties like "surface hardness and adhesion". It was noted that nanolacke UV varnish was found to be superior to conventional varnishes for furniture and parquet areas, where high hardness and bonding strengths of the varnish layer are desired.

The aim of this study is to compare the properties of specular gloss, pencil hardness and surface resistance to cold liquids of the newly-developed nanolacke UV varnishes (developed for wooden furniture and parquet surfaces) to conventional varnish types. Furthermore, different species of wood were used to determine whether the different wood types had any effects on specular gloss, pencil hardness and surface resistance to cold liquids.

MATERIALS AND METHODS

Wood materials

Beech and oak were selected as the wooden materials for this experiment. Some physical and mechanical properties of the wood types used in the experiments are given below.

Oak (*Quercus robur* L.): Oak has a high density with oven-dry specific gravity of 0.65 g/cm^3 and air-dry specific gravity of 0.69 g/cm^3. Stress resistance parallel to oak fibers is 610 kg/cm^2.

Beech (*Fagus Orientalis* L.): Oven-dry specific gravity of beech is 0.63 g/cm^3, air-dry specific gravity is 0.66 g/cm^3 and specific gravity by volume is 0.448 g/cm^3. Stress resistance parallel to beech fibers is 644 kg/cm^2.

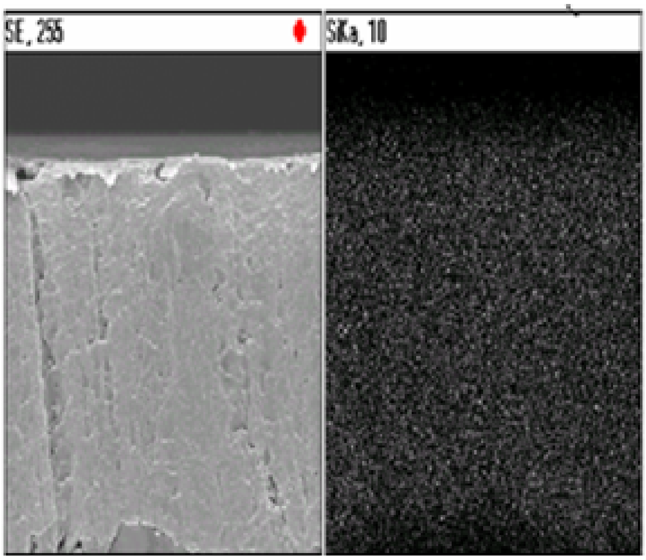

Figure 2. Cross section in a nanolacke layer.

Two significant factors were taken into consideration when choosing these species. The first was that these species are widely used in the furniture and parquet sectors, where most varnishes are consumed in Turkey. The second factor was that they represent different anatomical structures. Beech was chosen to represent diffuse porous trees and oak was chosen to represent ring porous trees.

Varnishes

The conventional cellulosic, synthetic, polyurethane and polyester varnishes and the newly-developed nanolacke UV varnish were used according to the manufacturer's instructions. Some of the properties of these varnishes are given below.

Celullosic varnish: The density of the cellulosic varnish used in the experiment was 0.95 g/cm^3, and its viscosity was 20 s/DIN CUP 4 mm/20°. The application of the varnish to the wooden panels was performed with a spray gun. The amount of surface application was approximately 125 g/m^2. The air pressure of the spray gun was 3 bars, and the nozzle gap was 1.8 mm. The specimens were air dried for 30 min.

Polyurethane varnish: The density of the polyurethane varnish used in the experiment was 0.95 g/cm^3, and its viscosity was 16 s/DIN CUP 4 mm/20°. The varnish was applied to the wooden panels with a spray gun. The amount of surface application was approximately 120 g/m^2. The air pressure of the spray gun was 2 bars, and the nozzle gap was 1.8 mm. The specimens were dried chemically and the drying process took 3 h.

Polyester varnish: The density of the polyester varnish used in the experiment was 0.94 g/cm^3, and its viscosity was 18 s/DIN CUP 4 mm/20°. The varnish was applied to the wooden panels with a spray gun. The amount of varnish applied was approximately 450 g/m^2. The air pressure of the spray gun was 3 bars, and the nozzle gap was 1.8 mm. The specimens were dried chemically and the drying process took 3 h.

Synthetic varnish: The density of the synthetic varnish used in the experiment was 0.94 g/cm^3 and its viscosity was 18 s/DIN CUP 4 mm/20°. The varnish was applied to the wooden panels with a brush. The amount of varnish applied was approximately 100 g/m^2. The specimens were air dried and the process took 8 h.

In order to make the varnish layers durable against various effects and to ensure the desired properties, it is very important to choose the right type of varnish, prepare the wooden surface for the application of the varnish, use an appropriate varnish application system and take post-application precautions, as recommended by the manufacturers. Therefore, materials used in the experiment were stored appropriately until they were to be used to prevent any changes in their properties. Varnishes were checked to confirm that they had the properties specified in their descriptions and they were applied after confirmation that they were appropriate for the tests (viscosity control).

Nanolacke UV varnish: The nanolacke UV varnish can be applied right out of the package. It is applied at a rate of 5 - 20 g/m^2 (depending on the surface being treated) through pouring or pumping into a cylinder machine. The surfaces on which the nanolacke UV varnish was applied were dried in 1 - 3 seconds by passing the specimens under 2 - 3 heat lamps of 80 W each on UV belts moving at speeds of 5 – 20 m/min.

Nanolacke UV varnish is a nanocomposite and polyacrylic-based varnish that includes nanosilica-based nano- minerals and that has been cured with UV light. Organic and mineral oxides obtained through sol-gel technology and formed in the varnish provide a flexible and unscratchable structure due to the formation of three-dimensional networks, the flexibility provided by the organic material and the resistance provided by the mineral oxides. The three-dimensional network can be seen on the SEM photograph in Figure 2. Despite the high silica content, a luminous and transparent film is obtained (Celiker et al., 2006). This is a patented product, which has been developed by the DYO Company (DYO Paint Manufacturing and Trading Company Co.) for the parquet and furniture industry.

Preparation of the test specimens

Oriental beech (*F. orientalis Lipsky*) and oak (*Q. petreae Lipsky*) were randomly obtained from timber merchants in Istanbul, Turkey. Special emphasis was given to the selection of the wood material (lumber). Accordingly, no-defect, suitable, knotless and normally-grown wood materials (without zone lines, reaction wood, and decay, insect, or fungal infections) were selected, according to the TS 2470 standard (1976).

Wood samples were randomly selected from the materials described above. The rough drafts for the preparation of test and control specimens (massive panels) were cut from the sapwood parts of massive woods with dimensions of 190 x 140 x 15 mm and conditioned at 20 ± 2°C and 65 ± 3% relative humidity until a 12% humidity distribution was reached, in accordance with ASTM D 358 (1983). Conditioned specimens with dimensions of 100 x 100 x 10 mm were cut from the drafts for varnishing. The conditioned panels were sanded prior to varnishing in order to obtain smooth surfaces. Test specimens were varnished according to ASTM D 3023 (1998). The varnish manufacturers' instructions were taken into account for the composition of the solvent and hardener ratio. One or two

Table 1. Dry film thicknesses of various varnish types.

Type of varnish	Dry film thickness (μm)
Cellulosic varnish	90
Polyurethane varnish	120
Polyester varnish	210
Synthetic varnish	100
Nanolacke UV varnish	**100**

finishing layers were applied after the filling layer. The spray nozzle distance and pressure were adjusted according to the manufacturer's instructions and moved in parallel to the specimen surface at a distance of 20 cm. Varnishing was performed at 20 ± 2℃ and 65 ± 3% relative humidity.

Specular gloss measurements

Gloss is a measure of the ability of the coated surface to reflect light and it is an important coating property when the purpose is for the surface to have an aesthetic or decorative appearance. Specular gloss measurements of the varnished surfaces were taken with a gloss meter according to ASTM D 523 -89 (1999) and TS 4318 (1985). These measurements were performed after the varnish coating; the test samples were conditioned at 23 ± 2℃ and 50 ± 5% relative humidity for 16 h. Then, the dry film thicknesses were determined before the tests. The thickness of the varnish layers was measured with a comparator, which has a sensitivity of 5 μm.

The gloss of the cured samples was measured at a 60° angle of reflectance using a digital mini gloss meter (Micro-TRI-gloss, Gardner) calibrated against an internal standard of known refractive index (BYK Gardner) and the results were reported in gloss units (GU). Ten panels for each varnish type and tree species were used in the experiments, and two measurements, that is, parallel and vertical to the fiber, were made on each sample.

Pencil hardness measurements

The pencil hardness of the varnish layers was determined according to the ASTM D 3363-00 standard (2000). The measurements were performed after the varnish coating; the test samples were conditioned at 23 ± 2 ℃ and 50 ± 5% relative humidity for 16 h. In this study, after the sample panels had been conditioned and prepared for the research, experiments were performed by pinning the drawing (marking) pencils to the experimental device, beginning from the soft degrees (6B - 5B - 4B - 3B - 2B – HB – F – H - 2H - 3H - 4H - 5H - 6H - 7H) respectively. At the end of the pencil-marking process, after the testing area had been wiped by a soft cloth dampened with ethanol and the pencil marks had been cleared, observations were made by using a magnifier and light source, and the pencil number was identified as the degree of hardness, depending on the layer of varnish on which the scratch appeared.

The measurement of surface resistance of varnish layers against cold liquids

The effects of cold liquids on the varnish layer were investigated by applying various liquids having different features on the varnished samples. In order to determine the surface resistance of varnish layers to cold liquids, TS 3584 EN 12720 (2002) standard was used. Depending on this standard, the varnished samples were prepared for the experiment by conditioning at a temperature of 23 ± 2 ℃ and a relative humidity of 50% for seven days. Following the conditioning process, the experiments were carried out at a temperature of 23 ± 2℃.

In this study, detergent, acetone, acetic acid and sodium hydroxide were used in the experiments, and the effects were observed after 16 and 24 h. The areas tested with each liquid were compared to a reference area and the test areas were appropriately classified using the following numerical classification codes:

5: No change observed (perfect).
4: When the light source is reflected on the experimental surface or when the taint is too close and is reflected through the observer's viewing direction, a minor colour change is noticed or only isolated taints identified.
3: Thin taints observed in several directions are insignificant surface taints. For example, most of them are only noticed as circles or rings.
2: Deep taints refer to the condition when the taints or marks are evident, yet, for the most part, there are no noticeable changes on the surface.
1: Deep taints are the condition of having a state of change on the filter paper or on the entire surface of the material or on the structure of the surface.

Data analysis

Through the combined use of two different species of wood and five types of varnishes, a total of 100 specimens (2 x 5 x 10) were prepared, with 10 specimens for each parameter. Data were analyzed using ANOVA and Tukey HSD tests. All statistical calculations were based on the 95% confidence level.

RESULTS AND DISCUSSION

Specular gloss

Varnish film thickness is an effective factor in making comparative tests. Therefore, before the experiments, the thickness of the dry films applied to the specimens must be measured after the applied films have dried completely. Dry film thicknesses of the varnishes obtained from the measurements are shown in Table 1.

As a result of the statistical evaluations, as seen in Table 2, it has been determined that there are significant and meaningful differences ($p < 0.05$) in specular gloss between the various varnish types applied on both beech and oak samples. Nanolacke UV varnish showed the highest specular gloss value among the tested varnish types for samples of both species of wood. Nanolacke UV varnish was followed by polyurethane, synthetic, polyester and cellulosic varnish respectively.

As can be seen in Table 2, the two different tree species had no statistically significant effect on the specular gloss of conventional and nanolacke UV varnish types. In

Table 2. Comparison of specular gloss results for varnishes and tree species.

		Statistical values ($p < 0:05$)	Specular gloss parameters (60° gloss)				
			Varnish types				
			Cellulosic varnish	Polyester varnish	Synthetic varnish	Polyurethane varnish	Nanolacke UV varnish
Tree species	Beech	Avg.	79.38 A	82.19 B	85.85 C	89.10 D	97.94 E
		± s	2.31	2.43	1.10	1.15	0.76
		s^2	5.32	5.91	1.21	1.33	0.57
		V	2.90	2.96	1.28	1.29	0.77
		N	10	10	10	10	10
	Oak	Avg.	79.41 A	82.36 B	84.86 C	89.56 D	97.45 E
		± s	1.75	1.26	1.49	1.25	0.79
		s^2	3.07	1.59	2.23	1.57	0.63
		V	2.21	1.53	1.76	1.40	0.82
		N	10	10	10	10	10

Avg.: Average
±s: Standard deviation
$s^{2:}$ Variance
V: Coefficient of variation
N: number of samples used in each test
Homogeneity groups: Same letters in each "column [↓] and line [→]" indicate that there is no statistical difference between the samples according to the Tukey's multiply range test.

Table 3. Pencil hardness test results.

Varnish types	Pencil hardness grade
Nanolacke UV varnish	7H
Polyester varnish	6H
Polyurethane varnish	5H
Cellulosic varnish	4H
Synthetic varnish	2B

similar studies (Ozen and Sonmez, 1990; Kaygin et al., 1999), it was also reported that the different tree species had no effect on either the specular gloss of the varnish layers or the dye layers; instead, the primary effect was either the type of varnish or dye. Furthermore,in Ozen and Sonmez's study, the best result for specular gloss was obtained by the polyurethane varnish, which was followed by synthetic, polyester and cellulosic varnish. The results obtained in this study are in agreement with the results from Ozen's and Sonmez's study.

Pencil hardness

The resistance of varnish layers against scratching is a function of surface hardness. The findings related to hardness measurements with a pencil are given in Table 3.

As a result of the experiments, it was found that the two different wood types had no effect on scratch resistance and that the principal effect was related to the varnish type. The varnish having the highest scratch resistance was nanolacke UV varnish (7H), which can be seen in Table 4. The nanolacke UV varnish was followed by polyester varnish (6H), polyurethane varnish (5H) and cellulosic varnish (4H). Synthetic varnish has the least hardness in proportion to the other varnishes and has the lowest scratch resistance.

Surface resistance to cold liquids

The results of the measurements of surface resistance of varnish layers coated on oak and beech wood panels against cold liquids are given in Table 4.

As observed in Table 4, nanolacke UV varnish provided a perfect surface view after exposure to all of the liquids used during the experiments. On the other hand, different reactions to applied liquids have been observed with conventional varnishes. Although polyurethane varnish maintained a perfect surface view after contact with detergent, sodium hydroxide and acetic acid, it showed the least surface resistance to acetone. Polyester varnish and cellulosic varnish provided a perfect surface view after contact with sodium hydroxide and detergent, but their surfaces were degraded after contact with acetone and acetic acid. Synthetic varnish provided a perfect surface view after contact with acetic acid and detergent, but it was the least resistant varnish to exposures to acetone and sodium hydroxide.

As a result of the study, it can be concluded that the use of different species of trees both with conventional varnish types and with the newly-developed nanolacke UV varnish has no significant effect on the specular gloss of the varnish layer. However, it was determined that

Table 4. Results of the measurements of surface resistance of varnish layers coated on oak and beech wood panels against cold liquids.

Varnish types	Classification code							
	Acetone		Sodium hydroxide		Detergent		Acetic acid	
	16 h	24 h	16 h	24 h	16 h	24 h	16 h	24 h
Nanolacke UV varnish	5	5	5	5	5	5	5	5
Polyurethane varnish	1	1	5	5	5	5	5	5
Polyester varnish	3	3	5	5	5	5	4	4
Cellulosic varnish	1	1	5	5	5	5	4	4
Synthetic varnish	1	1	1	1	5	5	5	5

there are significant differences among the varnish types. specular gloss value, followed by polyurethane, synthetic, polyester and cellulosic varnish.

According to the pencil hardness grade test results, nanolacke UV varnish gave the best result (7H). This varnish was followed by polyester (6H), polyurethane (5H), cellulosic varnish (4H) and synthetic varnish (2B).

According to the results related with the resistance of varnish layers against cold liquids, conventional varnish types showed low resistance to some of the liquids used in the experiments, whereas nanolacke UV varnish was the most resistant varnish type to all of the liquids used in the research.

The fact that the differences between the tools and production techniques used when making varnishes may have effects on the properties of the varnish layers and on their resistance performance against external agents cannot be ignored. The solidity of a varnish layer depends on its ability to resist the various physical, mechanical, and chemical effects that it encounters. However, wood surfaces that are coated with varnishes may be subjected to many other effects that relate to the locations where the products are used. For example, the effects that may be encountered are different between an office setting and a bathroom setting. Another example is the different effects encountered by parquet boards used on the floor of a house floor and the same boards used in a gym. In all of the various settings, it is expected that the varnish layer will last a long time due to its resistance to the effects stated above. Thus, determining which of the different varnishes can endure and determining the extent to which they can resist the various effects that will be encountered are extremely important. Consequently, in terms of the selection of the varnish to be applied on specific wood surfaces, future financial losses can be avoided at the very beginning by considering the features of the space where the product is going to be used and by selecting the varnish that has the best resistance to the anticipated effects.

Conclusions

The results of this study demonstrate that nanolacke UV varnish has better resistance properties compared to

Accordingly, nanolacke UV varnish gave the highest conventional varnishes in terms of dry film resistance properties, such as specular gloss, hardness, and surface resistance to cold liquids. As a result, using nanolacke UV varnish instead of conventional varnishes can be recommended for furniture and parquet areas for which varnish layer gloss, hardness and surface resistance to cold liquids are important.

Although the cost of nanolacke UV varnish is higher than the cost of conventional varnishes, it is an innovative product that provides benefits to the user when its long-term durability and quality factors are taken into account. Furthermore, this nanotechnology product varnish is very innovative and important in terms of bringing nanotechnology and wood technologies together.

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