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Chromatic Variations of Wood Surface Due to Laser Irradiation

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Abstract

The colour and chemical variations of poplar wood surfaces (*Populus* sp.), frequently used in works of art, were studied after laser irradiation by monitoring the wood surface modifications (colour measurements and FTIR) in order to assess the extent of the photochemical degradation on wood untreated and treated with shellac and beeswax, finishing materials of problematic removal in the restoration. The aim is to identify thresholds of minimum intervention.

Introduction

The application of surface finishes plays an important role in the aesthetics and protection of wooden surfaces as it offers a number of benefits: it improves the photo- and dimensional stability, maintains the aesthetic, morphological and chromatic qualities of an artefact.

Over time and in consideration of the conservation conditions, artefacts need cleaning interventions that remove the aged finishing layers. Conservators often use chemicals, scalpels and micro blasting. These methods can remove small fragments of the underlying substrate or in the case of chemicals they may penetrate the artefact with unpredictable effects. Furthermore, in many cases it is difficult to control the activity that easily translates into excess cleaning of the surface, with possible reduction in overall aesthetics of an object and in extreme cases even an acceleration of the degradation processes could be observed. In this context, the laser-assisted ablation of coatings is not only useful but also a unique method because it combines precision and control making it an ideal tool for use in conservation and restoration of archaeological artefacts and works of art [1]. The aim of this work is to identify thresholds of minimum intervention.

Materials & Methods

Circular wood samples were obtained by a board of poplar, 10 mm in diameter 2 mm in thickness, cut in longitudinal direction. Each plot treated (wood surface treated with shellac and with beeswax) was artificial aged up to 1008 hours and then irradiated with laser. Samples without surface treatment were irradiated in the same condition (tab. 1).The accelerated ageing of the samples was performed in a Model 1500E Solar Box equipped with a 2.5 kW xenon-arc lamp and an UV filter that cuts off the spectrum at 280 nm. The samples were exposed from 0 to 1008 h at 550 W/m^2 and 55°C.

Colour was measured using an X-Rite CA22 reflectance spectrophotometer according to CIELAB colour system, before and after the laser irradiation.

Laser tests were carried out with the MDTT45 Q-switched Nd:YAG system supplied by MEDICAM, changing the laser irradiation conditions as reported in tab. 1. Pulse duration was 2 s and the frequency 5 Hz.

The differences in lightness (ΔL*), chromatic coordinates (Δa* and Δb*), and total colour (ΔE*) were calculated according to Normal 14/93 (1993) and EN 15886 (2010). Data were analysed with the StatSoft Statistica 2010 advanced statistics software. As a first step, data distribution was plotted and visually checked for normality.

Tab. 1. Experimental parameters used in laser test

Wavelength (nm)	Fluence (J/cm^2)	Energy (mJ)	Spot diameter (mm)	Sample Wood/Shellac/Wax
532	0.01	4	7	15/15/15
	0.9	176	5	15/15/15
1064	0.01	4	7	15/15/15
	0.9	348	7	15/15/15

Differences between treatments were checked with the standard paired-test, with ANOVA and M-ANOVA analyses.

Results

At the wavelength and fluence values tested, the laser irradiation determines on wood colour parameters (L*,a*,b*) differences that are statistically significant ($p < 0.01$) compared to natural wood. In fig. 1 the effect on b*, due to laser irradiation on natural wood, is shown. Laser treatments that most influence the parameters L* and a* on natural wood are those at 1064 nm wavelength and fluence 0.01 J/cm^2 (darkening) and 532 nm and fluence 0.9 J/cm^2 (lightening). The colour variations, however, are not perceptible at naked eye. This evidence is highlighted by ΔE* values before and after irradiation (tab. 2).

The colorimetric parameters (L*a*b*) of wood "treated-aged-laser irradiated" compared with sample beeswax and shellac treated artificially aged (1008 hours) and natural wood showed statistically significant differences ($p < 0.01$). This implies that the wavelengths and laser fluences tested have not allowed to return to the colorimetric parameters of natural wood. Colour variation was observed by ΔE* higher values.

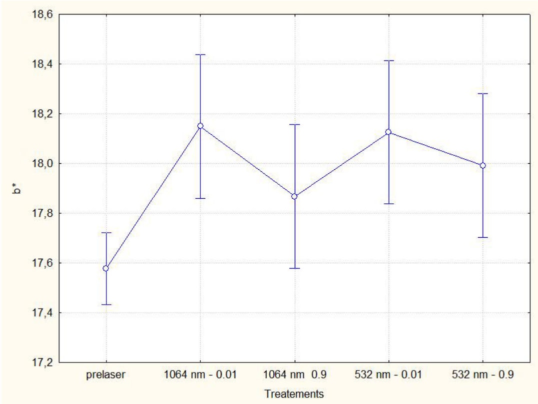

Fig. 1; MANOVA descriptive graphic. b* on natural wood after irradiation in different wavelengths (nm) and fluences (J/cm^2).

Tab. 2 ΔE* due to laser irradiation at different parameters on wood without surface treatment

Wavelength (nm) – **Fluence** (J/cm^2)	**ΔE***
1064 - 0,01	0.676
1064 - 0,9	1.108
532 - 0,01	0.639
532 - 0,9	0.583

Conclusions

The monitoring of the wood colour, and above all its variation, is an excellent method to assess the preservation state of artefacts on which interventions, including diagnostic, must be set according to criteria of minimum intervention and minimally invasive. Some authors highlighted the relationship between colour and surface chemical modification of wood [2, 3], outlining the possibility of using the colour in the monitoring of wooden surfaces. The results obtained encourage to further experiment with other methodologies (FTIR and SEM observation) in order to assess the state of preservation of the surfaces and to find threshold values of laser irradiation that could respect both the aesthetics and composition of the wood.

References

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