

COLOR CHANGES IN THE ARTWORK MATERIALS AGED BY UV RADIATION*

N. HERASCU, M. SIMILEANU, R. RADVAN

National Institute of Research and Development for Optoelectronics – INOE 2000, CERTO
1 Atomistilor Street, Magurele – Ilfov, Romania, e-mail: simileanu@inoe.inoe.ro

(Received August 9, 2006)

Abstract. Color is the main essence of most artworks: paintings, stained-glass windows, miniatures, statues, monuments, historical textile. Because some constituents of artwork materials are sensitive to UV light the color change will be occurs. Consequently, it directly affects the appearances of the art objects. The changes in art objects color caused by ageing of artwork materials are major problems encountered by artists, conservators and museum curators. Thus, for conservation and restoration purposes it is important to monitor color changes induced by the natural ageing and cleaning procedures using UV radiation. Thus, the goal of our study was to evaluate the effects of direct UV exposure of certain artwork materials using color spectroscopy. The samples were artificially aged under the UV light (254 nm) under constant environmental and room conditions (temperature -22°C and relative humidity -55% RH). Prior and after artificial UV ageing, the reflectance spectra of all samples were acquired using a JASCO V-550 spectrophotometer. To quantify the color changes that may occur because of UV exposure the colorimetric parameters were determined using the CIE $L^*a^*b^*$ procedure. Thus, it has been shown that accelerated and artificial UV ageing with 254 nm lamp yields to different (photochemical) effects show by color appearance changes such as strong discoloration of the organic artwork materials comparing with those of the UV laser irradiation used in the cleaning procedure.

Key words: UV radiation, organic material ageing, color changes, CIE $L^*a^*b^*$.

1. INTRODUCTION

The great variety of the art works in museums, historical buildings and archives is the main result of the human history and civilization. These could be characterized according to their shape, value, destination, structure (material) and color.

As some constituents of artwork materials are sensitive to storage conditions (humidity, temperature and light) a color change will likely occur.

Color is the main essence of most art works: paintings, stained-glass windows, miniatures, statues, monuments, historical textile. The changes in art objects color caused by ageing of artwork materials are major problems encountered by artists, conservators and museum curators [1, 2].

* Paper presented at the Annual Scientific Conference, May 26, 2006, Faculty of Physics, Bucharest University, Romania.

However, the deterioration in artwork materials could be considered according to the cause and the associated changes in external features. Thus, an important distinction should be made between physical-mechanical, biological damage and physical-chemical damage as photochemical damage.

Light is a major cause, which contributes to the deterioration of the artwork materials leading to the color fading, discoloration or other deteriorations in organic materials such as paper, parchment, textiles and leather. In other materials as ceramic, stone, glass and metals the damages are less important, inorganic materials being less vulnerable to the light exposure.

However, both organic and inorganic materials of art works are damaged by light and the effects are cumulative and irreversible. Further, a component of the electromagnetic spectrum, the ultraviolet (UV) radiation, is particularly harmful for artwork materials and it is most responsible for the fading of color or discoloration and for the deterioration of the organic materials structure. Consequently, it directly affects the appearances of the art objects. Thus, a minimization of light damage while artworks are on display, is required.

The light damage in leather, especially by the UV part of sunlight, implies the photochemical damage of it and the ageing of the organic material. The photochemical damage is very difficult to detect in the early stages. It becomes evident after the organic material has already suffered an important loss of strength and changes in color.

The organic materials are predominantly made up by polymers, that with ageing breakdown by depolymerisation process.

In the photochemical degradation of the leather, the UV radiation acts as a catalyst of the oxidation process in organic materials (collagen). The result is the formation of peroxides from tannins and oils, which catalyze further hydrolysis [3].

The category of damage is characterized by different features (weakening, surface powdering, pH change), one of these being the changes in color. Thus, for conservation and restoration purposes it is important to monitor color the changes induced by the natural ageing and cleaning procedures using UV radiation [4].

Many color models have been developed to monitor some specific task in color processing. The international committee on colorimetry (CIE) has defined certain color models as CIE X, Y, Z, CIE $L^*a^*b^*$, CIE $L^*u^*v^*$, CIE $L^*C^*H^*$ (Lightness, chroma, Hue), and CIE HVC (Hue, Value, Chroma). The most used color models are the perceptually uniform models CIE $L^*a^*b^*$ and CIE $L^*C^*H^*$ because of their features as humans vision and the underling both the color components (color lightness – L^* , color coordinates: $\pm a^*$ – reddish/greenish and $\pm b^*$ – yellowish/bluish) and the color difference (ΔE^*_{ab}) [5].

$$\Delta E^* = [(\Delta L^*)^2 + (\Delta a^*)^2 + (\Delta b^*)^2]^{1/2}$$

In this paper one of the common color models CIE $L^*a^*b^*$ has been used, to quantify the color changes that may occur because of UV exposure.

2. MATERIALS AND METHODS

2.1. SAMPLES

Four types of leather were considered for accelerated and artificially ageing, in this study:

- I. Cattle leather vegetal tanned, chromium treated TC₂;
- II. Cattle leather Quebracho tanned, chromium treated 6Qa;
- III. Sheep leather vegetal tanned, chromium treated MaC;
- IV. Goat leather Quebracho tanned, chromium treated iQ.

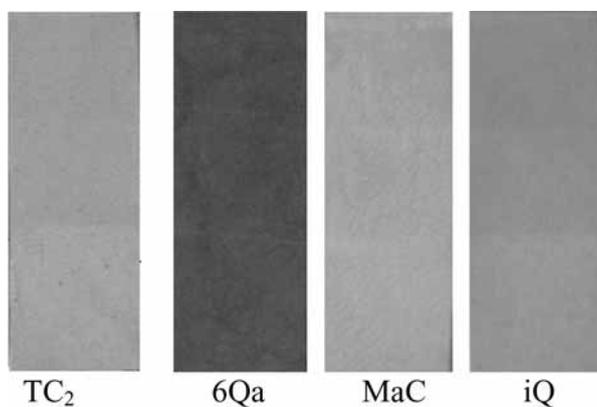


Fig. 1 – Leather samples used in the study.

All samples were divided in three areas (chromatic homogenous), which had been exposed to UV radiation for two periods.

2.2. LIGHT SOURCE

A halogen lamp type (wavelength: 253,7 nm, radiation flux: 800 mW, radiance: 15 mWcm⁻²sr⁻¹) was used for irradiation.

2.3. ARTIFICIALLY AGEING METHOD

The leather samples were irradiated according with the following irradiation procedure: the 1st area of each sample was irradiated for 800 s and the 2nd area of each sample was irradiated for 900 s. The 3rd area represent the control sample, which wasn't exposed to UV radiation.

The experiments were performed under constant environmental and room conditions (temperature –22°C and relative humidity –55% RH).

The accelerated and artificially ageing effect of UV exposure, in the 1st and 2nd areas of each sample was evaluated by the spectroscopy method.

Prior and after artificial UV ageing, the reflectance spectra of each area of all samples were acquired using a JASCO V-550 spectrophotometer.

The accelerated and artificially ageing effect of UV radiation in terms of color changes, was quantify following the CIE L*a*b* procedure. Thus, the reflectance data were downloaded in a computer interfaced with the JASCO V-550 spectrophotometer.

A software provided with JASCO V-550 spectrophotometer was used for the reflectance data processing in terms of lightness (L^*), color coordinates (a^* , b^*) and color difference (ΔE^*_{ab}). The graphical analysis of the results was performed for each area of all samples using the classical procedure provided by Microsoft Office package.

3. RESULTS

In each are of all samples, the UV ageing effect was monitored. The reflectance spectra of the UV irradiated leather area and the control area are displayed in Fig. 2.

From the reflectance spectra acquired after 1800 s and 900 s of UV irradiation it could be observed that the reflectance of these areas is modified as compared with the control area. The color changes induced by UV irradiation was quantified in terms of lightness (L^*) and color coordinates (a^* , b^*). The differences in this terms (dL^* , da^* , db^*) for each irradiated and control area and the color difference (ΔE^*_{ab}) were determined (Fig. 3).

The graphic analysis shows that the lightness L^* is higher the higher the irradiation time and the color coordinates a^* and b^* increase with the length of exposure to UV radiation.

However, an exception was sample (6Qa) which presented an unexpected random variation of b^* color coordinate during UV irradiation (Fig. 3 b-i). The color difference ΔE^*_{ab} presents an important increase for each sample area exposed to UV radiation for a longer length ($t_2 = 1800$ s).

4. CONCLUSIONS

The results of this study have shown that the accelerated and artificially UV ageing of leather yields to color appearance changes of this organic artwork material. This color changes depends on the leather type and processing.

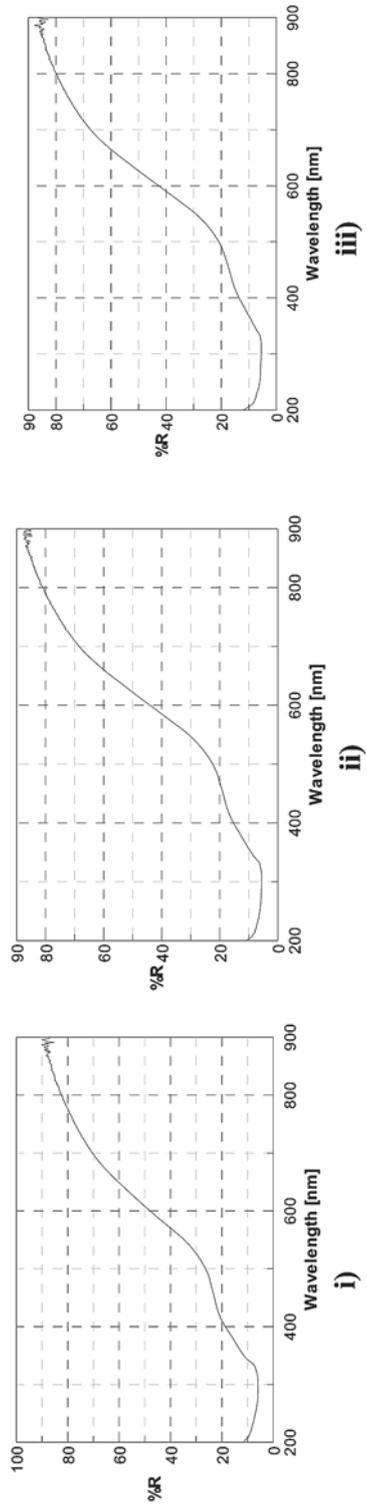


Fig. 2a – Cattle leather vegetal tanned, chromium treated TC₂.

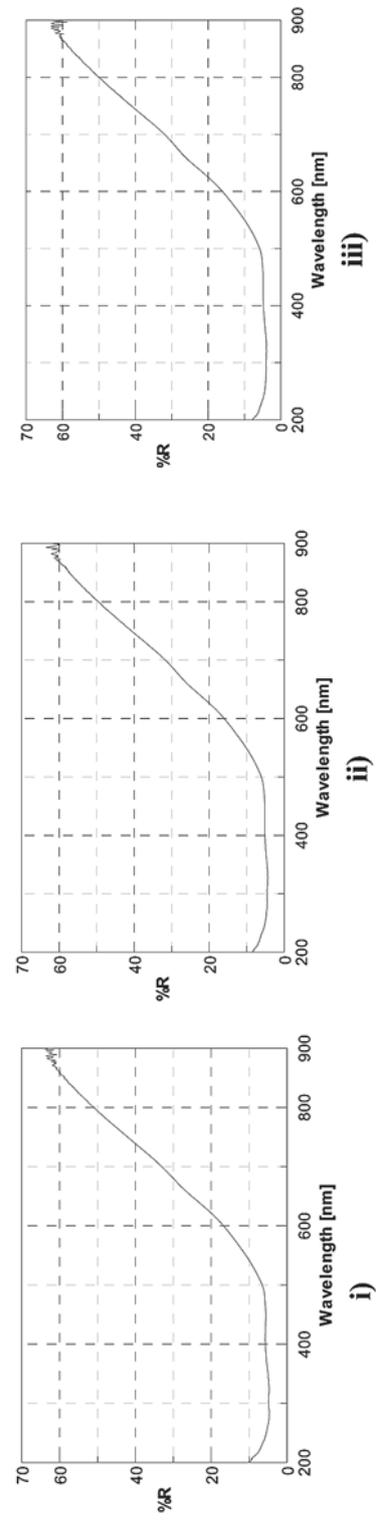


Fig. 2b – Cattle leather Quebracho tanned, chromium treated 6Qa.

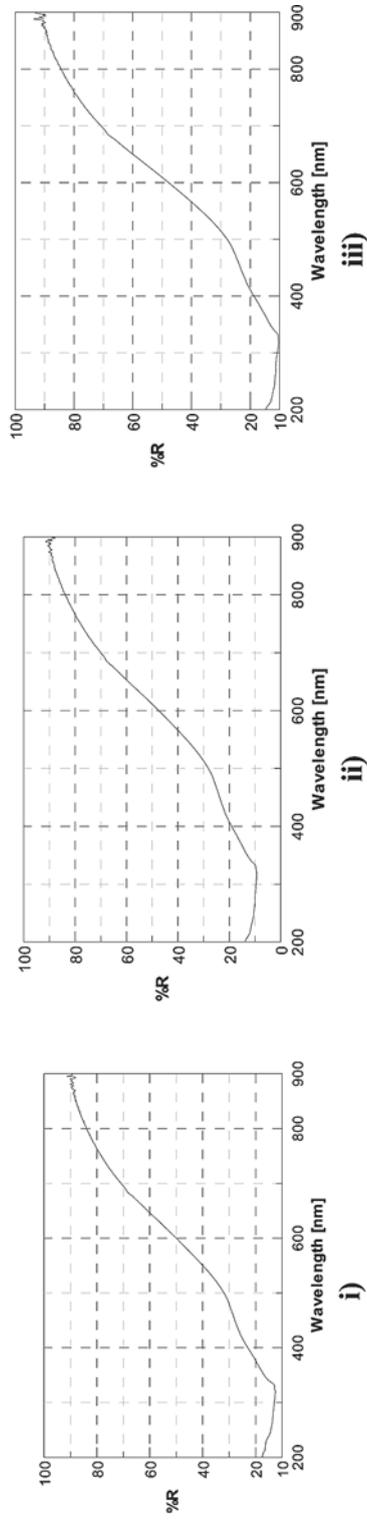


Fig. 2c – Sheep leather vegetal tanned, chromium treated MaC.

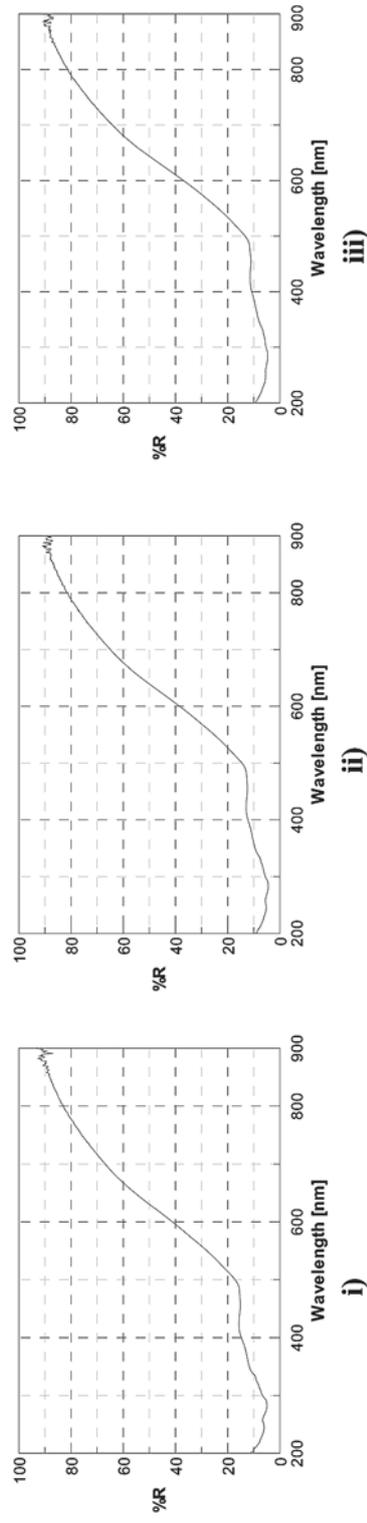


Fig. 2d – Goat leather Quebracho tanned, chromium treated iQ.

Fig. 2 – Reflectance spectra of different type of leather: i) sample UV irradiated $t_2 = 1800$ s; ii) sample UV irradiated $t_2 = 900$ s; iii) control sample.

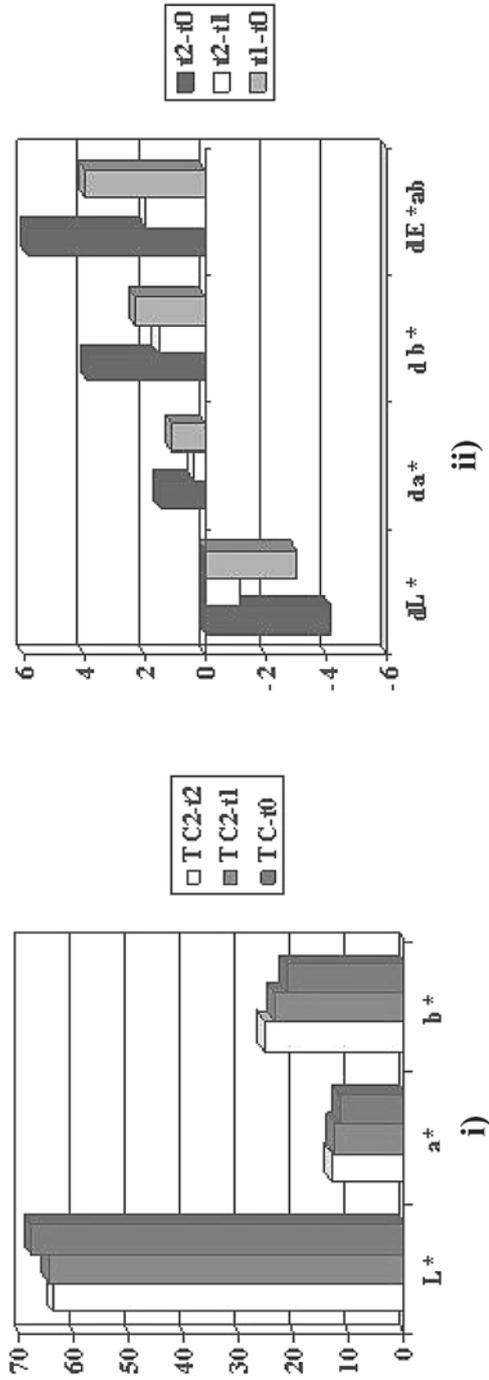


Fig. 3a – Cattle leather vegetal tanned, chromium treated TC₂.

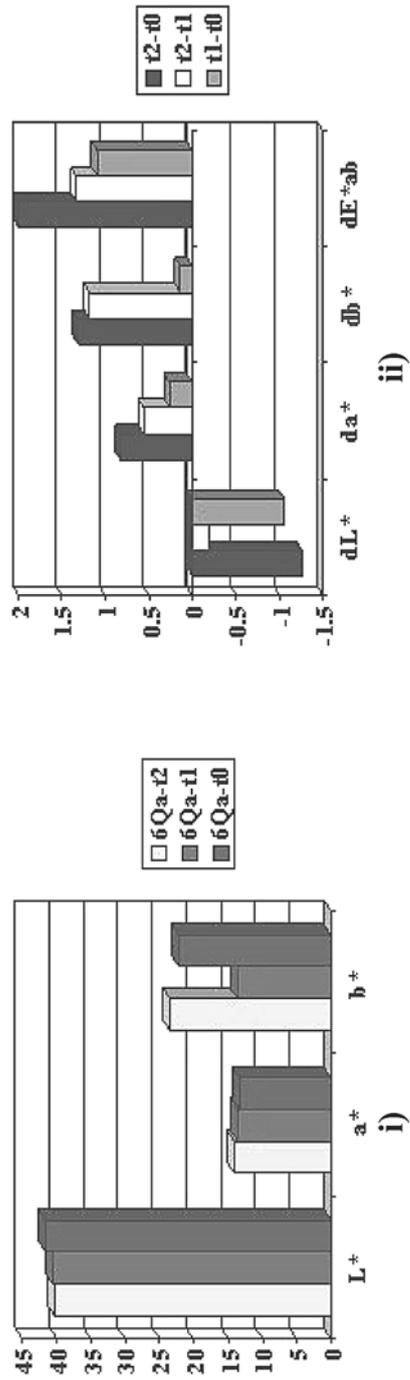


Fig. 3b – Cattle leather Quebracho tanned, chromium treated 6Qa.

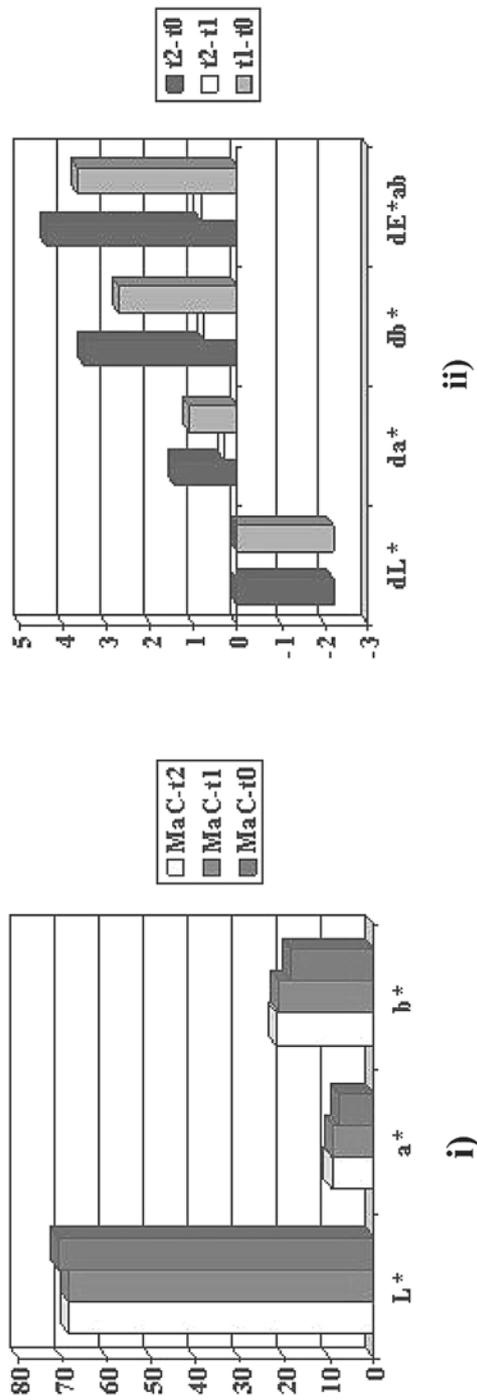


Fig. 3c – Sheep leather vegetal tanned, chromium treated MaC.

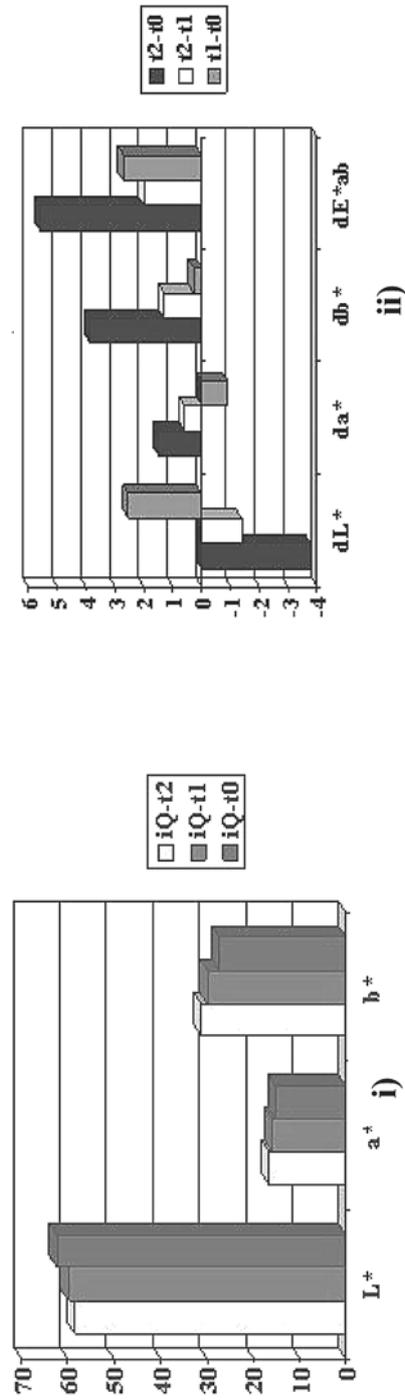


Fig. 3d – Goat leather Quebracho tanned, chromium treated iQ.

Fig. 3 – Color changes in leather: i) Lightness and color coordinates (L^* , a^* , b^*); ii) Lightness and color coordinates differences (dL^* , da^* , db^* , dE^*_{ab}) and color difference ΔE^*_{ab} .

However, the analysis of the color coordinates (L^* , a^* , b^*) and color difference (ΔE^*_{ab}) have demonstrated that they are proportional to the irradiation time.

The use of the CIE $L^*a^*b^*$ procedure, for the quantification of lightness, color coordinate and color difference was a suitable procedure to monitor the color changes in the UV exposed leather.

Acknowledgement. The National Institute of Research and Development for Leather and Footwear is kindly acknowledged for their help in providing leather samples.

REFERENCES

1. G. Thomson, *The museum Environment*, 2nd Edition, Butterworth Heinemann, Oxford, 1994.
2. R. Salimbeni, V. Zafiropulos, R. Radvan, V. Verges-Belmin, W. Kautek, A. Andreoni, G. Sliwinski, M. Castillejo, S. R. Ahmad, *The European community research concerning laser techniques in conservation: results and perspectives*, Coalition – CSIS Thematic Network on cultural Heritage, Newsletter no. 9, 2005.
3. J. Lodewijks, 'The Influence of Light on Museum Objects', in: *Recent Advances in Conservation: Contributions to the IIC Rome Conference, London 1963*.
4. M. Simileanu, R. Radvan, IANUS, vol. 9–10, *Laser Conservation of Organic Artworks*, Ed. HAR Foundation, Bucharest 2006.
5. Yoshi Ohno, CIE Fundamentals for Color Measurements, IS&T NIP16 Conference, Vancouver, Canada, Oct. 16–20, 2000.