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HYPERSPECTRAL IMAGING FOR EARLY DETECTION OF ALTERATION PHENOMENA IN PAINT LAYERS

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Abstract

Hyperspectral imaging (HSI) is a technique that can be applied in various fields of science and recent developments in hardware and software allow to increase its power and to decrease the costs of the analysis based on reflectance spectrum in the visible and near infrared wavelength range. This monitoring technique is particularly suitable for pigment classification and for the monitoring of pictorial materials without the need of sampling [1]. In order to study the alteration of paint layers by solar aging , samples were prepared with different pigments, binders and supports and artificially aged using solar box. The results obtained for a sample composed by yellow ocher mixed with Arabic gum and applied to a canvas support are presented in this work [2].The sample was acquired in the VIS-NIR (400-1000 nm) and SWIR (1000-2500 nm) ranges by HSI after196 hours and 400 hours. Besides, for comparison, color measurements were carried out before and after aging the sample to monitor color changes during the two steps. The goal of this study is to verify the possibility to detect alteration phenomena before they become macroscopically visible by HSI in the VIS-NIR and SWIR ranges.

Materials and methods

The yellow ocher mixed with Arabic gum was applied on a canvas with a primer composed of gypsum and calcium. After 30 days the following measures were carried out:

- Colorimetric measurements by a Konica Minolta CM2600d spectrophotometer with the following setup: CIE L * a * b * color scales, illuminant D65, 10 ° standard observer, geometry of measurement 45 °/0 °.
- Hyperspectral imaging was carried out in two ways:

1) The first acquisition was carried out in the VIS -NIR range from 400 to 1000 nm by means of an ImSpector model V10E (Specim, Finland), mounted on a stereomicroscope.
2) another Specim system, the SISUCHEMA XL, was used, equipped with a hyperspectral camera sensitive in the range from 1000 to 2500 nm with a resolution sample / pixel of about 6 nm.

Chemometric analysis was performed in both cases using the PLS Toolbox (C) by Eigenvector Research, Inc. Version: 7.3 Release: (16217) running on MATLAB Version 7.10.0.499 (R2010a) [3]. .

Colorimetric measurements results

The PCA analysis of color measurements (Fig. 1) carried out using the spectrophotometer shows a color change (indicating an alteration of the pictorial surface) with a thinning of the measurement cloud points performed after 400 aging hours.

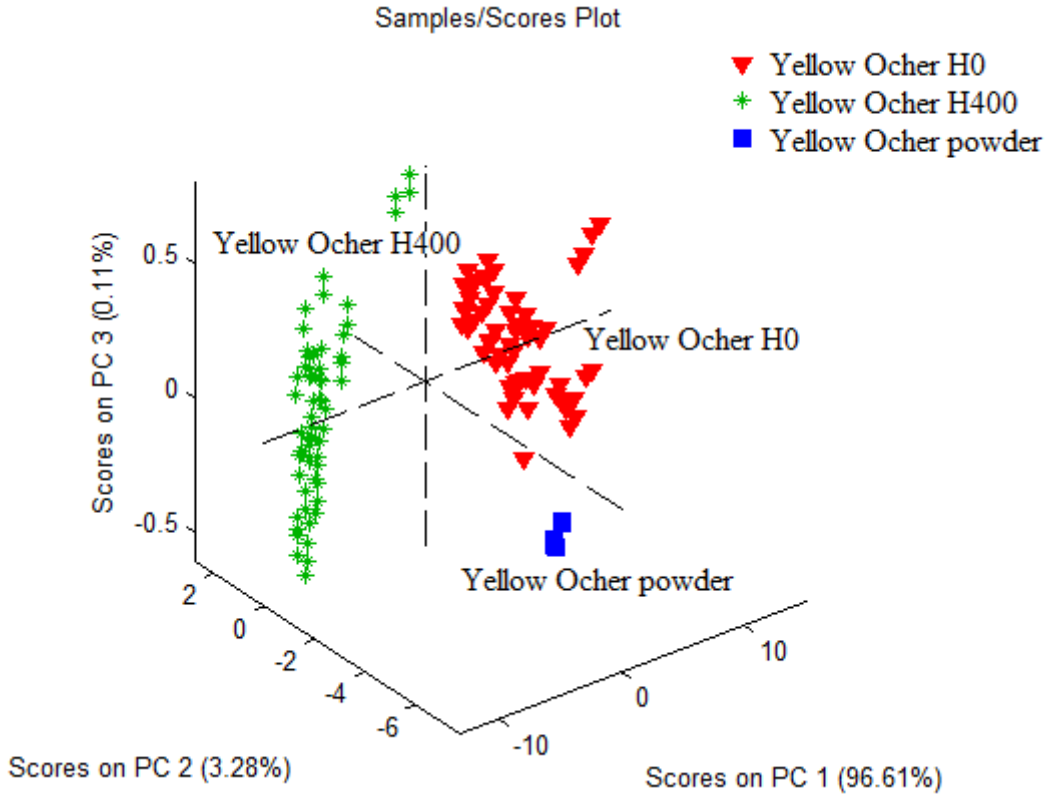
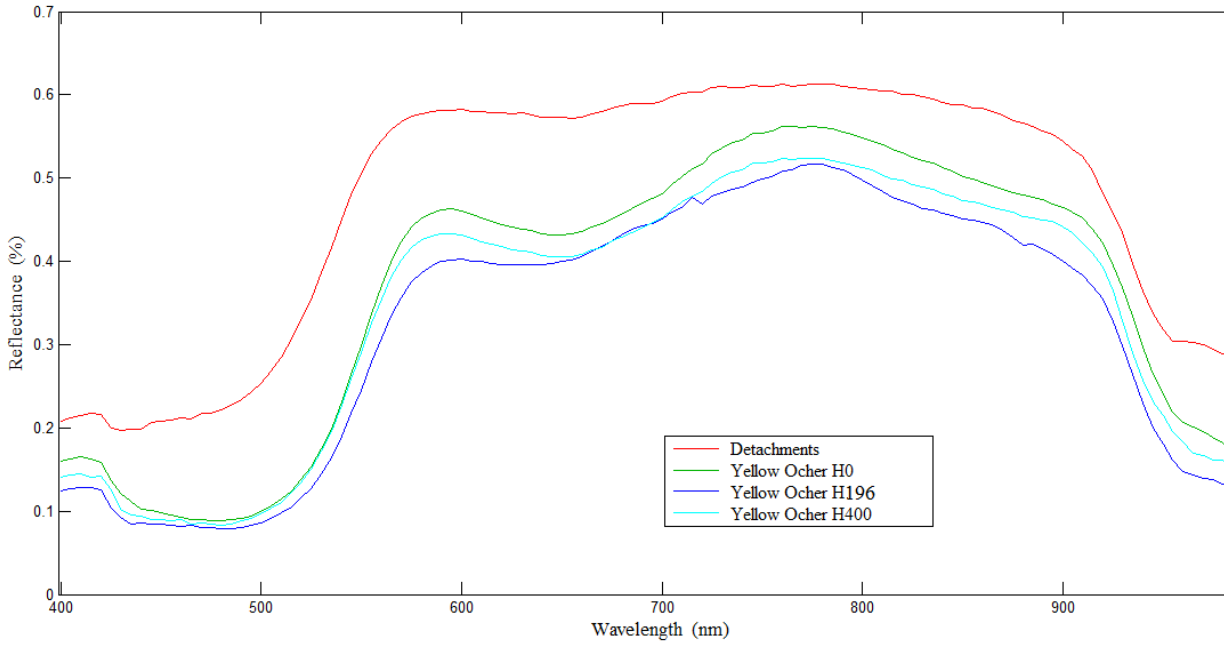


Fig. 1. Score plot of the colorimetric data processed by PCA.

VIS-NIR HSI results

The reflectance spectra (Fig. 2a) of the sample aged for 17 days shows slight reflectance changes varying the irradiation time. Applying PCA (Fig. 2b) the different aging times of the samples are highlighted as well as the detachment areas.

(A)



(B)

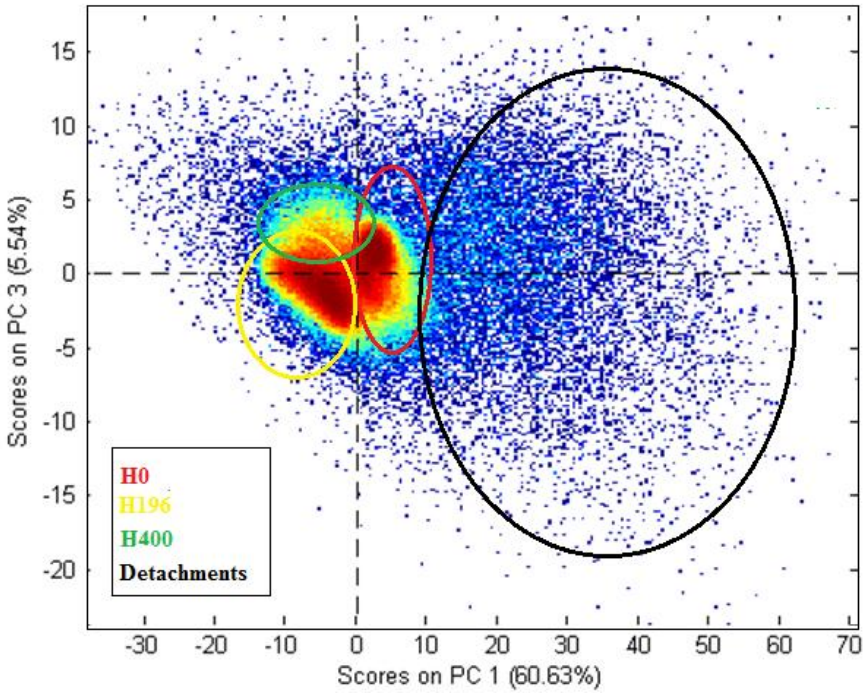


Fig. 2. A) average spectra of the acquisitions performed on the sample in VIS-NIR range; B) score plot of PCA performed on the sample at different aging times.

Selecting small ROIs (Region of Interest) on areas characterized by pigment and binder detachments before aging, it was possible through PLS-DA classification to automatically recognize all the alterations present in the investigated sample (Fig. 3).

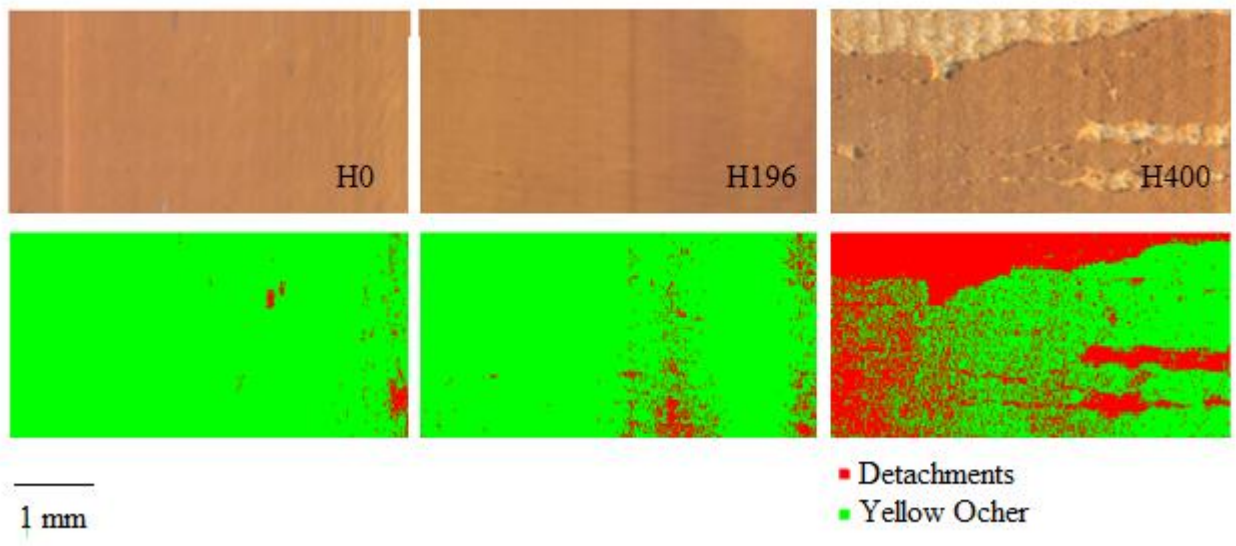
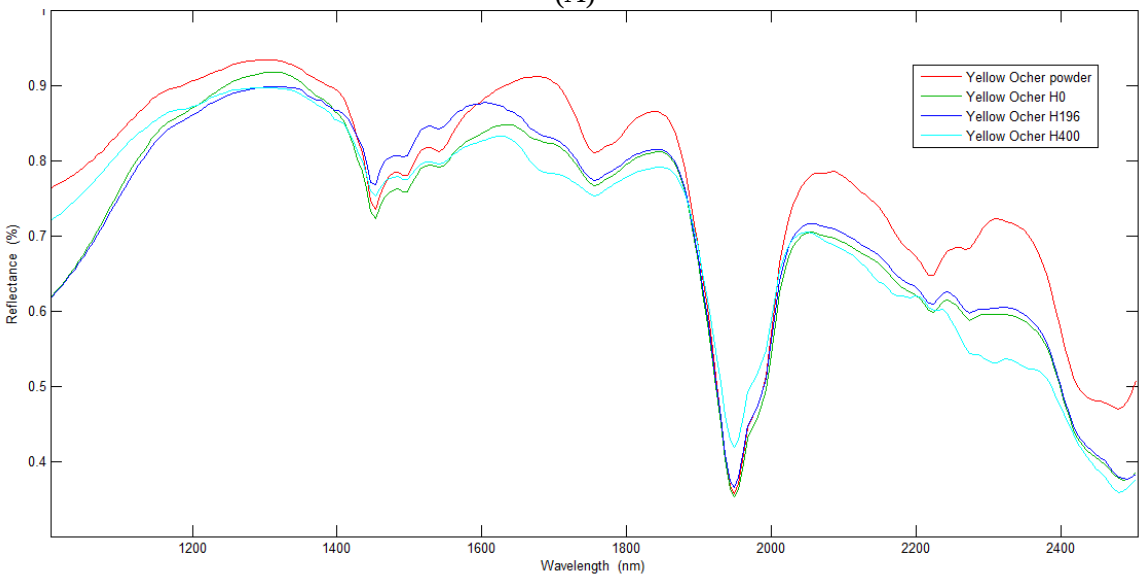


Fig. 3. Mapping carried out on the area analysed at different aging times by PLS-DA classification.

HSI SWIR results

The average spectra in the SWIR range of the samples aged at different times (Fig. 4a) show the main differences in the region from 2200 nm, probably caused by a reduced thickness of the paint layer and the increase of the underlying layer of preparation. The PCA analysis (Fig. 4b) highlights on the sample before aging some anomalies due to an incomplete adherence of the pigment to the support.

(A)



B)

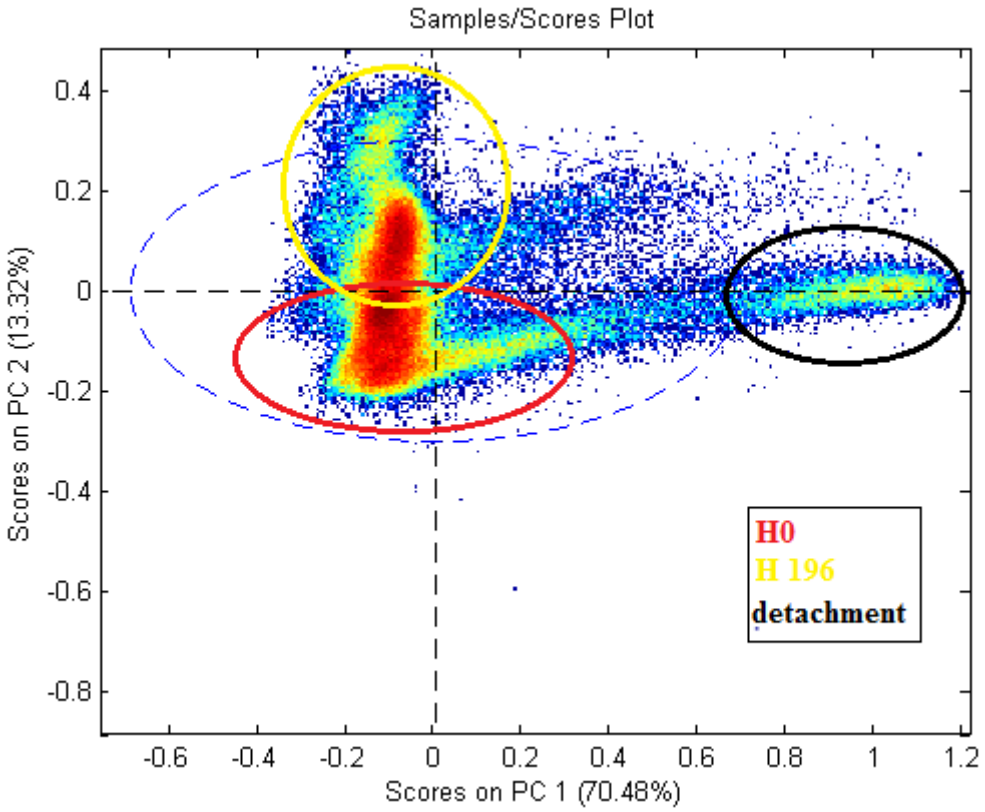


Fig. 4. A) average spectra of the acquisitions performed on the sample in SWIR range; B) score plot of PCA performed on the sample at different aging times

To check the distribution of the paint layer alteration varying the irradiation time, yellow ochre powder has been acquired and processed and it has been used to set the model. Using PLS-DA (Fig. 5) it was possible to verify the alteration of the pigment varying the irradiation time.

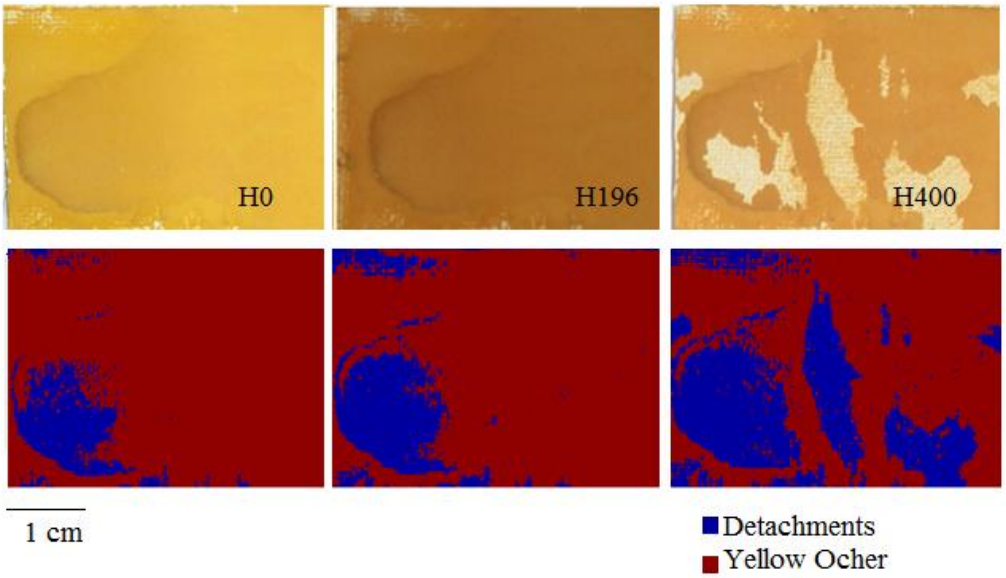


Fig. 5. Mapping carried out on the area analyzed at different aging times by PLS-DA classification.

Conclusions

Using HSI it has been possible to monitor all degradation phases on the sample. In particular, in the SWIR range, it has been possible to get information on the non-adherence of the paint layer to the substrate and the posting occurred during aging in solar box. The use of the HSI combined to chemometric methods not only allows monitoring the state of alteration over the time of a painting, but in particular in the SWIR range it is possible to get information before the deterioration becomes macroscopic.

References

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