Journal of Industrial and Engineering Chemistry xxx (2015) xxx–xxx

Contents lists available at ScienceDirect

Journal of Industrial and Engineering Chemistry

journal homepage: www.elsevier.com/locate/jiec

Identification of natural inorganic pigments used on 18th century Korean traditional mural paintings by using a portable X-ray fluorescence

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ARTICLE INFO

Article history:
Received 18 December 2014
Received in revised form 11 March 2015
Accepted 13 March 2015
Available online xxx

Keywords:
Natural inorganic pigments
X-ray fluorescence spectroscopy
18th century
Korean traditional mural paintings

ABSTRACT

Inorganic pigments on 18th century Korean traditional mural paintings were investigated by using a portable XRF. To investigate inorganic pigments, two different mural paintings were chosen. The elements such as Al, Hg, Cu, and Pb were estimated. The main colors of those mural paintings were white, red, and green. Same chemical compositions were detected from those mural paintings, but the red colors were divided into two elements as Hg and Pb. These results showed that the inorganic pigments such as cinnabar (HgS), lead red (Pb_3O_4), lead white ($2PbCO_3{\cdot}Pb(OH)_2$) and malachite ($CuCO_3{\cdot}Cu(OH)_2$) had been used to draw the mural paintings during 18th century in Korea.

Introduction

Natural inorganic pigments have been used since pre-historic times, for example the drawings in the Pech-Merle caves in the south of France, Northern Spain, and Northern Africa were made with charcoal, ochre, manganese brown and clays [1,2]. Ancient pigments were created by all human cultures on earth at least since the early modern humans used ochre to stain themselves, to paint walls and objects [1].

In case Korean history, natural inorganic pigments have been founded at *Dan-chung*, mural paintings, and so on. Mural Paintings of several 4th century tombs allow us to investigate the beginnings of this most intricate cultural assets form to the Koguryo Kingdom (37 B.C.–A.D.668). The use of *Dan-chung* continued throughout the Chosun Dynasty (1392-1910), especially on wooden structures [1,3].

Recently, the synthesized inorganic pigments have been used for restoration and repairing of *Dan-chung* on the Korean ancient buildings including mural paintings of ancient temples [3,4]. And thus the Korean natural inorganic pigments have been replaced to chemical and artificial, and Korean traditional colors have been lost.

For this reason, scientific researches on the nature of the inorganic pigments with Korean traditional colors are required, and the non-destructive technique of X-ray fluorescence spectroscopy have been chosen for the analysis of the pigments in the conservation science field of cultural assets.

The X-ray fluorescence spectroscopic technique is very important in the study of materials, especially in arts and archeology. It is helpful of the evaluation of the cultural assets, neither touching it nor damaging it at all. With portable equipments the investigations can be run in situ, without moving the objects from its original place. It is one of the harmless ways to obtain information about the materials and technique applied by the archeologists and conservators [5,6].

In this research, several pigments of 18th century were investigated by using a portable X-ray fluorescence equipment without damage to the ancient mural paintings.

Experimental

In this study, the two different mural paintings (Silsangsa temple and Bulyoungsa temple) which were built at 18th century (Cho-sun Dynasty) were chosen as subjects, because those two

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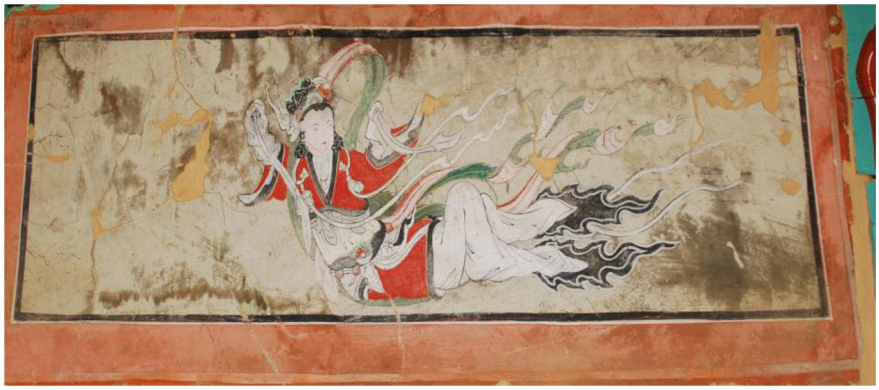
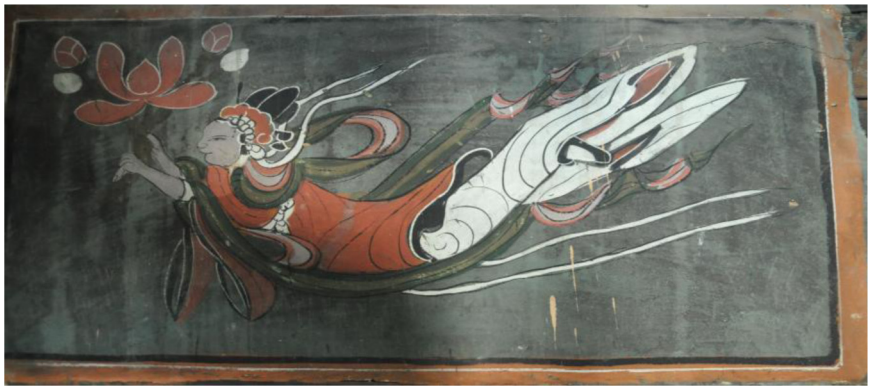
http://dx.doi.org/10.1016/j.jiec.2015.03.011
1226-086X/

Table 1
Pictures of heavenly maid painted on the wall of both mural paintings.

Classification	Pictures
Silsangsa temple	
Bulyoungsa temple	

mural paintings are under restoration. Some missing pigments of the paintings should be replaced with similar pigments.

For investigating the original pigments painted on the two different ancient mural paintings, a non-destructive analyzing method was conducted. A portable XRF and a spectrophotometer and a digital microscope were used to trace natural inorganic pigments of the both mural paintings.

Table 1 shows the two different mural paintings and Fig. 1 shows the non-destructive investigation with a portable XRF.

The equipment used for the present work is an energy dispersive XRF (EDXRF, T1 Turbo, Burker, USA, Analysis mode: Geometry) with a Rh X-ray tube, while the detector is a silicon drift detector (SDD) with an energy resolution of 147 keV. The pigments were recognized on the bases of characteristic chemical elements from the XRF spectra of analyzed points. The traced elements were identified by the energies of their characteristic X-ray peaks. The comparison of the counts per second (cps) of the different elements in a particular point with regard to the background, gives us the possibility to asseverate the presence or not of a particular element in that analyzed point [6]. In case the spectrophotometer (CM700d, Konica Minolta Sensing Inc., Japan), it was used for evaluation the traditional color tone and the digital microscope (Scalar Japan Magnification: 10×) was used to investigate morphology of the pigments.

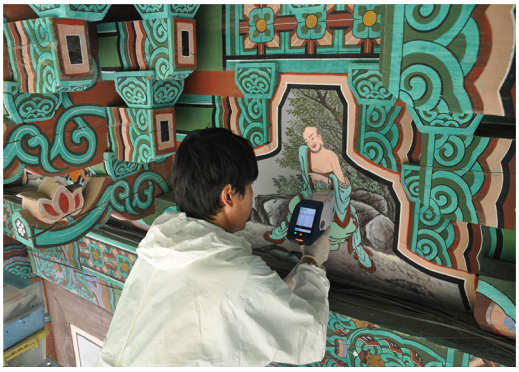


Fig. 1. Picture of investigation by using a portable XRF.

Results and discussion

The portable X-ray fluorescence (XRF) analysis is a non-destructive technique widely used in the study of works of art and archeology. Although it can only detect limited elements (from magnesium to uranium) and provide semiquantitative results, it can be helpful in a very wide range of applications in cultural assets [5,6]. Using XRF analysis sometimes it is possible to detect undocumented pigments or to characterize traditional materials better. This technique of analysis also allows the investigation of impurities of elements having medium or high atomic number, in some cases such impurities can help to establish the provenance of the materials or to characterize differences in the same work due to restoration or to the presence of unoriginal parts [7]. These portable instruments have given researchers in art conservation and archeology the opportunity to study a broad range of materials with greater accessibility and flexibility than ever before [8].

Some inorganic pigments for mural paintings of ancient temples built at 18th century have been investigated. It has been