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Study of decoration techniques used in Islamic luster-painted (stained) glasses excavated from Egypt by XAFS and XRF imaging techniques

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Introduction

Luster was one of the most important decorative techniques of archeological Islamic glass and pottery. Painting on glass that achieved a ruby red and yellow color or a lustrous effect was thought to cause chemical changes of metal ions in pigment at surface of glass. Recently, the mechanism of Renaissance luster potteries was studied [1] but that of Islamic luster glass remained to be solved. The aim of this study is to elucidate the details of coloring mechanism and change of decoration techniques across the ages. The chemical state analysis of the luster decorations by XAFS and XRF imaging utilizing synchrotron radiation (SR) were carried out for this purpose.

Experimental

Samples were loaned from the collections of the museum of the Middle Eastern Culture Center in Japan (MECCJ). SR X-rays were monochromatized to 14.2 keV and converged to 5 x 7 μm^2 by K-B mirror were used for the spot analyses and two-dimensional XRF imaging at BL-4A. The XRF intensities for these elements were measured for 5 s at each point and normalized by the intensity of scattered X-ray. The XAFS measurement was performed at BL-12C utilizing a Si (111) double-crystal monochromator. Cu K-edge EXAFS spectra of the samples were measured in a fluorescence mode using a Lytle-type detector or a 19-elements SSD. Copper foil, Cu_2O, and CuO were also measured as reference materials of copper.

Results and Discussion

Qualitative spot analyses revealed that bulk glass contained K, Ca, Ti, Mn, Fe, Cu, Zn, Pb, Br, Rb, and Sr, meanwhile luster-painted part contained Fe, Cu, Ag, and Pb. XRF imaging of Si, K, Ag, and Cu were shown in Fig. 1(b). Figure 1(b) shows that Ag and Cu exist in the luster-painted part on the glass surface with ca. 10-20 µm thick.

Figure 2 shows Cu K-XAFS spectra of luster-painted glasses with red and brown colors and reference materials. The spectrum of red luster was distinct from those of brown and resembled to the spectrum of metallic Cu. On the other hand, the spectra of brown luster were similar to cupric oxide. This suggested that red and brown colors of luster-painted were activated in reducing and oxidizing atmospheres of the furnace, respectively. The chemical information of luster-painted will indicate the technical capabilities of glass decoration during Islamic age.

[1] S. Padovani, *et al.*, *J. Appl. Phys.*, **93**, 10058 (2003).

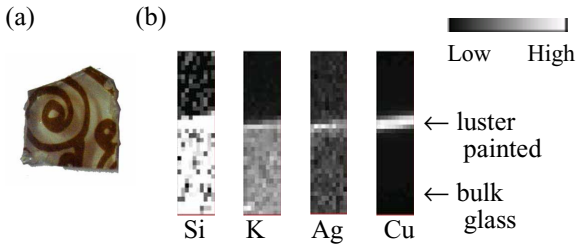

Fig. 1 (a) Photograph of luster-painted glass (LG11), (b) XRF imaging of Si, K, Ag, and Cu in cross-section of luster-painted glass. (252 x 50 μm^2 region)

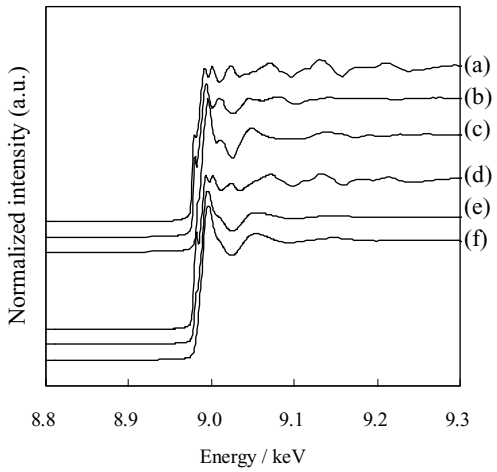

Fig. 2 Cu K-XAFS spectra of (a) Cu metal, (b) Cu_2O, (c) CuO, (d) LG15 (red), (e) LG12 (brown), and (f) LG11 (brown).

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