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Non-destructive and quantitative multi-elemental analysis by muonic X-ray spectroscopy for archeological bronze samples

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Quantitative elemental analysis is one of the most important themes in the field of natural science. For example, in the field of archeology, determination of elemental composition provides useful information to understanding the history and propagation of technology and culture. The archeological samples are highly valuable and the surface of these samples is usually oxidized or coated. Therefore, it is essential to get elemental composition deeply inside of the sample without destruction, however, such an analysis method is very limited.

In this paper, we report the development of a non-destructive, position-sensitive and quantitative multi-elemental analysis method for bulk samples by characteristic muonic X-ray measurements. When a negative muon that is one of the elementally particles is stopped in material, the muon is captured on a nucleus and muonic atom is formed. A muonic atom is an atomic system that has one negatively charged muon instead of an atomic electron. After formation of the muonic atom, the captured muon immediately de-excites to lower muon atomic levels through muon characteristic X-ray emissions. Because the mass of the muon is 207 times larger than that of the electron, characteristic muonic X-ray is much harder than electronic X-ray and muonic X-rays even from inside of a bulk sample are detectable.

In this study, we determined the elemental composition of old Japanese coins (tempo-tsuho) and old Chinese mirror (seiun-kyo). Muon irradiation experiments were performed in J-PARC (Japan) and Rutherford Appleton Laboratory (UK). Characteristic muonic X-rays were measured by high purity germanium detectors. We also performed muon irradiation for standard bronze samples to determine relation between characteristic muonic X-ray intensity and elemental composition. The details will be discussed in our presentation.

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