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Non-Destructive Analysis of Bronze Heritages Using Muon Induced X-rays in J-PARC

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Bronze, an alloy mainly composed of copper with additions of tin and lead, has been used for creating historical cultural artifacts across the world. Analysis of the composition of these artifacts provides important insights into their manufacturing techniques, trade routes, and cultural backgrounds. However, surface degradation due to aging—such as oxidation, copper carbonate formation, and leaching of lead and tin—has significantly altered the surface compositions of these materials. Conventional non-destructive X-ray fluorescence (XRF) techniques are unable to probe sufficiently deep to access unaffected regions. Negative muons generated by accelerators can penetrate materials to depths on the order of millimeters. By measuring high-energy characteristic X-rays emitted following negative muon capture, the elemental composition at original, unaffected depths can be non-destructively revealed. At J-PARC MUSE, non-destructive elemental analysis of cultural heritage materials using high-intensity pulsed muon beams is actively being developed. A hemispherical chamber system equipped with nine germanium semiconductor detectors optimized for high sensitivity at low energies has been designed and operated[1]. This presentation introduces a non-destructive elemental analysis of the bronze dolphins (”Shachihoko”) of Nagoya Castle, believed to have been produced during the Edo period, as a case study demonstrating the applicability of this technique.
[1] 10.1007/s10751-024-01885-2

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