Development of elemental analysis by muonic X-ray measurement in J-PARC

K. Ninomiya¹, T. Nagatomo², K. M. Kubo³, P. Strasser³, N. Kawamura³, K. Shimomura³, Y. Miyake⁴, T. Saito⁴ and W. Higemoto¹

¹ Japan Atomic Energy Agency
² International Christian University
³ High Energy Accelerator Research Organization
⁴ National Museum of Japan History

Abstract
It is expected that muon irradiation and muonic X-ray detection can be applied to non-destructive elemental analysis [1]. In this study, to develop the elemental analysis by muonic X-ray measurement and to investigate the molecular effects on the muonic atom formation, we constructed a new X-ray measuring system in J-PARC. We performed muon irradiation for Tenpo-koban (provided from National Museum of Japan History) for test experiment of elemental analysis. Some muonic lines originated from muon transition in muonic silver and gold were identified, and we determined the component of Tenpo-koban (Au:51%) by muonic X-ray intensities.

Introduction
Muonic atom is atom like system that contains negatively charged muon instead of an electron. The energies of muonic X-rays are very large (keV-MeV) because of the large mass of muon (207 times larger than that of an electron). Such high energy X-rays can pass long range without photo absorption, so muonic X-ray detection is expected as a new elemental analysis method for bulk sample without destruction.

Experimental
Experimental condition
J-PARC, MUSE, port-D2
sample: tenpo-koban (old Japanese coin)
muon momentum: 40MeV/c
a number of incident muon: ~10 muons/pulse
irradiation time: ~4 h

Results
From muonic X-ray spectra, Tenpo-koban is Ag-Au alloy
Following information is required for quantitative elemental analysis

Discussion
Atomic muon capture ratio for Ag-Au alloy: A(Au/Ag)
The Z-low (A(Z1/Z2)=Z1/Z2 [3]) is not suitable for most of alloys. Following empirical equation well reproduce the atomic capture ratio for Nb-Ta alloy [4], so we use this equation.

Contents of tenpo-koban
Our result is well reproduced the result for general tenpo-koban (Au:57%) and for the same tenpo-koban from prompt gamma-ray analysis by neutron irradiation on J-PARC NOBORU (Au:54%) [6].

References
[6] H. Matsue et al., the 53rd Symposium on Radiochemistry, 3A01
**Detector unit:**

**Front side**
- PCB
- Connector (25 pin)
- Detector (Pixel structure)

**Back side (HV-side)**
- Detector holder
- Connector (25 pin)
- Detector

Please note: This detector unit (detector holder, PCBs, mounted and tested detector) is subject of the purchase order!

---

See questions (part 1)!
**Version 1 with closed cryostat cap:**

Detector is irradiated from the front side (structured contact).

Detector is irradiated from the back side (not structured contact) through the cold plate.