Non-destructive elemental analysis of bulk object interiors using muonic X-ray

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Negative muons entering materials lose kinetic energy and are eventually captured by atoms to form muonic atoms. After atomic capture, the negative muon in the muonic atom experiences a cascade transition from higher energy muonic orbitals to lower ones with emission of muonic X-rays. The energy of the muonic X-ray is about 200 times greater than the corresponding electronic X-ray and also characteristic of the atom which captured the muon. The yield of muonic X-rays from the material is proportional to the atomic density of the element in the material. The energetic muonic X-ray emitted inside a bulk sample can penetrate and escape to the surface of the sample without significant absorption. By measuring the muonic X-rays with a Ge detector, elemental analysis of the muon capture site in the sample is achievable non-destructively. The high energy of muonic X-rays facilitates the detection and analysis of low-Z elements, such as carbon and oxygen, for which electronic X-ray measurement is difficult due to the low photon energy. Charged particles including the negative muon stop within a narrow depth range from the surface depending on the initial kinetic energy when entering the sample. Depth profiling as deep as a few cm is possible by varying the incident muon beam energy. Thus we are developing a muonic X-ray elemental analysis system at the J-PARC/MUSE facility.

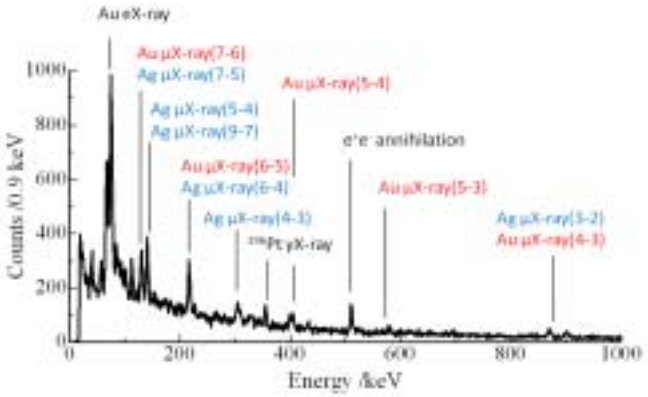

Fig. 1. Muonic X-ray spectrum of an old Japanese gold coin (Tempo koban).

Application of the technique to the analysis of the interiors of old bronze and gold Japanese and Chinese coins [1,2] and depth profiling of a mock sample for encapsulated cosmic materials [3] will be presented.

References

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[3] K. Terada et al., Sci. Rep. 4, 5072 (2014).