Application of AMS for the Analysis of Primordial Nuclides in High Purity Copper

N. Famulok[1], K. Hain[1], T. Faestermann[1], L. Fimiani[1], J.M. Gomez Guzman[1], G. Korschinek[1], P. Ludwig[1], and S. Schönert[1]

[1]Technische Universität München, James-Franck-Str.1, 85748 Garching

INTRODUCTION

The sensitivity of rare event physics experiments like neutrino or direct dark matter detection crucially depends on the background level. Therefore, all material surrounding the detectors requires high purity to not create additional background. However, still a significant contribution originates from the primordial actinides thorium and uranium and the progenies of their decay chains. For the first time, ultra-sensitive AMS (accelerator mass spectrometry) was used successfully for the detection of those impurities in a copper matrix.

METHODS AND MATERIALS

A well established technique for screening materials for radioactive impurities in samples at ultra pure levels is gamma spectrometry. By using germanium detectors in ultra low background conditions underground, sensitivities in the μBq/kg range can be achieved [1]. However, copper, which usually is the material located closest to the detectors in rare event experiments can be produced extremely radiopure using electrolysis. This kind of copper (total mass of 125 kg) produced for the Low Energy Neutrino Spectroscopy (LENS) experiment was screened at the LGNS (Laboratori Nazionale del Gran Sasso) for 100.7 days, but only upper limits in the order of 10^{-12} g/g could be determined for the concentration of ^{238}U and ^{232}Th [1]. New methods that use different approaches to reach even lower limits therefore are needed.

The AMS setup at the MLL has proven to reach outstanding sensitivities for actinides, e.g. in the order of 10^{-19} g/g(sample material) for ^{244}Pu [2]. Hence, it is well suited for the detection of ^{238}U and ^{232}Th contaminations at trace level. However, AMS has not been used in the context of primordial actinides embedded in a copper matrix until now. For this purpose, a new approach was chosen by extracting the actinides as a compound with copper which lead to stable and reproducible conditions. Two different samples of copper, ordinary copper from the workshop ("M-Copper") and high purity copper ("LENS"), and one sample of a copper alloy ("Korrodin") were investigated. The copper alloy with established concentration obtained by gamma spectrometry was used as a standard. The concentrations of uranium and thorium in the two copper samples were determined relative to the concentrations in the standard sample. Just a few mg of sample material was consumed.

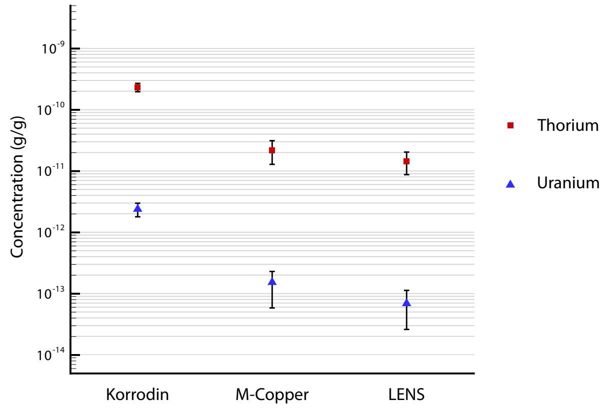

Figure 1: Concentrations of uranium and thorium in copper alloy (Korrodin), machine copper (M-Copper) and high purity copper (LENS) detected by AMS. [3]

RESULTS AND OUTLOOK

According to expectations, the copper alloy showed significantly higher concentrations than the copper samples and uranium was generally less abundant than thorium (see Fig.1). The lowest concentrations determined with AMS until now were $(1.4\pm0.6)\cdot10^{-11}$ g/g for thorium and $(7\pm4)\cdot10^{-14}$ g/g for uranium which corresponds to $(56\pm16)\,\mu$Bq/kg and $(0.9\pm0.5)\,\mu$Bq/kg, respectively. These results demonstrate that AMS can reach higher sensitivities than gamma spectrometry while only fractions of measuring time and sample mass are required. Whether the observed contaminations for the LENS copper are true or just upper limits can be decided with even cleaner copper samples. Future measurements could use copper purified by different methods, e.g. the Czrochalski process or zone melting, which might lead to even lower contaminations. Other materials that can be produced ultra-pure as well might also be worthwhile to be examined with AMS, i.e. germanium.

REFERENCES

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