Improved source/absorber preparation for radionuclide spectrometry based on low-temperature calorimetric detectors

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Abstract

Within the European Metrology Research Project "MetroBeta", beta spectrometry based on metallic magnetic calorimeters (MMCs) and radionuclide sources embedded in absorbers have been developed. Since this technique requires compatible source/absorber elements that provide optimal detection efficiency and avoid spectrum artefacts, new preparation techniques for reliable source/absorber fabrication have been established and tested. Here, we discuss the details of the source/absorber preparation techniques as well as its quality control by means of radiographic imaging and contamination measurements [1-7].

Beta spectrometry with metallic magnetic calorimeters

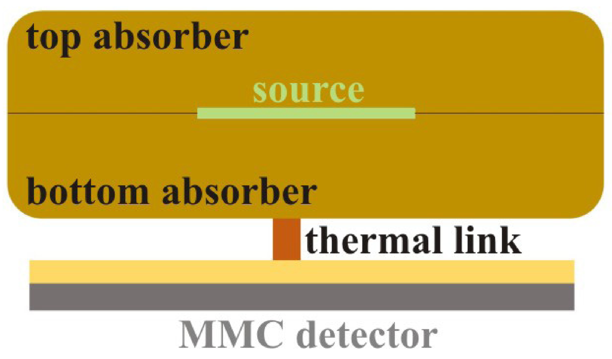

FIG.1: *Schematic cross-section of a 4π absorber with embedded radionuclide source mounted on an MMC detector*

Ideally,

- the radionuclide is completely embedded into an absorber material (4π geometry)
- no energy loss of beta particles
- fast thermalization
- control of the deposited activity level

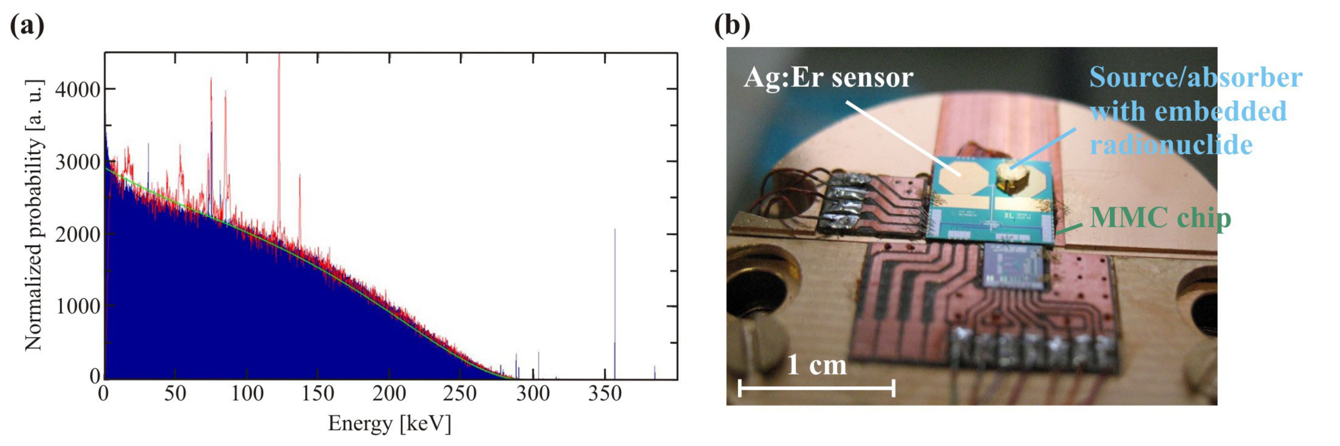

FIG.2: *(a) Beta spectrum of ^{99}Tc measured with sources fabricated in two different ways to demonstrate the quality of the improved preparation technique. (b) MMC detector with a source/absorber assembly.*

Absorber design and fabrication

To simplify the handling, an array of absorber elements is formatted by laser cutting or milling techniques from noble metal foils with thicknesses ranging from 15 µm to 300 µm.

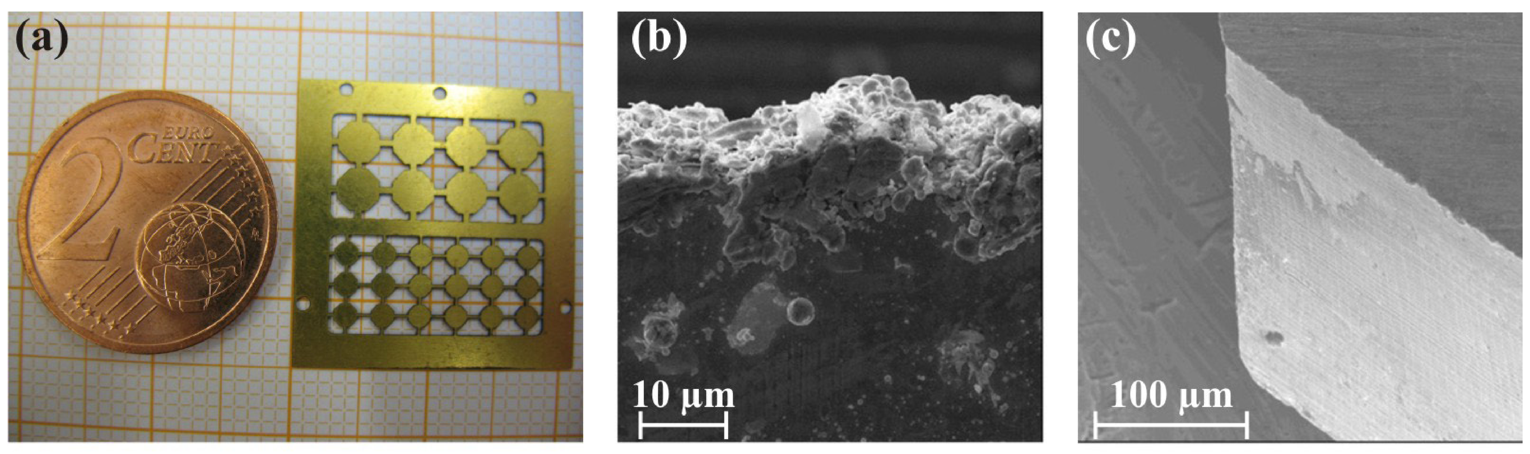

FIG.3: *(a) Example of an absorber array for the two largest absorber types. SEM pictures of absorber arrays defined by laser cutting (b) and milling (c).*

Absorber design and fabrication for higher energies E>300 keV

Using the Monte Carlo software EGSnrc, several simulations were carried out to compare the energy escape reduction capacity of different absorber configurations [8]. Some possible configurations are shown in figure 4.

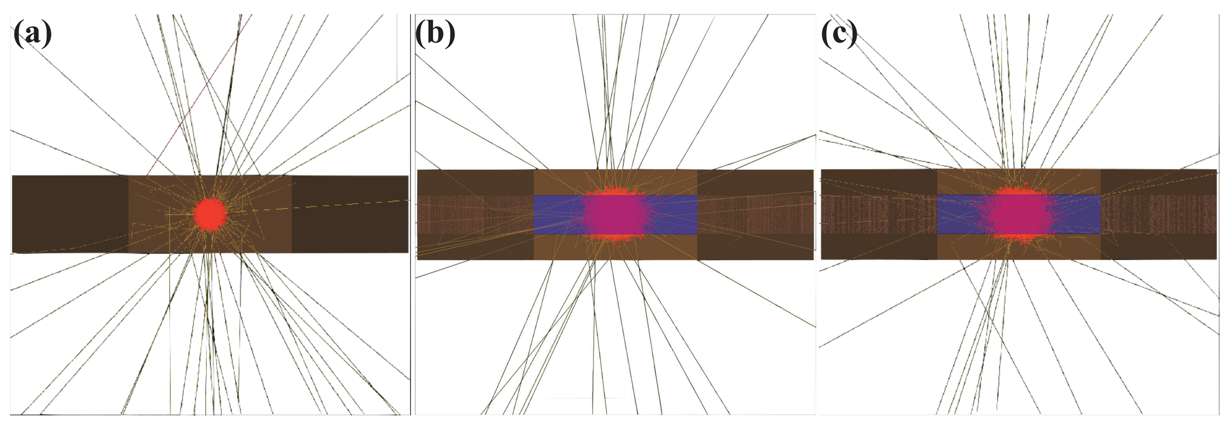

FIG.4: *Plots of 10^3 simulated tracks for electrons (red) having initial energies 800 keV, showing the cross-sections for three absorber configurations: (a) Au-absorber, (b) Au-Cu-absorber and (c) Au-Cu-Au-absorber. The tracks of the photons that escape from the absorber are also depicted.*

Preparation of Au-Cu bilayers is possible by means of diffusion welding. To avoid oxidation of Cu during source deposition a comparably thin non-oxidizing capping layer can be deposited onto the Cu surface.

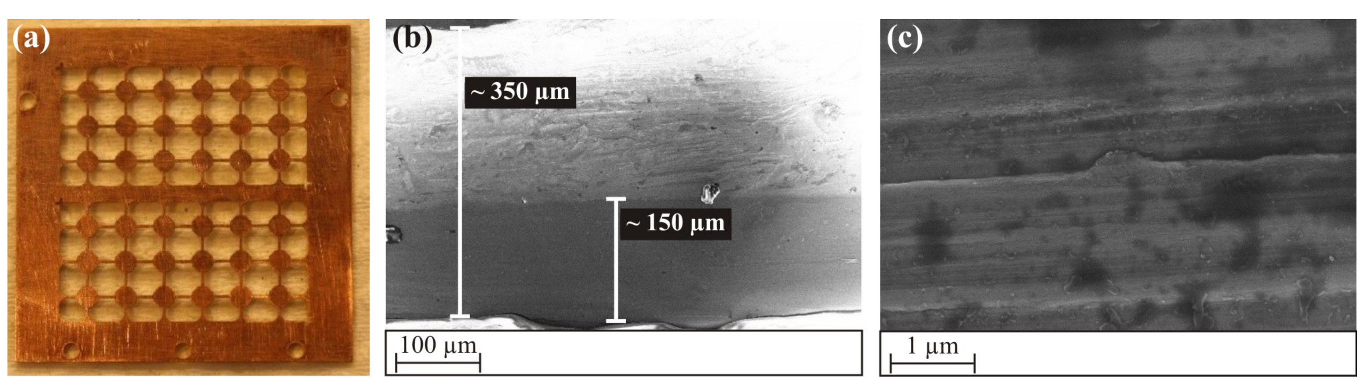

FIG.5: *(a) Optical image of formatted Au-Cu bilayer absorber array, Cu-surface is shown. (b) SEM cross section picture of diffusion welded Au-Cu bilayer, nominal thicknesses are Au 0.2 mm and Cu 0.15 mm. (c) Magnification of the Au (top) – Cu (bottom) interface*

Drop deposition by automated micro dispensing system

Drop deposition by a commercial automated micro dispensing system is one of the best approaches to obtain sources reproducible in terms of activity.

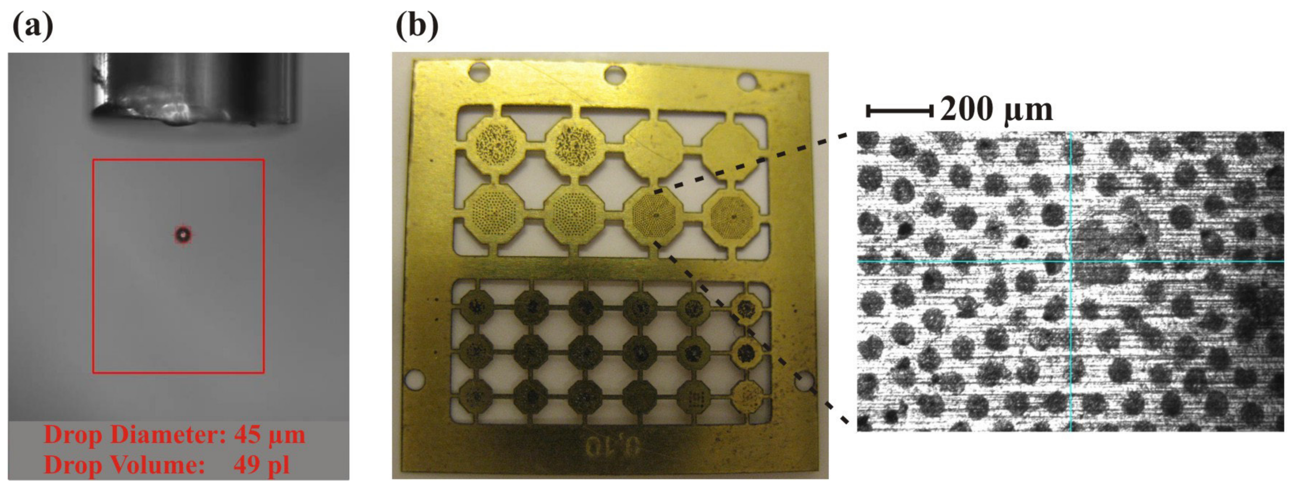

FIG.6: *(a) Calibration of the drop size with the help of a camera (b) Drop disposition done by a micro dispensing system, a total volume of 0.5 µl was dispensed in a drop pattern.*

Check of the unsealed source in terms of activity

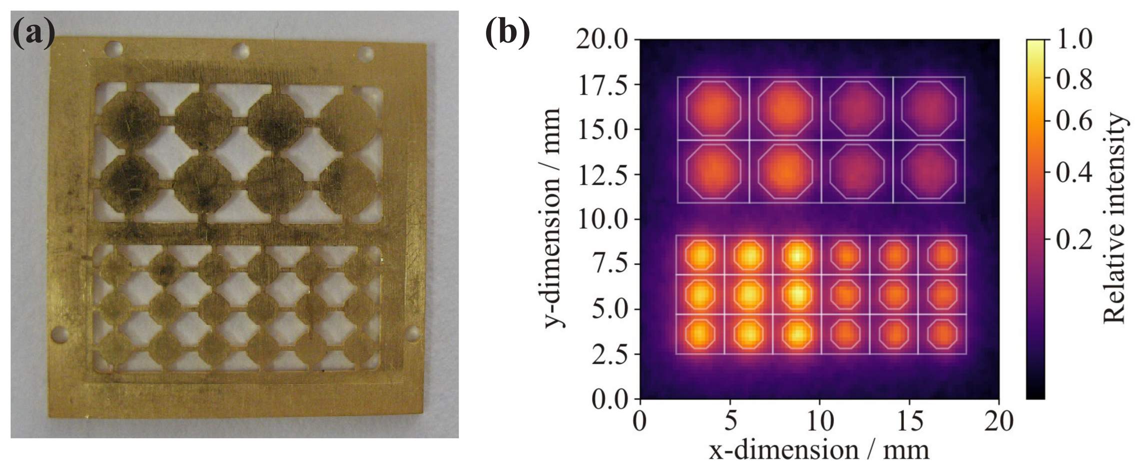

FIG.7: *(a) The unsealed source is controlled optically (a) and by autoradiography (b). The two different activity levels, 5 Bq left and 2.5 Bq right, are seen in the picture of the autoradiography.*

Diffusion welding

The radionuclide must be completely embedded into an absorber material by diffusion welding.

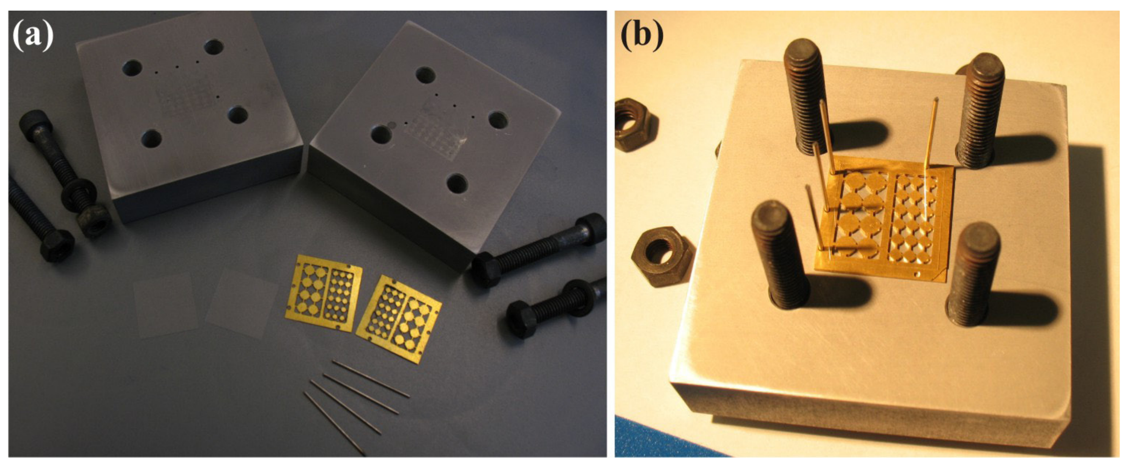

FIG.8: *(a) Design of the press used for diffusion welding consisting of two halves of aluminum, four screws and four guidance pins. (b) The lower part of the press with a glass-absorber-source-absorber-glass sandwich.*

Contamination Control and Quality check

We establish two methods to ensure that the 4 π geometry is fulfilled:

- The glass slides are checked for potential contamination with the help of liquid scintillation counting [9].
- Another means of quality check of the welded absorber array is autoradiography.

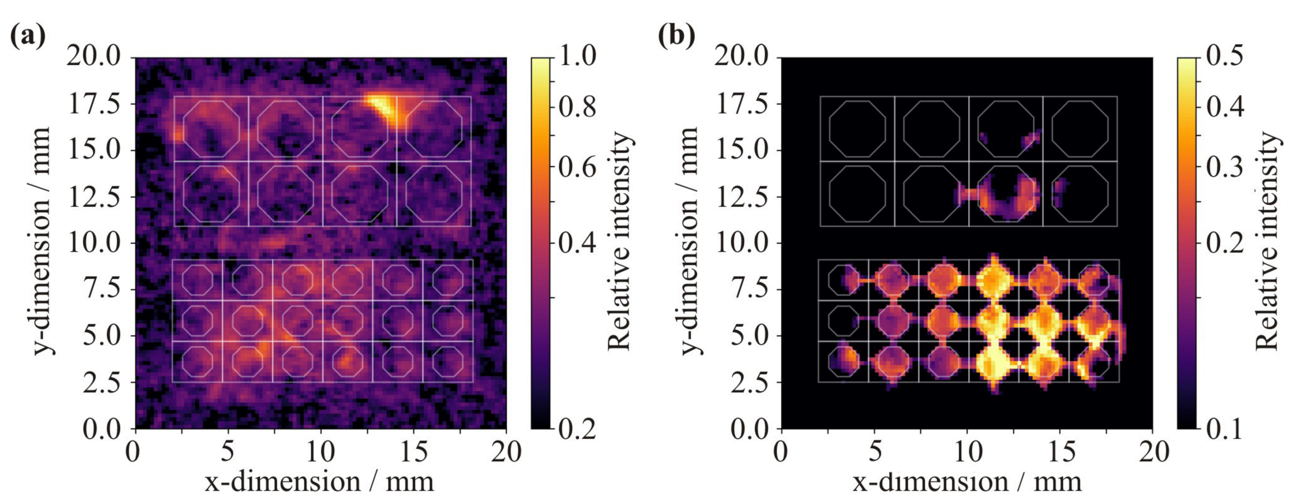

FIG.9: *Autoradiographic images after diffusion welding of (a) ^{36}Cl absorber array. The emission of bremsstrahlung is seen. (b) ^{99}Tc absorber array. The radioactive material melted during the diffusion welding and contaminated the absorber surface.*

Acknowledgement and References

This work was performed as part of the EMPIR Project 15SIB10 MetroBeta. This project has received funding from the EMPIR programme co-financed by the Participating States and from the European Union's Horizon 2020 research and innovation programme.

[1] A. Fleischmann *et al.*, Topics in Applied Physics 99, 150–216, (2005)
[2] A. Fleischmann *et al.*, AIP Conference Proceedings 1185, 571, (2009)
[3] S. Kempf *et al.*, J. Low Temp. Phys. 193, 365–379, (2018)
[4] H. Rotzinger *et al.*, J. Low Temp. Phys. 151, 1087, (2008)
[5] M. Loidl *et al.*, Appl. Radiat. Isot. 87, 302–305, (2014)
[6] M. Loidl *et al.*, J. Low Temp. Phys 193, 1251-1256, (2018)
[7] M. Paulsen *et al.*, JINST, (accepted), (2019)
[8] M. Loidl *et al.*, Appl. Radiat. Isot., (submitted), (2019)
[9] R. Broda, P. Cassette, K. Kossert, Metrologia 44, S36-S52, (2007)