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Experiences with a new shielding material

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Abstract

Recent modifications of the NECTAR facility included the set-up of a new beam dump. One of its main components is based on a reusable shielding material developed at TUM. The provided base material was characterized and its advantages and limitations were investigated by simulation studies and by measurements.

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1. Introduction

Radiation protection is an important aspect in the layout process of a neutron imaging facility. Two contradictory requests compete with each other: minimization of neutron and gamma dose on the outer facility borders while minimizing the dimension of the shielding. An additional complication arises when varying neutron and gamma spectra occur. For example, hydrogen-containing samples can result in neutron beam weakening for fission neutrons and in beam hardening for thermal neutrons. Depending on the sample composition, nuclear reactions by neutron capture may take place, too, causing secondary (high energy) gamma radiation.

At TUM, a new shielding material was developed (Calzada 2011, European Patent) and used for the set-up of the new ANTARES II facility (Calzada 2009) at FRM II. It is a powder of neutron and gamma attenuating materials

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mixed with oil in a well-defined ratio. This material was also used for a new beam dump at the fission neutron radiography and tomography facility NECTAR (Heinz Maier-Leibnitz Zentrum 2015) at FRM II. During the commissioning phase, measurements of the gamma dose rates and the neutron count rates behind the beam dump and the concrete wall surrounding the facility were performed for different arrangements. The results were compared with simulation studies based on detailed information on the shielding material determined by X-ray fluorescence spectroscopy (XRF) and scanning electron microscopy with energy dispersive X-ray analysis (SEM-EDX).

2. Characterization of the Shielding Material

A shielding material developed at TUM was provided for the set-up of a beam dump as a powder, which has to be homogeneously mixed with oil to achieve the desired shielding properties. As the material composition of the powder was required as an input parameter for simulation studies accompanying the optimization of the beam dump design, a characterization was performed using scanning electron microscopy with energy dispersive X-ray analysis (SEM-EDX) and X-ray fluorescence spectroscopy (XRF). The latter was mainly applied with the intention to learn more on its applicability and limitations rather than to use it for exact quantification.

2.1. Scanning Electron Microscopy with Energy Dispersive X-Ray Analysis Measurements

The measurements were performed using the EVO® MA25 (Carl Zeiss Microscope) scanning electron microscope with an attached energy dispersive X-ray analysis system. At the ZTWB Radiochemie München RCM, it is used for a wide spread field in the characterization of radioactive samples.

For determining the elemental composition of the powder, a bulk measurement was performed. For this purpose, the powder was "glued" on the sample holder using liquid conductive silver. After drying, bulk EDX measurements at three different positions were performed integrating on an area of about 1.7 mm^2 each. To correct these spectra for the undesired contribution of the conducting silver, calibration measurements with the conductive silver only were performed first. The resulting corrected elemental compositions from the EDX spectra (Fig. 1) were averaged and the statistical error (1-σ values) determined applying Gaussian error propagation. The results are given in Table 1.

Two SEM images of the investigated bulk material are shown in Fig. 2. The magnification factor was 74 and 133, respectively. The conducting silver becomes visible as bright material between the big sized grains, which have varying sizes and forms.

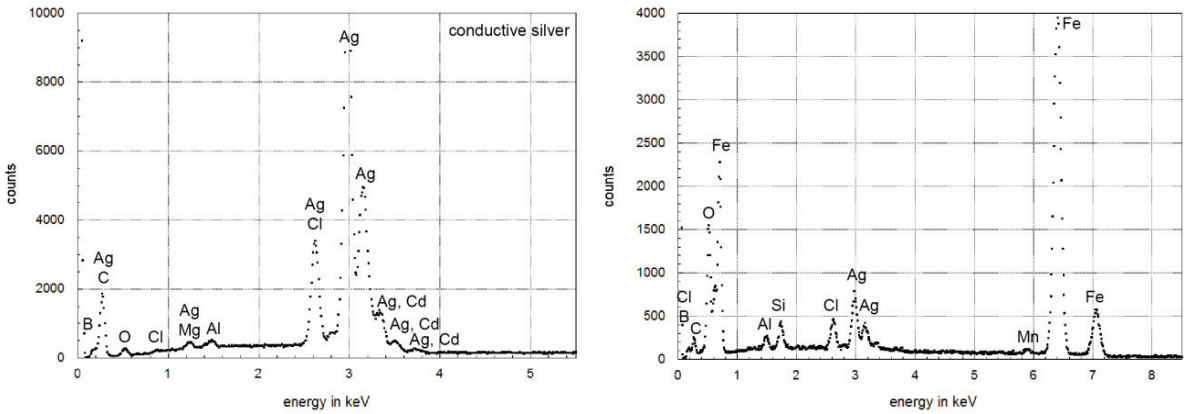

Fig. 1 EDX spectra. Left: Spectrum of conductive silver used for background correction. Right: Spectrum of the powder sample fixed by conductive silver (corrected for spectral components of the latter).