Max-Planck-Institut für Physik
(Werner-Heisenberg-Institut)

Radioactive Material Safety Data Sheet

June 1, 2017

W10-450-1, W4-300-2, W8/6

1 Description of Source

The three sources *W10-450-1, W4-300-2, W8/6* are proton irradiated Si chips with a rectangular surface area of $2 \times 2\,\mathrm{cm}^2$ and a thickness of $400\,\mu$m attached to $100 - 150\,\mu$m thick Si sensors. They have been exposed to a fluence of $\sim 2.0 \times 10^{15}\,\mathrm{p/cm}^2$ of 25 MeV protons in May 2017. Some of the elements used inside the chips have been activated by the protons and therefore they are now a source of β and γ radiation.

2 Isotopes

The main radio-isotopes inside each chip are $\sim$ 2.3 kBq of ^{7}Be, $\sim$ 330 Bq of ^{48}V, $\sim$ 670 Bq of ^{51}Cr, $\sim$ 670 Bq of ^{54}Mn, $\sim$ 330 Bq of ^{56}Co, and $\sim$ 670 Bq of ^{65}Zn (on 1 June 2017).

- ^{7}Be deacys by electron capture with a half life of $\tau = 53$ days and a 10.4% probability of emitting a 0.47 MeV photon.
- ^{48}V decays by β^+ decay emitting photons, electrons and positrons with a half life of $\tau = 16$ days. The maximum β^+ energy is 0.70 MeV and the average energy is 0.29 MeV. The monoenergetic electrons are too low in enegy to play a role for dosimetry. The gamma radiation reaches energies of up to 2.36 MeV but typical energies are at 0.511 MeV and 1.0 MeV. The average gamma energy is 0.91 MeV.
- ^{51}Cr decays by electron capture with a half life of $\tau = 27.7$ days emitting photons and electrons. The electron energies are below 5 keV while the maximum energy of emitted γ radiation is 0.32 MeV.
- ^{54}Mn decays by electron capture with a half life of $\tau = 312.7$ days emitting photons and electrons. The electron energies are below 5 keV while the maximum energy of emitted γ radiation is 0.83 MeV.
- ^{56}Co decays by β^+ decay emitting photons, electrons and positrons with a half life of $\tau = 77$ days. The maximum β^+ energy is 1.46 MeV and the mono-energetic electrons are all below 0.14 MeV and the maximim gamma radiation energy is 3.55 MeV.
- ^{65}Zn is an emitter of β^+ and γ irradiation with a half life of $\tau = 244.4$ days. The maximum β^+ energy is 0.33 MeV; the average β^+ energy is 0.14 MeV. The maximum energy of emitted γ radiation is 1.12 MeV.

The main activity from all isotopes together stems from the γ-radiation which goes up to 3.55 MeV in energy and averages at 0.81 MeV.

3 Radiation Dose Rates

The γ radiation is not shielded by the chips themselves nor by the attached sensors. Directly on top of the chips the γ dose rate is 15 μSv/h. The β^+ and electron emissions are largely shielded by the chips (for the radiation below) and the attached sensors (for the radiation above). Hot areas remain the chip edges on all sides and the sensor-free regions on top where the bond pads are located. In these regions the radiation levels can reach 200 μSv/h. In 1 cm distance from the chips the γ radiation dose rates reduce to 5 μSv/h and drop quadratically with distance beyond. Figure 1 shows a simulation of the expected radiation levels in the vicinity of one chip.

4 Protective Measures

The β radiation can be fully shielded by 0.75 g/cm^2 of light material (glass, plastic, or similar). Assuming a density of 1.5 g/cm^3 this would correspond to 5.0 mm of required shielding to block all β and electron emissions. A rubber glove with thickness 2.7 mm reduces 95% of the β and electron induced irradiation dose. To achieve the same 95% attenuation for the γ induced irradiation dose a 4.5 cm thick lead layer would be needed.

5 Handling Instructions

The chips have to be carried in plexi-glass boxes whenever they are transferred from one place to another. 2.7 mm thick rubber gloves and protective goggles need to be worn when handling the chips. Workstations have to be equipped with plexi-glass shields of 3.5 mm thickness. Assuming a distance of 0.5 m from a chip behind such a plexi-glass screen (or equivalent) will result in a full body dose rate of 2 nSv/h.

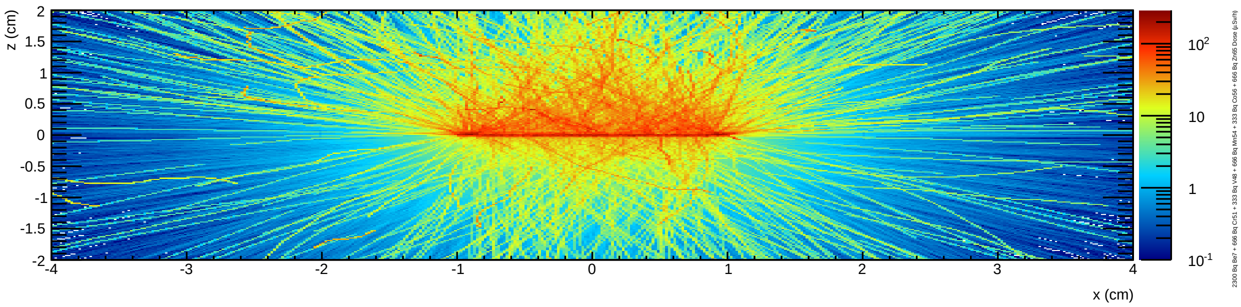

Figure 1: Simulated dose rate in air in μSv/h for a chip with 2.3 kBq of ^{7}Be, 0.33 kBq of ^{48}V, 0.67 kBq of ^{51}Cr, 0.67 kBq of ^{54}Mn, 0.33 kBq of ^{56}Co, and 0.67 kBq of ^{65}Zn. The radioactivity is assumed to come uniformly from the chip surface which is covered by Au bump bonds and a 150 μm thick Si sensor except for the last 1.3 mm on the $\pm x$ sides of the chip where the Bond Pads are. The plot shows a side view from the chip with radiation levels in the center of the chip in the not shown y dimension.

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