Induced radioactivity problem for high power heavy ion accelerators

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In the recent years, new requirements from technological and research applications for particle accelerators have emerged, giving rise to new radiation shielding aspects and problems. Several laboratories in the world have already started or plan to build new powerful ion accelerators. These facilities promise to provide very valuable tools for experiments in the physics of high energy density in matter, in fundamental nuclear physics, accelerator physics and for medical applications as well. One of the key issues in the construction of such devices is the calculation of radioactive inventories of the target and beam dump regions as well as activation of accelerator parts, shields, cooling media and ambient air. This is not only of importance with respect to short-lived radionuclides, but also with respect to long-lived ones since the latter decide about potential environmental impact and problems when such devices have to be decommissioned and disposed. Nuclide production by medium and high energy heavy ions irradiating thick targets is extremely complicated. So it is hardly possible to obtain reliable radionuclide production data for accelerator structure materials from radiation transport codes. The production of residual nuclides by protons for a wide variety of applications was systematically investigated [1]. The comparison [2] of the results demonstrated that activation yields can be predicted at best with uncertainties of about a factor of two. Frequently, average deviations are much lager and individual reaction dependent deviations may go up to two or three orders of magnitude. Thus, for the application to basic accelerator technologies, the existing models and codes have to be considerably improved in the future. But accurate knowledge of the radioactive species inventory within an accelerator complex is of urgency and important for specifying disposal options and for determining operation and maintenance procedures. This activation is a direct result of beam loss occurring during normal operation: lost particles interact with the structure, producing a variety of radioactive nuclides, which cause the residual radioactivity. The species could potentially create large dose rates in the immediate area. As is shown in [3] the largest fraction of the induced radioactivity will be produced in the accelerator structure and in the beam transport components. Furthermore the induced γ - radioactivity provides the main contribution to the exposure dose for the personnel of high-energy heavy ion accelerators [4]. Thus, the experimental data, which can be measured at the presently existing facilities (SIS-18, Ganil), are necessary for the estimation of the induced levels of radioactivity around heavy ion accelerators with intense beams.

So, first irradiation test experiments were carried out at SIS-18 area (GSI). Copper targets have been irradiated by a primary beam of ^{12}C 100 MeV/u ions. The total surface of a sample with the diameter of 5 cm was irradiated. The thickness of the target was 10 mm. The range of carbon ions in copper is approximately 4.2 mm for the real energy of the carbon ions of ~ 97 MeV/u in our case. Thus the beam is completely stopped in the target. The beam delivery system at Cave A allows the homogeneous irradiation of the target surface or a part of it with different intensities up to $6 \cdot 10^8$ particles per pulse. Precise gamma-spectrometry measurements for element identification were carried out with a Canberra HpGe – GEM-45195-S-SV detector powered by a Selena HV supply and interfaced to a Canberra spectroscopy amplifier. Data acquisition is processed via a software package running on a PC. This spectrometer allows to measure γ-ray spectra up to 2 MeV. The produced radioisotopes can be identified by the energies of their characteristic γ-radiation. The activity is obtained from the γ-ray peak area taking into account the efficiency of the Ge detector. The activity A_0 at the end of the irradiation time for each nuclide that can be observed is related to activity A of the sample (measured at the time t after irradiation) by the simple formula $A = A_0 \cdot exp(-\lambda t)$, where λ is the decay coefficient. An example of a gamma spectra of a copper cylinder irradiated by $5 \cdot 10^9$ ions per cm^2 is shown on fig. 1.

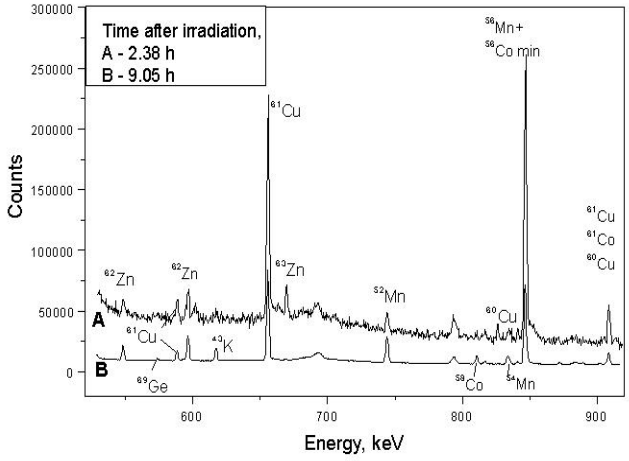

Fig.1 Spectra of the Cu sample irradiated uniformly by ^{12}C beam (E_0 = 97 MeV/u) up to the dose $5*10^9$ p/cm^2 on the target.

References

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