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Laboratory of Neutron and Gamma Radiation Diagnostics

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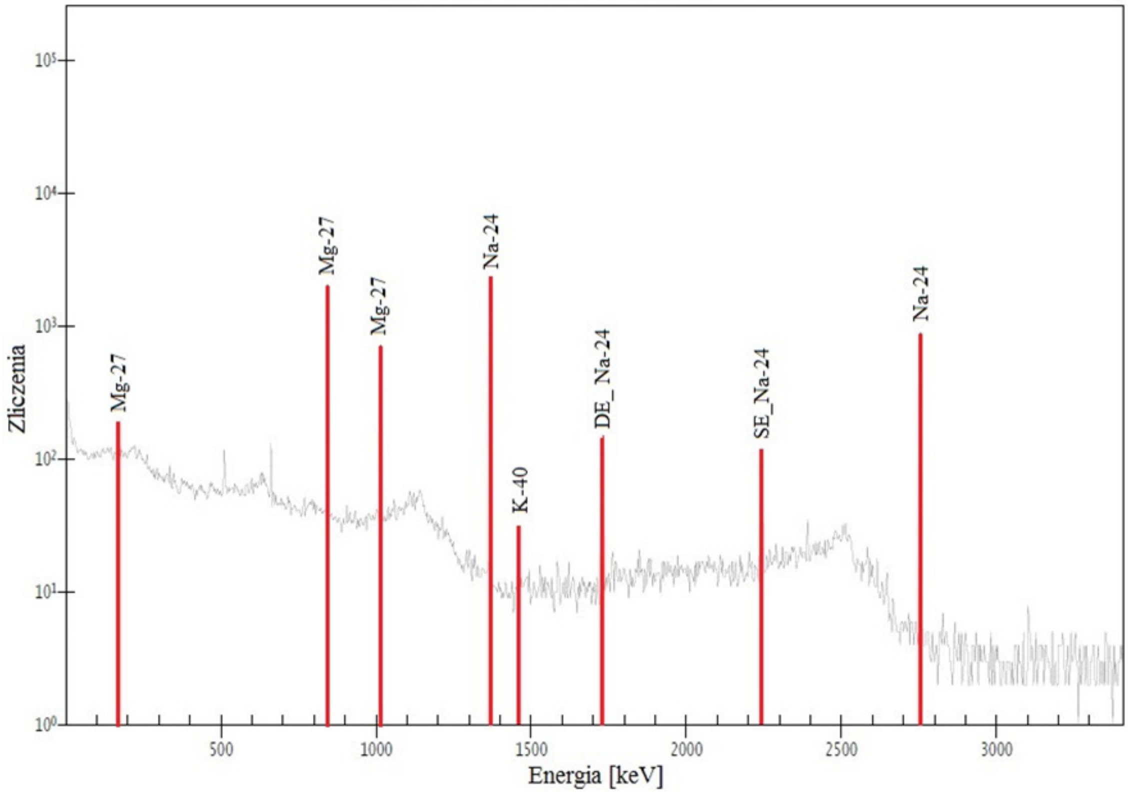
An activation analysis is a method for the determination of elements based upon the conversion of stable nuclei to other, mostly radioactive nuclei. It means that method is used for the measurement of the reaction products. In case of neutron activation analysis (NAA) the nuclear reactions occur via irradiation the target material to be analysed with neutrons. As a result of the neutron capture by the nuclei of the target material, the reaction products may emit either immediate or delayed radiation.
In principle, therefore, with respect to the time of measurement, NAA falls into two categories:
W zależności od momentu, w którym następuje pomiar promieniowania, neutronową analizę aktywacyjną możemy podzielić na dwie kategorie:

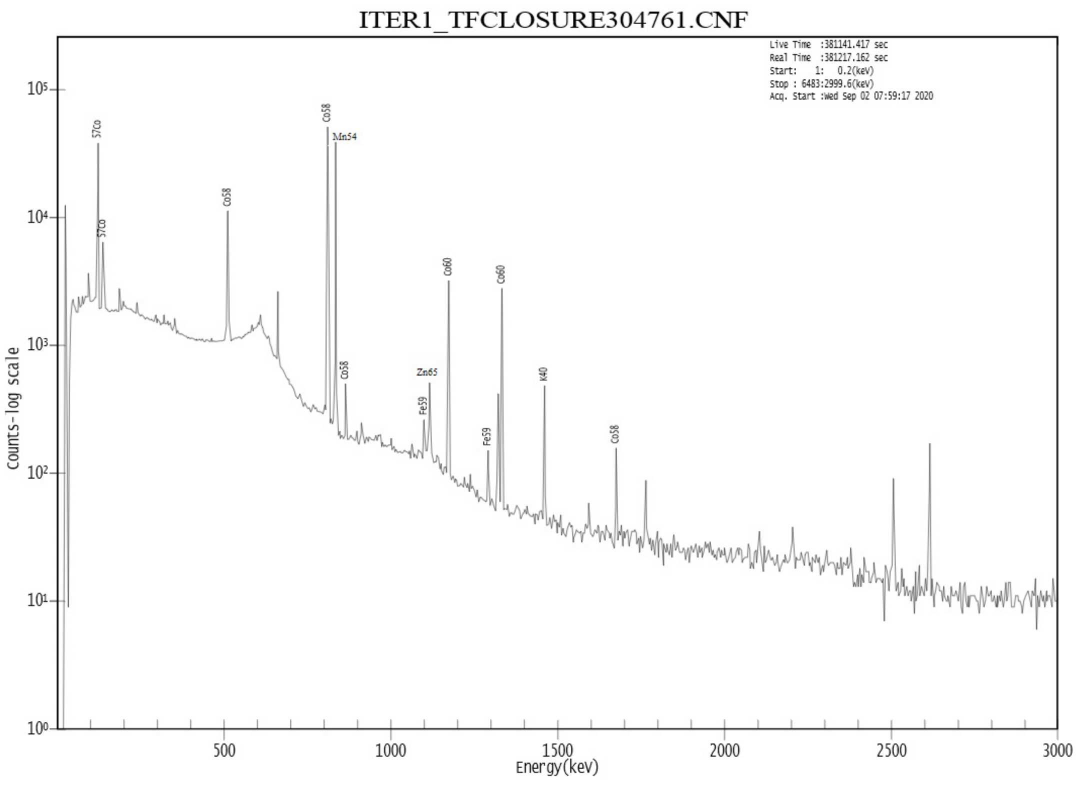
- Prompt Gamma-ray Neutron Activation Analysis (PGNAA), where measurements take place during irradiation;
- Delayed Gamma-ray Neutron Activation Analysis (DGNAA), where the measurements follow radioactive decay.
- The DGNAA is sometimes called conventional NAA and is commonly used as a non-destructive method.
- The neutron activation methods can fall into the following categories as well:
- Radiochemical Neutron Activation Analysis (RNAA), where the resulting radioactive sample is decomposed, and through chemical separations, it is divided into fractions with a few elements each.
- Instrumental Neutron Activation Analysis (INAA), where the resulting radioactive sample is kept intact, and the elements are determined by taking advantage of the differences in decay rates via measurements at different decay intervals utilizing equipment with a high energy resolution.

This method is commonly used in Laboratory of Neutron and Gamma Radiation Diagnostics.
The radioactivity of the reaction products induced by neutrons is determined via gamma radiation measurements using scintillators or semiconductor detectors. The activation analysis method is one of the modern instrumental analytical methods. This method has been widely used since 1950 to analyse trace elements at ppm and lower levels on a wide range of materials. It is considered that neutron activation analysis is very sensitive and accurate method and is therefore used to check the reliability of other analytical methods. Neutron activation analysis has found numerous applications in various fields of science and technology, such as geology, metallurgy, biology, medicine, forensics, environmental pollution control as well as plasma physics and nuclear fusion.
When it comes to the application of the activation method in nuclear fusion, this method is one of the most important methods used to determine the integrated neutron flux (fluence) e.g. for fusion devices. Additionally, it enables the determination of the neutron spectrum as a function of their energy in different parts of the tokamak. The activation method, due to the small size of samples, is often used in plasma devices, access to which is difficult due to their design. Moreover, the small size of the samples does not affect the plasma parameters such as its temperature or density. An important feature of this method is the lack of sensitivity to other types of ionizing and electromagnetic radiation. Measuring neutron emission using the activation method allows for a precise estimation of the power released in nuclear fusion reactions. This method gives stable and linear responses, adequate to the level of power released from nuclear fusion. The neutron activation method is also used to calibrate neutron measurement systems that are installed at large fusion devices. In addition to the above-mentioned tasks, the research team of the Neutron and Gamma Radiation Diagnostics Laboratory is also involved in activation measurements for ITER construction materials. The materials that will be used to build the ITER tokamak are activated in the 14-MeV neutron flux during experimental campaigns on the JET tokamak. The experimental results will ensure the validation of numerical simulations performed with state-of-the-art codes (FISPACT-II) and nuclear data used in nuclear analysis for ITER. Examples of gamma radiation spectra recorded in Laboratory of Neutron and Gamma Radiation Diagnostics using the HPGe detector are presented below.

The gamma spectrum recorded for Al sample irradiated in 14 MeV neutron flux.



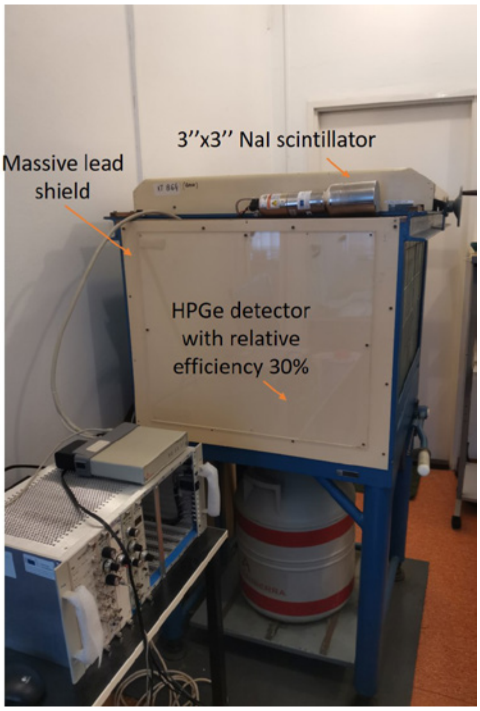
The gamma spectrum recorded for sample made from 316L(N) steel irradiated in 14 MeV neutron flux.

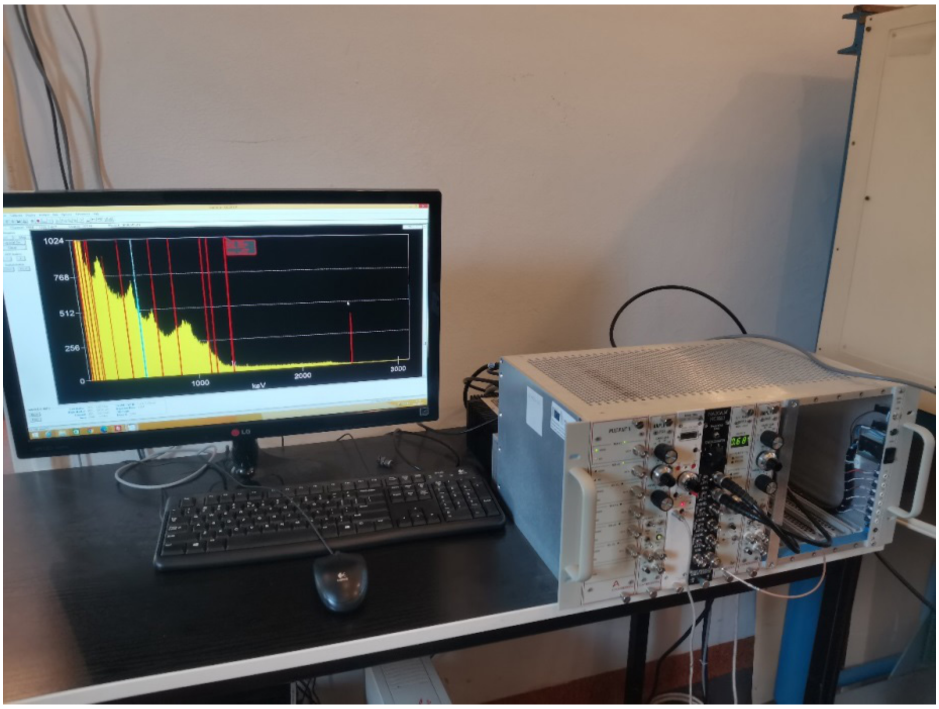


Laboratory of Neutron and Gamma Radiation Diagnostics – the measurement system

The Laboratory of Neutron and Gamma Radiation Diagnostics includes the Laboratory of Gamma Radiation Spectrometry, in which measurements of gamma radiation emitted from activated samples are performed, as well as qualitative and quantitative analysis of products emitting radiation. An anti-coincidence system has been recently installed in the Laboratory, which allows to significantly reduce the influence of background on the determination of individual radionuclides in the samples (see photos below). The main element of this system is the HPGe detector (Canberra) with a relative efficiency of 30% and an energy resolution of 1.76 keV for the energy of gamma quanta 1332 keV. This spectrometer is equipped with Numerical Characteristics and GENIE 2000 software, which allows for energy-efficiency calibration for considered measurement geometry without using a physical reference source, which is often very costly and time-consuming. The anti-coincidence system also includes a 3 ″x3″ NaI scintillator. Both detectors are placed in a massive lead shield (15 cm thick) with a low content of 210Pb, which allows for a significant reduction of the background radiation impact on the quality of the determination of the analysed radionuclides. In order to improve the quality of the measurements, the inner side of the lead sheath is additionally covered with a copper layer.

The general view of anti-coincidence system installed in the Laboratory (left);
The elements of the anti-coincidence system during performing measurements (right).

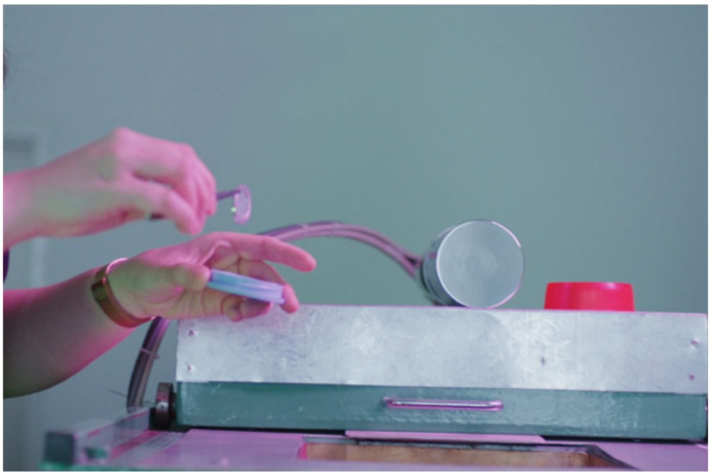


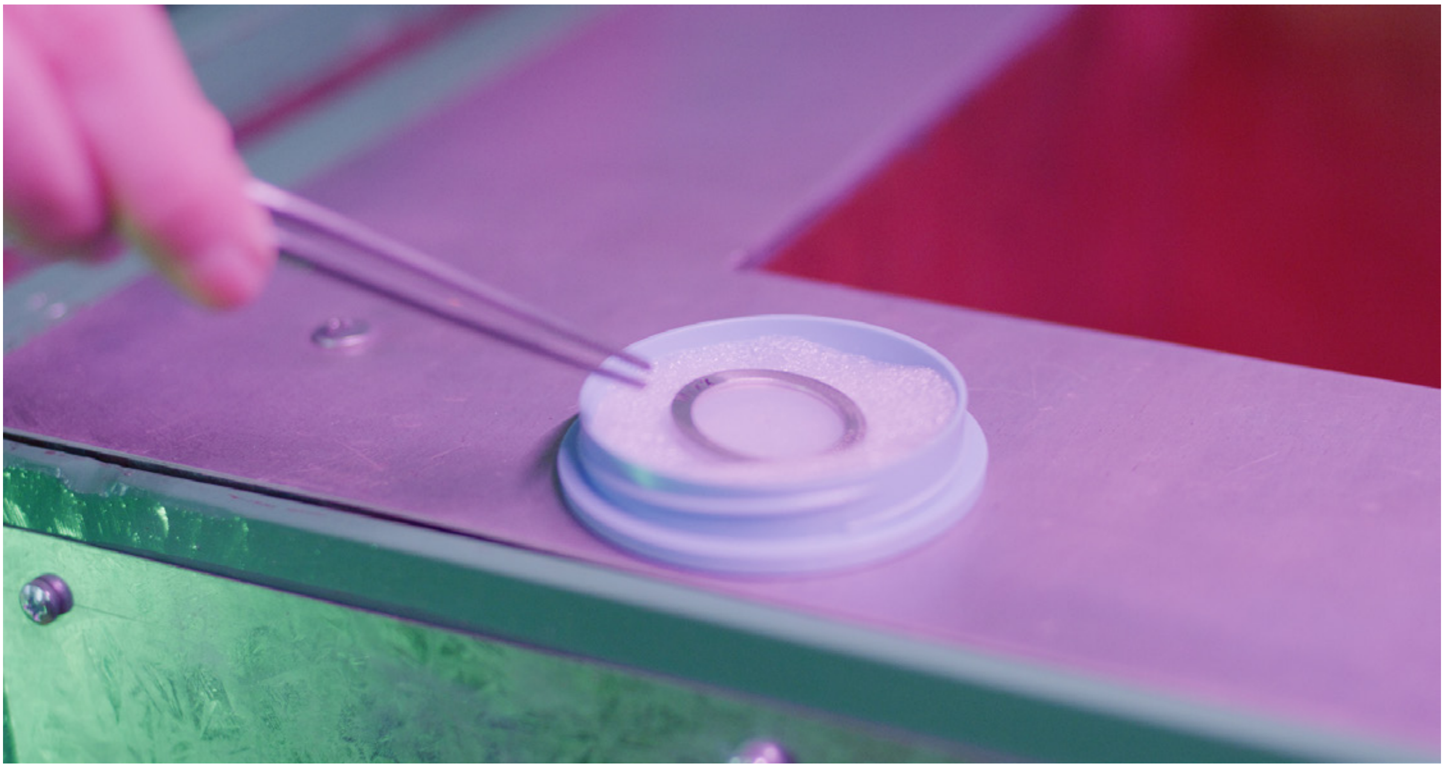


Laboratory of Neutron and Gamma Radiation Diagnostics – the measurement system

The Laboratory of Gamma Radiation Spectrometry commonly uses a certified multigamma calibration source containing 241Am, 109Cd, 57Co, 51Cr, 113Sn, 85Sr, 137Cs, 54Mn, 65Zn and 60Co radionuclides with total activity of about 100 kBq for 01.12.2020 for energy and energy-efficiency calibration of gamma radiation detectors. The IPPLM possess the Am-Be neutron source with radioactivity of about 180 GBq for 30.07.1976.

This neutron source can be used for the irradiation of metal samples in the neutron flux. After the end of irradiation, the activated samples are transported to the Laboratory of Gamma Radiation Spectrometry where they are measured by using an anti-coincidence system and then qualitative and quantitative analysis is performed.





Laboratory of Neutron and Gamma Radiation Diagnostics offers:

- Testing the level of radioactivity of various materials (metals, alloys, environmental samples, etc.);
- Qualitative analysis of reaction products created in irradiated samples;
- Quantitative analysis (determination of radioactivity) nuclides contained in the analyses samples;
- Detection of trace amounts of impurities in the samples (ppm and ppb) based on the

neutron activation analysis;
- Verification of the composition of materials offered by producers and monitoring of the amount of