Applications of positron annihilation spectroscopy in irradiation-induced defect studies

I. Introduction

Positron Annihilation Spectroscopy (PAS) is a non-destructive technique of detecting open-volume defects in solids, such as vacancies, vacancy clusters, microvoids or dislocations [1,2]. Applied defects research methods include, for example, the study of fatigue damage of materials that must withstand a wide range of mechanical, radiation or thermal loads during service. Long-term exploitation and external loads, including irradiation, lead to the evolution of small defects in the material. This process is the driving force for embrittlement and cracking in nuclear reactors. For example, radiation embrittlement is critical for high-pressure vessels. The use of common methods to study such problems (e.g. high-resolution electron microscopy) is not always appropriate or does not give the necessary accuracy [3]. The various methods of positron annihilation spectroscopy, in these cases, may be more accurate and provide additional information about the processes taking place in the material [4].

II. Experimental setup

In experiment positron will be produced through β^+ decay of ^{22}Na. The measurements will be performed using conventional encapsulated ^{22}Na positron source and variable energy positron beam. The encapsulated source during measurement will be placed between the identical samples. In conventional experiments positrons implanted into samples annihilate and creates 511 keV quants. The registration of times difference between detection of 511 keV annihilation quanta and 1274 keV gamma quantum from β^+ decay gives information about positron lifetime. Its value can be related to kind of defect. The second method Doppler broadening spectroscopy is based on observation of broadening of annihilation line. The changes in shape of this line are caused by e.g. changes of defects concentration. To get the defect depth characteristics in near surface region a variable energy positron beam will be applied.

III. Project description:

The project includes a few steps. At first, the students will be introduced to positron annihilation spectroscopy methods and apparatus. Then the students will participate in current experiments and learn how to use positron spectroscopy to analyze irradiation defects. Finally, the students will present their results on the forum of Student Practice participants.

IV. Requirements:

- The basic knowledge about material structures and interaction of matter with ionizing radiation.
- Advanced knowledge of the English language.

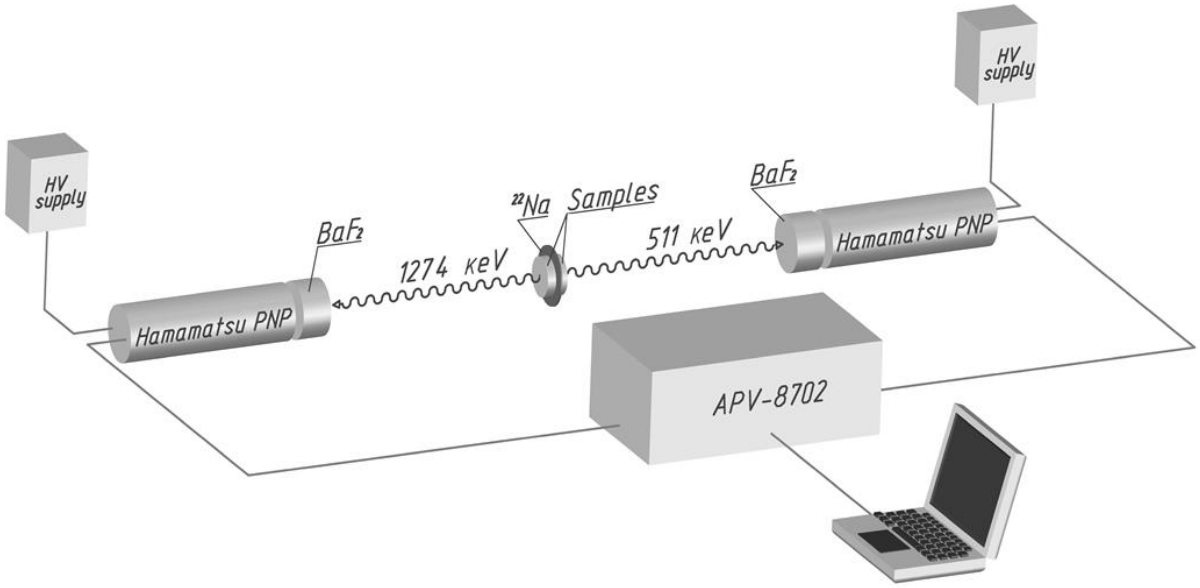

Fig. 1 Positron lifetime spectroscopy apparatus schema.

Fig. 2 Variable energy positron beam at JINR.

V. References:

[1] I. Makkonen, E. Korhonen, V. Prozheeva, F. Tuomisto J. Phys. Condens. Matter **28** 2016 1-7

[2] I. Prochazka Materials Structure **8** 2001 55-60

[3] P. Horodek, M. Eseev, A. Kobets Nukleonika **60** 2015 721-724

[4] Slugeň, V.; Sojak, S.; Egger, W.; Krsjak, V.; Simeg Veternikova, J.; Petriska, M. Radiation Damage of Reactor Pressure Vessel Steels Studied by Positron Annihilation Spectroscopy—A Review. Metals **10** (2020) 1378

VI. Number of vacancies: 2

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