Positron annihilation spectroscopy in materials structure 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]. Nowadays, this technique is of a great interest due to the practical character of obtained results. It allows to connect changes of electrical, optical, mechanical and magnetic properties of materials caused by presence of defects in their structure. PAS gives possibility to determine the defect concentration and its type starting from a single vacancy up to pore size. Such small defects as single vacancy cannot be detected by the most of methods, even for transmission electron microscopy [3]. Nowadays, many investigations at JINR are focused on the studies of materials by ion exposure. PAS has frequently shown its usefulness in such research, which together with other experimental techniques gives information about damages of materials. Positron spectroscopy studies of defects can be performed by means of Doppler broadening spectroscopy of annihilation radiation, or positron lifetime spectroscopy (PALS). During the Summer Student Practice students will have an opportunity to learn the basics of these spectroscopies in theory and practice.

II. Experimental setup

In experiment positron will be produced through β^+ decay of ^{22}Na. The measurements will be performed using encapsulated ^{22}Na positron source. The source during measurement will be placed between the identical samples. 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.

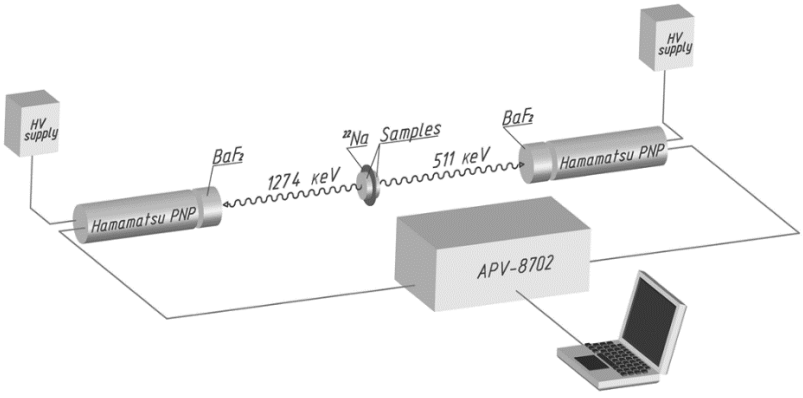

Fig. 1 Positron lifetime spectroscopy apparatus.

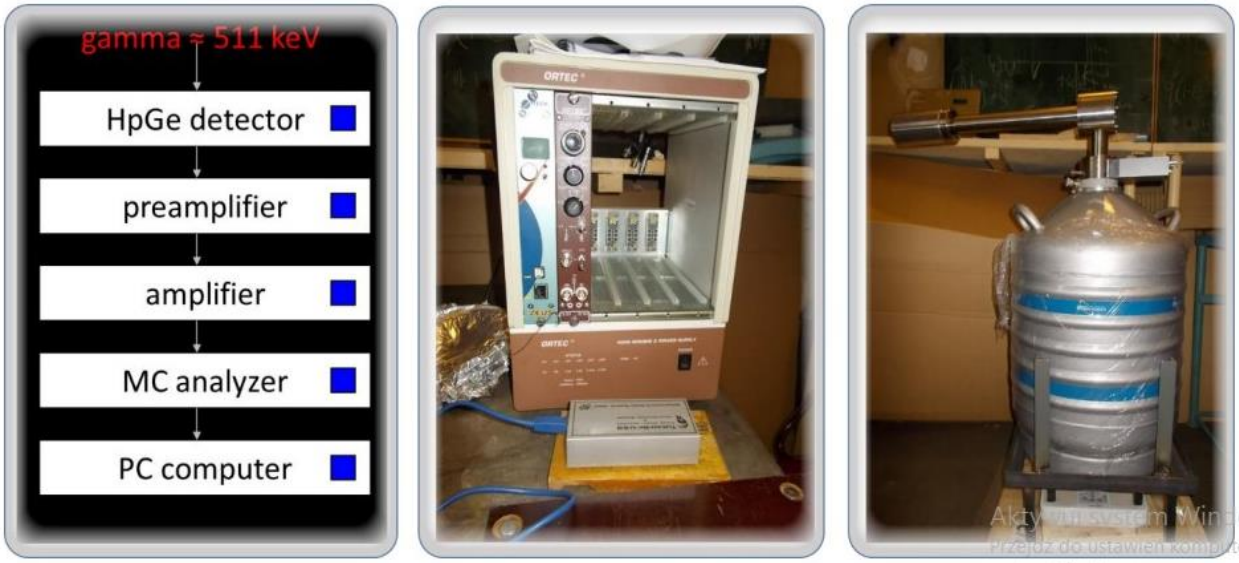

Fig. 2 Positron Doppler broadening spectroscopy equipment.

III. Project description:

The project include few steps. At first the students will be introduced with positron annihilation spectroscopy methods and apparatus. Then each person gets own scientific problem. The students with their own samples are also welcome. For prepared samples the profiles of defects will be determined using positron lifetime and Doppler spectroscopies. To link up measured lifetime also simple molecular calculations using ABINIT [4] program will be performed. However, the skill of ABINIT usage is not obligatory. Finally, the students presents their results on the forum of Summer Student Practice participants.

IV. Requirements:

The basics knowledge about material structures and open mind.

V. References:

[1] I. Makkonen, E. Korhonen, V. Prozheeva, F. Tuomisto 2016 J. Phys. Condens. Matter **28** 1-7
[2] I. Prochazka 2001 Materials Structure **8** 55-60
[3] P. Horodek, M. Eseev, A. Kobets 2015 Nukleonika **60** 721-724
[4] http://www.abinit.org

VI. Number of vacancies: 2

VII. The Project supervisor:

Krzysztof Siemek (Ph.D. researcher at DLNP at JINR)
e-mail: siemek.krzysztof@gmail.com
tel. +7 9645587940