§6. Positron Annihilation Measurement and ZrNi Alloys

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Positron annihilation technique has been successfully adopted for investigating the feature of materials in various fields. In the present studies, ZrNi alloys have been examined by using this technique. ZrNi alloys are typical nonvolatile getter materials, which have been utilized for wide-ranging purposes like vacuum process and, in our case, decomposition process to convert tritiated compounds into a form of hydrogen molecules.

A positron implanted into materials eventually encounters with one of electrons and instantly annihilates with the electron producing a pair of annihilation γ rays. A positron life time is defined as a time interval between the birth and the annihilation of a positron, and the length of positron lifetime reflects the electron density where the positron annihilates in materials. In the present studies, an external type of ^{22}Na positron point source with a radioactivity of about 370 kBq(<1 mm in diameter) was used, which emits 1275 keV prompt γ ray at the birth and a pair of 511 keV γ rays at the annihilation.

The positron lifetime were measured by a conventional coincidence system. Our coincidence system consisted of a pair of BaF_2 scintillator crystals attached to photomultiplier tubes, a time-to-pulse height converter and a fast-fast coincidence module. Using the system, the spectra of positron life time were measured. The full-width at half-maximum (FWHM) of time resolution of the system was about 0.210 ns. Observed lifetime spectra contained 4×10^6 counts respectively. These lifetime spectra were analyzed by use of a program cord "RESOLUTION".

In the positron annihilation method, the spectrum of Doppler broadening of 511 keV annihilation γ ray is commonly measured simultaneously with the lifetime spectrum measurement. Concerning the Doppler broadening, S-parameter is defined as the ratio of the central area to the entire area under the photopeak of the annihilation γ rays. The higher the probability of positron annihilation with free electrons is, the larger the value of S-parameter is, because the spectrum of positron annihilation γ rays with free electrons is distributed around the 511 keV line narrower than that of annihilation γ rays with core electrons. Therefore, from S-parameter, we can extract useful informations related to a positron annihilation occurrence rate with free electrons and that with core electrons. S-parameter is useful to extract totalized information on the behavior of positrons in materials.

In the present experiment, Doppler broadening spectra were measured using an intrinsic Ge detector. Two Doppler broadening spectra were successively measured for the specimens. The total count under each spectrum was more than 2×10^7. The value of S-parameter was calculated from each spectrum using our own made simple program.

Before started the present experiments, the time scale calibration of our measuring system and the estimation of source contribution to lifetime spectra were carried out. Concerning the time scale calibration, the lifetime spectrum of well annealed nickel specimens were measured and the time width corresponding to one channel of the spectrum was determined under the condition that the bulk lifetime of a positron in the nickel specimens must be 110 ps. And using the same lifetime spectrum, the source contribution to the spectrum was estimated by two components fitting, in which one component attributed to positron annihilation in the bulk of the nickel specimens and another, that in the source. As a result, the lifetime of positron annihilated in the source was 0.373 ns and its intensity was 13.6%.

The measurement of positron life time and Doppler broadening of 511 keV annihilation γ ray were simultaneously carried out at room temperature, before and after ZrNi alloys being used in decomposition processes of methane.

The values of S-parameter and positron life time obtained are shown in Table 1. It is found that S-parameter decreased from 0.4607 to 0.4529 and the positron life time lengthened from 0.154 ns to 0.163 ns and appeared another one of 0.405 ns after ZrNi alloys being used in decomposition process. These are positron data of ZrNi alloys obtained for the first time by us and we think that the data must be pregnant with interesting physical meanings. Consequently, we will continue the present studies with the positron method to make interpretation of these results through further investigation next year.

Table 1 S-parameter and Positron life time

	S-parameter	Life time (ns)	
Before the use	0.4607	0.154 (100 %)	
After the use	0.4529	0.163 (90.7 %)	0.405 (9.3%)