Improvement of positron lifetime measurement systems for the KUR slow positron beamline

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Energy-variable slow positron beams have been extensively used to investigate vacancy-type defects in thin-films and surface-modified layers (e.g., ion-implanted layers). Among major analytical methods of positron annihilation spectroscopy, positron lifetime annihilation spectroscopy (PALS) can give direct information on sizes of vacancy-type defects from lifetime values. Positron pulsing is one of the important methods to perform PALS measurements with slow positron beams. A slow positron beamline of Kyoto University research Reactor (KUR) has a pulsing system consisting of RF-driven chopper, prebuncher and buncher electrodes. This paper shows results of recent developments on the PALS measurements of the KUR slow positron beamline.

Performance of the pulsing system has been evaluated by electron beams in our previous study [1]. The best pulse width of 143 ps was obtained, indicating that the design of the pulsing system is appropriate. Numerical simulation of the pulsing system was also performed using the SIMION and GPT codes. It revealed the importance of uniform electric fields among pulsing electrodes. Even after these evaluation procedures, it has been difficult to obtain appropriate PALS results with our pulsing system. A series of experiments suggested that the PALS measurements using the KUR slow positron beamline is influenced by background radiation (~1 μSv/h during 1 MW operation) caused by the reactor.

Two preliminary experiments have been performed to avoid the influence of the background radiation. Firstly, the distance between a sample holder and a scintillation detector was reduced to improve the effective ratio of positron annihilation gamma-rays to background gamma-rays. Secondly, an additional circuit to improve an energy resolution of the scintillation detector was installed to cut unwanted gamma-ray signals. A lifetime value of 387±12 ps was obtained for a Kapton film with the second method. This lifetime value was in agreement with the previous studies. Further improvements as well as age-momentum correlation (AMOC) measurements are in progress.

References

[1] A Yabuuchi et al., J. Phys. Conf. Series. 791 (2017) 012013.

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