# Evaluation of energy-resolved spin polarization of surface electrons by spin-polarized positronium time-of-flight method

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Using spin-polarized positronium (Ps) annihilation spectroscopy, the electron spin polarization of top-surface layer can be determined because Ps is formed only at the vacuum side of the surface [1, 2]. If the energy-resolved and spin-polarized Ps annihilation spectroscopy is available, the spin-polarized electron density of states associated only with the top-surface layer of metals will be obtained. In particular, the spin polarization at the Fermi level is very important to evaluate the spin transportation in devices in connection with the spin-Hall effect, Rashba effect and topological insulators. The spin-polarized Ps time-of-flight method (SP-PsTOF) will respond to such offers. We have been developing SP-PsTOF apparatus as shown in Fig. 1.[1]

A spin-polarized positron beam generated from a Na-22 source (440 MBq) and a solid Kr moderator is transported to the sample by the electrostatic lenses. The Ps emission energy is obtained from the difference between the detection time of the secondary electrons due to the positron incident into the sample and the detection time of annihilation gamma ray of ortho-Ps using NaI detectors equipped with a lead slit. By alternating the direction of sample magnetization, a difference Ps-TOF spectrum (SP-PsTOF spectrum) is obtained. Figure 2 shows a typical SP-PsTOF spectrum obtained for a nickel film. The negative polarization near the Fermi level (E=0eV), which is reproduced by a theoretical calculation, is successfully measured. Using this apparatus, we attempt to obtain the energy-resolved surface electron spin polarization of some half-metals, such as $Co_2MnSi$ or $Co_2FeGa_{0.5}Ge_{0.5}$.

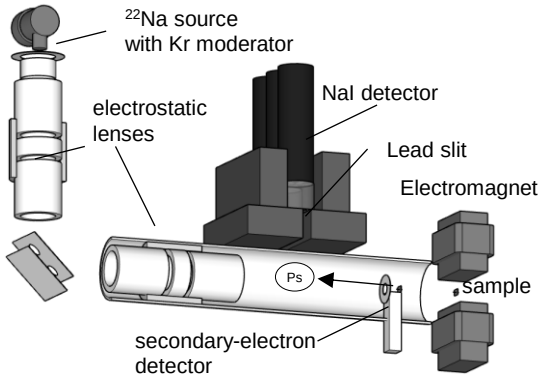


Fig.1. Schematic of the spin-polarized positronium time-of -flight apparatus.

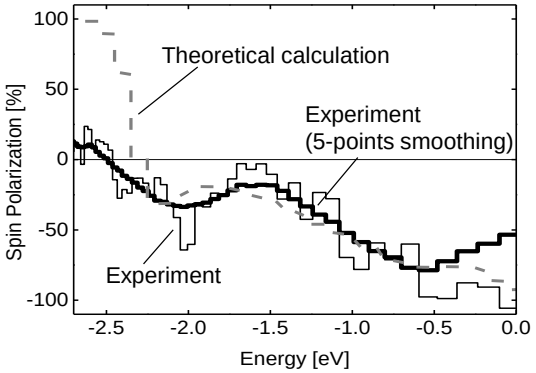


Fig.2. The SP-PsTOF spectrum obtained for the nickel thin film.

[1] M. Maekawa *et. al.*, *Phys. Rev. Let.* **126**, 186401 (2021).