# Research Group for Spin-Polarized Positron Beam

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The research aim for Spin-Polarized Positron Beam Research Group is to investigate spintronic materials using positron beams. Recently, spintronics has attracted much attention because of its potential application fabricating new devices without a power loss due to the Joule heating. Accompanied by the increasing progress of spintronics, new techniques to probe the electron spins in materials need to be developed. We have been attempting to utilize positron beam for spintronic materials. We produced a $^{68}$Ge positron source with a proton irradiation and succeeded in obtaining a spin-polarized positron beam with polarization of 47% [1]. We demonstrated that the ferromagnetic band structure [2] and the current-induced surface spin polarization of nonmagnetic materials [3] can be studied by spin-polarized positron annihilation spectroscopy. We have also been investigating spintronic materials using reflection high-energy positron diffraction (RHEPD). In the last fiscal year, we succeeded to determine the correlation between the atomic configuration and the Rashba spin-splitting of the surface states.

**Atomic configuration and spin-splitting on Rashba surface**

Spin polarization at nonmagnetic material surface attracts much attention in the spintronics research and development. The Rashba effect is one of the mechanisms to generate the surface spin polarization. At surfaces and/or interfaces, the electronic states can be spin-split due to the spatial inversion asymmetry. Historically, the Rashba effect was discovered in semiconductor hetero-structures such as InGaAs/InAlAs [4]. In 2007, so-called giant Rashba effect was found in a surface alloy of $Ag_2Bi$ [5]. Since then, the giant Rashba effect has been extensively investigated in various surface alloys. A theoretical study suggested that the spin-splittings of $Ag_2Bi$ and $Ag_2Pb$ are the functions of distances of Bi and Pd layers from the first Ag layer [6]. In this study, we investigated the change of the distance of Pb layer from the Ag layer ($z_{Pb}$ in Fig. 2) with changing the Ag film thickness ($t_{Ag}$ in Fig. 2) using the RHEPD.

We prepared the $Ag_2Pb$ surface alloys with different Ag film thicknesses. The angle-resolved photoemission spectroscopy measurements exhibited that the spin-splitting increases with increasing the Ag film thickness. This is attributed to the hybridization between the spin-split surface states and the quantum well states. Considering the theoretical study [6], the above result further implies the change of $z_{Pb}$ depending on $t_{Ag}$.

Figure Fig. 1 shows the RHEPD rocking curves (intensity of the specular spot as a function of the glancing angle of the incident positron beam) from the $Ag_2Pb$ surfaces for $t_{Ag}$ = 8, 14, and 21 atomic layers (monolayers: MLs). Although the difference in three rocking curve shapes is very small, a shoulder appears at around 3.0º with increasing $t_{Ag}$. This suggests the shift of $z_{Pb}$. The solid lines in Fig. 1 are the best fitting curves using the dynamical diffraction theory with $z_{Pb}$ as the fitting parameter. Figure Fig. 2 shows thus determined $z_{Pb}$ as a function of $t_{Ag}$. It is found that $z_{Pb}$ linearly increases with $t_{Ag}$.

This result confirmed that the surface potential change through the hybridization between the spin-split states and the quantum well states leads to the repulsive force from the Ag film surface and hence the magnitude of the spin-splitting increases with increasing $t_{Ag}$, accompanied by the increase in $z_{Pb}$.

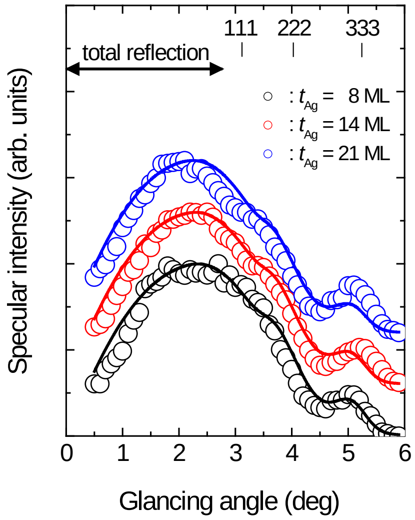


Fig. 1 TRHEPD rocking curves from the $Ag_2Pb$ surfaces with the Ag film thicknesses ($t_{Ag}$) of 8-21 ML. Open circles are the experimental curves and solid lines are the calculated ones using the optimum Pb heights.

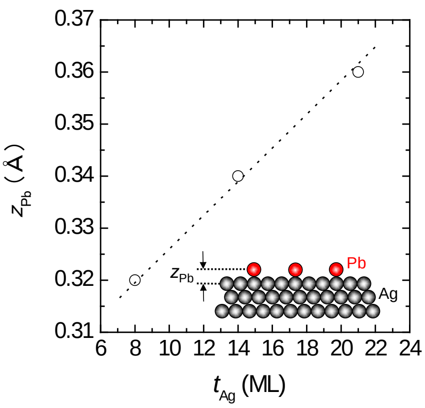


Fig. 2 Optimum Pb height ($z_{Pb}$) from the underlying Ag layer in the $Ag_2Pb$ surface alloy at each Ag film thickness ($t_{Ag}$).

**References**

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