Positron and Positronium Interactions in Solids

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Positronium (Ps) in vacuum is a simple two-body system. It has been a topic of extensive experimental and theoretical investigation during the past several decades since the investigation of its properties allows for a very accurate test of QED. The lifetime, hyperfine splitting, and energy levels are now known with high accuracy.

In contrast, Ps in solids is a very complicated, many-body Coulomb interacting system. Our knowledge of the fundamental properties of Ps in solids is very limited because of theoretical and experimental difficulties.

In this talk we will focus on delocalized Ps state in $\alpha-SiO_2$, which was identified in the angular correlation of annihilation radiation (ACAR) spectrum more than thirty years ago[1]. The mean lifetimes of para-Ps and ortho-Ps in $\alpha-SiO_2$, however, have not been unveiled for many years. It has been impossible to resolve the para-Ps decay component from those due to ortho-Ps, positrons which do not form Ps (free positrons), and positrons trapped in lattice defects. The main reason for this is the instrumental limitations and small differences in the decay rates among these components.

Recently, we have succeeded in developing a new PAL spectrometer using a digital signal processing technique which has a high resolution in addition to high stability and a good signal-to-noise ratio[2]. We performed high-statistics measurements of the PAL spectra for $\alpha-SiO_2$ with this spectrometer, and determined the mean lifetime of para-Ps in $\alpha-SiO_2$. [3]

The lifetime of the para-Ps in $\alpha-SiO_2$ is found to be 156 ± 4 ps, which is much longer than its intrinsic lifetime of 125 ps. This indicates clearly that Ps in $\alpha-SiO_2$ is swollen. The average distance between the electron and positron in Ps becomes larger than its vacuum value, because of the screening of the Coulomb interaction between the constituent particles by electrons of the medium.

From this value and ACAR results for the identical sample, the electron-positron contact density κ is obtained to be $\kappa = 0.34\pm0.01$. This value is in agreement with the results of the Zeeman mixing study[4], which suggests that a simple "two body picture" is valid. It is also valuable to compare this results with that of Time-Of-Flight measurements[5] and effective mass study[6].

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