Statistical analysis of the Doppler Broadening coincidence spectrum of the Electron-Positron Annihilation Radiation in Aluminum

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Positron annihilation spectroscopy is a well-established technique and has been extensively utilized to probe condensed matter systems [1]. With the incorporation of a second Ge detector to measure both annihilation photons [2], the Doppler Broadening Spectroscopy undergoes a great improvement, with a gain of $\sim\sqrt{2}$ in the relative energy resolution of the two detectors for the observation of the annihilation peak, and a great reduction of the background. Other important aspect, that does not receive much attention, is that in this coincidence measurement one obtains a two-dimensional spectrum in energy (Doppler-broadening coincidence spectrum), where the phenomena related to annihilation and those to the acquisition system are distributed through the spectrum. Then, one can distinguish these effects quite clearly. With the goal of treating all of these phenomena, we accomplished a statistical treatment for the Doppler broadening coincidence spectrum [3, 4, 5]. The Doppler-broadening coincidence spectrum was modeled by a two-dimensional function that was fitted, after convolution with the response function of the detector system, to an experimental spectrum. The obtained reduced chi-square value was 1.11. The relative intensities of positron annihilation with conduction band was 94.0 (3)%, with the 2p shell electrons was 5.7(3), with the 2s electrons was 0.29(16), with 1s electrons was 0.0126(13), in-flight positron annihilation was 0.064(3). The three Fermi cutoff parameters resulted 6.758 (9), 10.013 (11), and 15.532(10), expressed in 10^{-3} m_0c units. We have found that a complete analysis of the Doppler-broadening coincidence spectrum of the annihilation radiation is possible, in this case. Differently from the usual approach, this procedure allows the determination of data uncertainties. Thus, hypotheses can be tested and different results can be averaged.

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