Versuch No. 60

Positron Lifetime Measurement in Indium

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Christoph Hugenschmidt, Christian Piochacz, Martin Stadlbauer, Klaus Schreckenbach

Objective

Positrons as antiparticles of electrons have only a short lifetime in solid states, since they annihilate with electrons. In the present experiment a spectroscope for positron lifetime measurement is set-up comprising a sample irradiated by positrons and two fast BaF_2-detectors with the corresponding nuclear pulse electronics. Following the determination of the time resolution function of the spectroscope using the positron lifetime in an annealed indium sample the change in the lifetime spectrum due to a well defined stress on an indium plate is measured. In addition the typically long lifetime of positrons in polymers will be investigated.

Basics

A positron penetrating into a solid state underlies various processes. The positrons is inelastically scattered till it is slowed-down to thermal energies. Then it can diffuse as a quasi-free particle in the solid till it annihilates either with an electron directly on the diffusion path or till it is trapped in a defect (positron trap) and annihilates then with the trap surrounding electrons. Such traps are for instance atomic voids, micro cavities, displacements and corn or phase boundaries. At those trap sites the positively charged bare atoms are missing such that the trap can be considered as an attractive potential for the positrons compared to the perfect crystal. Since the electron density at the trap site is lower than in the undisturbed bulk material, the lifetime in the traps are longer compared to the bulk. Due to this trapping and thus delayed annihilation process, positrons are very sensitive probes for defect spectroscopy. In conventional positron lifetime spectroscopy a radioactive sample of Na22 is conveniently used as positron source. This isotope emits immediately after the β^+ emission a gamma quant, which serves as a start signal for the appearance of the positrons: The delay of the gamma ray emission and the slowing-down time of the positron in the bulk are negligibly short compared to the diffusion positron lifetime. The annihilation manifests itself by the emission of two gamma rays of 511 keV, which serves a s the stop signal, i.e. disappearance of the positron.

Performance of the experiment

In course of the experiment the basics of positron physics and the techniques for high resolution time spectroscopy are introduced. In the first part of the experiment the specific measurement methods in solid state physics with positrons are learned. In addition there is the opportunity to visit the high intensity positron source NEPOMUC at the FRM-II, which provides insight into a modern monoenergetic positron source with the various possibility for future experimental activities in this field.

A basic experimental set-up for a positron lifetime spectrometer is put together. The electronics present a typical fast-slow coincidence with two BaF_2-detectors.The corresponding electronic components are presented, their functioning explained, the signal shape and flow presented and the components are connected. A digital oscilloscope serves as a visualization of the various slow and fast signals and allows a judgment and eventual correction of the signals.

Following the tuning and calibration of the electronics various positron lifetime spectra are recorded. Firstly the time spectra of an Indium sample is measured which was annealed from the defects by a temperature treatment. Then by a well defined stress on the Indium probe defects are created in which positrons are trapped showing a longer lifetime component with increasing intensity. In a second investigation a typical long lifetime of positrons in a polymer sample is observed.

Evaluation of the experimental results

In the first step the resolution function in the measured time spectra are deduced from the annealed Indium sample, for which a comparably short lifetime is expected due to the low defect concentration.

In the next step the positron lifetime components with their intensities in the Indium sample during stress and in the polymer are determined. The resolution function is experimentally known from the annealed Indium sample and is now folded with estimated positron lifetime components till the measured spectrum is reproduced.

This iterative deconvolution method is preferred to an automatic fit procedure since the functioning and interplay between lifetime components and resolution function are more transparent.