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Abstract of Doctoral Dissertation

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Title of Doctoral Dissertation

Developments of New Analysis Functions for the Muon Spin Relaxation Spectroscopy
(ミュオンスピン緩和分光法の新解析機能の開発)

The muon spin relaxation method (μ SR) is a powerful microscopic tool to probe electronic states of materials observing local magnetic field distributions on the muon. How to choose analysis functions is a key matter to deduce the information in physics from the μ SR results in order to understand changes in electronic states in various temperature regions. It often happens that a distribution of local magnetic fields shows intermediate states between Gaussian and Lorentzian shapes. An intermediate μ SR time spectrum can be considered as a crossover distribution, which has characteristics somewhere between Gaussian and Lorentzian. For instance, in case that there are two independent field contributions, one having the Gaussian distribution and the other Lorentzian, the intermediate local field distribution can be realized. Another possible case is when the source is from one magnetic origin but the number of contributing magnetic spins is small though not one. Recently, another example to realize the intermediate μ SR time spectrum was reported in the case that systems had non-uniform and/or low-density distributions of nuclear magnetic moments. Organic molecular superconductors are typical examples showing this kind of distribution. For the current study, we described the crossover field in terms of a convoluted function of Gaussian and Lorentzian. We derived the equation of the three-dimensional (3D) convolution in two ways. The first derivation uses the convolution integral starting directly in the 3D space. The other derivation starts from that of the one-dimensional (1D) convolution and make it to be converted to the 3D form. From the latter, we showed that the equation can be decomposed to a sum of three known convolutions. By applying the Fourier transform to this equation, we achieved the correct relaxation function for the zero-field condition, which was found to be given by a simple analytical equation. We also approximate 3D-convolution in the form of mixing 3D-Gaussian and -Lorentzian distributions with a weighting factor, and the approximation equation well approach the analytical one with maximum discrepancy 10% concentrated around the dip of approximation function. In addition, we tried to describe the intermediate analysis function under applied magnetic fields and under dynamic fluctuations on the basis of the development of the zero-field intermediate analysis function. Finally, we applied our developed analysis function to some μ SR results in order to make sure its validity. We also provide some other analytical functions with different intermediate states between Gaussian and Lorentzian distribution for zero-field and longitudinal-field conditions for generalizing current analysis functions. We fit the μ SR time spectra of λ -(BETS) $_2$ GaCl $_4$ with a static analysis function, and the function well approach the μ SR time spectra of the sample. The fitting results proposed the random internal fields are static at all considered temperatures indicating the local random local fields originate from nuclear dipole moments. The dynamic function is applied the three samples of La $_{2-x}$ Sr $_x$ CuO $_4$ material for $x = (0.024, 0.04, 0.115)$ and the dynamic analysis function also well approaches the μ SR time spectra of the three samples. The fitting results suggest: 1. The intermediate relaxation between Gaussian- and Lorentzian-shape induced by the static parameter. 2. Nuclear dipole moment dynamics enter the μ SR time windows caused by a coupled state with another sources of weak random fields.