A new MIEZE technique for investigation of relaxation on magnetic nanoparticles

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In the MIEZE, sample is placed after the analyzer and there are no optical components between sample and detector. Therefore, the MIEZE spectrometer can be applied to small angle neutron scattering and neutron reflectometry. The contrast of MIEZE signal can be observed without reduction even in magnetic scattering although the contrasts of NSE and NRSE are less than half. However, in general, it is not easy for simple MIEZE setup to separate magnetic and nonmagnetic fluctuations of magnetic nanoscale particles since it measures the both intensities of qausielastic scattering, simultaneously. We propose a new MIEZE technique which is to set a second analyzer and an additional π flipper, in order to separate the magnetic and nonmagnetic quasielastic scattering intensities. We succeeded in observing the superparamagnetic fluctuations of magnetite particles in ferrofluid by using the new technique(Fig.1)[1]. Magnetic ferrofluid consists of magnetite particles and solvent (heavy water). The magnetite particles with a diameter on the order of 10 nm are coated by oleic acid. There are two kinds of dynamical mode in magnetite ferrofluid. One is Brownian diffusion mode of magnetite particles and the other is superparamagnetic fluctuation which is a relaxation of magnetic moment in magnetite particles. Both relaxation time depends on particle size and temperature. The Brownian relaxation time of the particle with the diameter 10 nm is reported to be longer than 2 ns which is out of measurable Fourier time range in this MIEZE experimental setup. On the other hand, the relaxation time of superparamagnetism (Neel) is much faster than the Brownian relaxation time. We tried to observe the effect of relaxation on superparamagnetism. Here MIEZE signal is sensitive to the path length dispersion in neutron trajectories from sample to detector. We estimated instrumental resolution function of the MIEZE spectrometer by using Monte Carlo(MC) simulation. The contrasts from nuclear scattering were well reproduced by MC simulation. On the other hand, these contrasts from magnetic scatterings were almost less than half of nuclear scattering ones.It is clear that the superparamagnetism relaxation contributes to reducing the contrast of MIEZE signal from magnetic scattering.

[1]H.Hayashida, M.Hino, *et. al.*, Nucl.Inst.Meth.A**600**(2009)56.

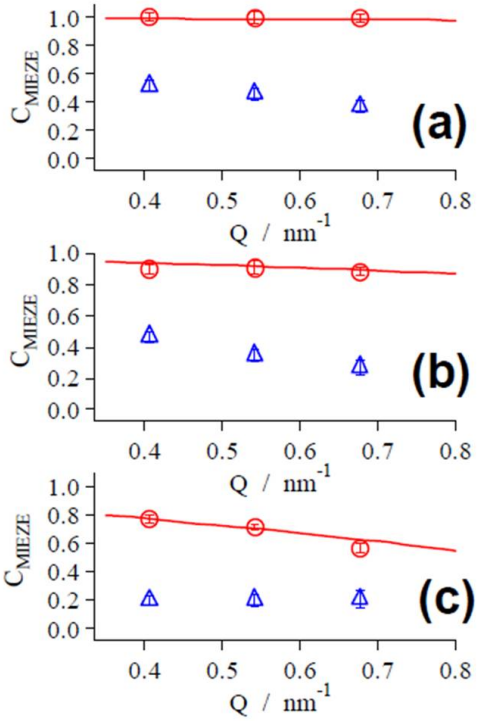

Fig. 1. Contrasts of MIEZE signals of nuclear (open circles), magnetic (open triangles) scattering with the ferrofluid and resolution functions at (a) τ= 0.3, (b)τ =0.8, (c)τ= 1.6 nsec as a function of Q, respectively.