Field-induced assembly of Fe_3O_4 magnetic nanoparticles

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Iron-oxide magnetic nanoparticles (IOMNPs) have been of considerable interests due to a variety of their unique magnetic characters and high potential of biomedical applications. Under a magnetic field, IOMNPs move, rotate, and may aggregate and arrange through interparticle magnetostatic interactions. As compared with dispersed IOMNPs, such arrangement strongly affects magnetic properties of IOMNPs, therefore biomedical performance under magnetic field. Moreover, the process of arrangement depends on the morphology of IOMNPs (size, shape, structure etc.). Therefore, it is important to know how IOMNPs behave and arrange within an organism under magnetic fields.

In this study, we performed small-angle neutron scattering (SANS) experiments at SANS-U for spherical Fe_3O_4 MNPs. The MNPs with the diameter of 14.1±1.1nm were dispersed in a mixture of decalin and d_{18}-decalin. By tuning the ratio of the two solvents (5:95), the scattering length density (SLD) of the solution can be contrast-matched to the nuclear SLD of Fe_3O_4. A magnetic field up to 0.3 T was applied along the horizontal direction and perpendicular to incident neutron beam using an electromagnet. SANS data were collected at three detector positions of 1, 4, and 10 m, covering the Q range of 0.003-0.4 Å^{-1}.

First, we checked a behavior of Fe_3O_4 MNPs in a 50:50 mixture of decalin and d_{18}-decalin. In this condition, both magnetic and nuclear scattering can be detected. We observed a small peak at around $Q \sim 0.03$ and 0.1 Å^{-1}, which may be due to a form factor of spherical MNPs. However, due to a large incoherent scattering, data could not be analyzed in more detail.

Figure 1 shows the circular average of 2D SANS data at the contrast-matching condition with and without a magnetic field of 0.3 T. In this case, only the magnetic contribution to SANS intensity can be extracted. For the both cases, there is a small peak around $Q \sim 0.05$ Å^{-1} and SANS intensity changes as $\sim Q^{-2}$ at $Q < \sim 0.03$ Å^{-1}. To better understand this behavior, the pair-distance distribution function (PDDF) was calculated by a direct Fourier transform of the SANS data using the ATSAS software. For both B = 0 and 0.3 T, the PDDF has a peak at the distance of ~ 40 nm, which is larger than the particle diameter of 14.1 nm. This suggests that Fe_3O_4 MNPs aggregate and form a cluster with interparticle magnetic correlations before the magnetic field is applied. Further SANS experiments using well-dispersed Fe_3O_4 MNPs are planned to see the effect of magnetic field on the alignment.

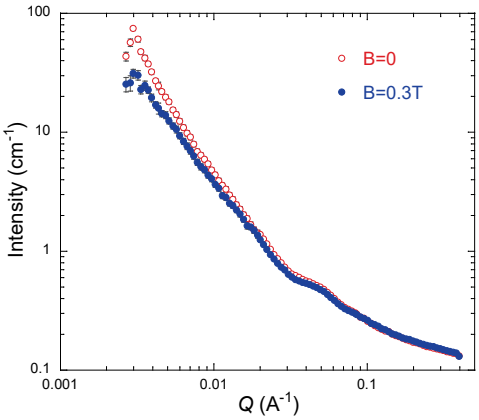

Fig. 1. Circular average of 2D SANS data at the contrast-matching condition with and without a magnetic field of 0.3 T.