High Resolution Magnetic Nano-Particle Analyzer

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The most important issue for magnetic materials is an understanding of the magnetic and physical properties of a nanometer-sized particle because the use of magnetic nanoparticles (MNPs) in many applications depends predominantly on their inherent magnetic properties. In the case of biomedical applications, the forces that influence the translational, rotational, and vibrational motion of a MNP- tagged biomolecule are the magnetic force due to the magnetization of an individual MNP and the external magnetic field under a given condition. Popular magnetic biosensing platforms such as giant magneto-resistance (GMR) sensors, Hall sensors, and magneto-optical sensors that are used to quantitatively analyze the existence of target molecules are based on the detection of a stray field from a single MNP . Furthermore, structural assemblies of MNPs form various recording media and permanent magnets.

Recently, there have been many attempts to quantitatively analyze a biomolecule by magnetically manipulating the motion of magnetic beads in a microfluidic system because magnetic interactions are generally not affected by changes in the surface charges, pH, or ionic concentration of the surrounding medium, contrary to electrical-driven manipulation.

To precisely manipulate the motion, we should know the characteristics of the MNP, e.g., the size, charge state, and magnetism. There are well-established techniques for investigating the physical and electrical properties of a nanoparticle. For instance, the size and surface charge state of a nanoparticle can be routinely characterized by dynamic light scattering (DLS) and zeta-potentiometry, respectively. These methods can provide information on the distributions and the average values of the size and charge number of each particle. Magnetic characteristics have been usually determined by a superconducting quantum interference device (SQUID) and by a vibrating sample magnetometer (VSM). Unlike DLS and zeta-potentiometry, these techniques, although they have excellent sensitivities, are limited to the average properties of a large number of MNPs. To the best of our knowledge, the resultant data from these techniques do not provide sufficient information on the magnetism of a MNP, which may be considered as a critical bottleneck in facilitating the use of MNPs in various industrial applications. Therefore, the need to characterize a single MNP has been increasingly recognized.

In this work, we investigate the motion of MNPs, 30 nm in diameter, that are driven by both magnetic and electric forces in a nanopore membrane. In this investigation, we measured the velocity of the MNPs passing through the nanopore using an ionic current blockade. We found that the magnetic force enables the MNPs to move more rapidly and that the velocity is linearly proportional to the magnetization of a MNP. Thus, we were able to measure the magnetization of a single colloidal MNP and to acquire hundreds of data points on the magnetization within a few minutes.