# Microscale Manipulation by NdFeB-Based Magnetic Tweezers: Applications to Microrheology

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**Abstract:** NdFeB-based magnetic tweezers allow well-controlled forces (fN – nN range) to be applied to micron-scale particles, and offer an attractive alternative to optical tweezers for materials characterization. Here, instrument design, testing, and implementation will be presented.

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Active microrheology methods enable manipulation of microscale objects to determine the structure-mechanics relationships of complex polymeric materials [1]. Experimental platforms commonly incorporate an optical microscope to visualize samples as forces are applied to micron-scale probes using external fields. Optical trapping methods provide nanometer-resolution of probe position and can operate at high frequencies. However, optically transparent materials of fairly low index of refraction are required, and the application of constant force requires computer–controlled feedback control to compensate for instrument compliance. Since the maximum applied force is typically tens of picoNewtons, use of optical trapping methods has been limited to fairly soft materials (<50 Pa).

Magnetic tweezers devices provide a valuable alternative, allowing for characterization of 3-dimensional materials while providing forces in the ~nN range. Prior implementations of magnetic tweezers have typically relied on the use of electromagnets operating at high current [2-4]. Although powerful, electromagnets can heat samples and exhibit hysteretic responses, and extremely small distances between the pole pieces and magnetic beads are typically required. These small separation distances can degrade high-resolution imaging, and can create steep force gradients within the image plane. By contrast, Neodymium Iron Boron (NdFeB)-based magnetic tweezers are non-invasive and easily provide constant force to the sample plane without the use of feedback control. Because of these advantages, NdFeB magnets have become a standard technology for single molecule force-spectroscopy where femto- to picoNewton forces are required; however, these have thus far found limited utility in materials characterization, which typically requires larger forces to achieve measurable deformations.

We present the design and construction of three new microscope-mounted NdFeB-based magnetic tweezers devices that overcome these limitations (1) high-force devices that enable the application of nN forces and make possible meso- to macroscale materials characterization; (2) ring magnet devices that enable oscillatory microrheology measurements; and (3) portable magnetic tweezers that enable visualization of the microscale deformation of soft materials under applied force through fluorescence imaging [5-7]. We demonstrate their utility in characterizing many aspects of polymer mechanics [8,9].

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