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Magnetic Field-Based Microfluidic Devices

▶ Magnetic Field-Based Lab-on-Chip Devices

Magnetic Fields

Definition

Magnetic fields are created by permanent magnets or magnetic coils and can be used to magnetize and/or apply forces on other magnetic materials.

Cross References

▶ Magnetic Field-Based Lab-on-Chip Devices

Magnetic Filter

Synonyms

Magnetic mass spectrometer

Definition

A mass filter that separates ions according to their trajectories in a magnetic field. A device with a fixed magnetic field normally acts as a mass spectrograph, whereas a device with a variable field acts as a mass spectrometer.

Cross References

▶ Mass Spectrometry

Magnetic Fluid

▶ Ferrofluids in Microchannels

Magnetic Mass Spectrometer

▶ Magnetic Filter

Magnetic Microbeads

Definition

Magnetic microbeads are micrometer spherical particles that have magnetic entities embedded in a latex shell.

Cross References

▶ Magnetic Field-Based Lab-on-Chip Devices

Magnetic Pumps

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Synonyms

Electromagnetically actuated pumps; Magnetohydrodynamic pumps

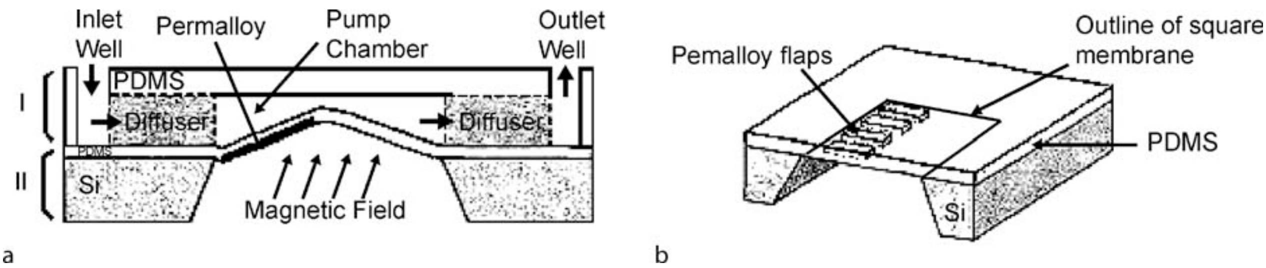
Definition

Magnetic pumps are pumps using electromagnetic or magnetic fields to actuate or to control the fluid motion in microchannels. The application of electromagnetic or magnetic forces is a flexible way of manipulating fluids in lab-on-a-chip devices.

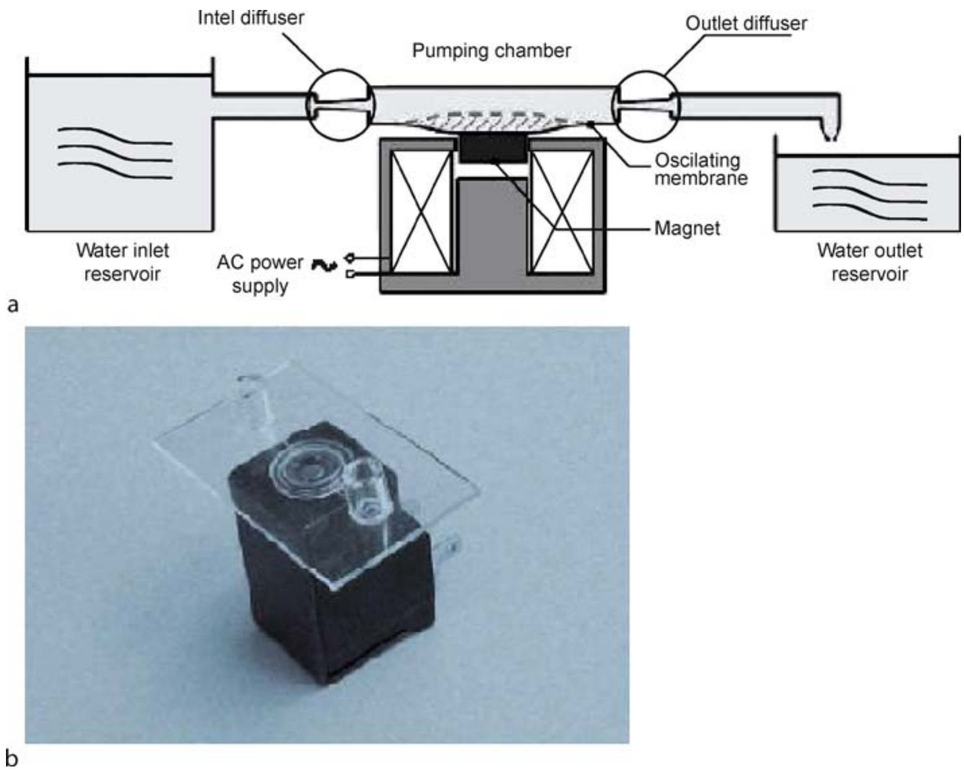
Overview

Micropumps can be classified into two general categories: mechanical and non-mechanical micropumps (an excellent review on micropumps can be found elsewhere [1]). In most mechanical pumps, a membrane is used to produce the pumping action. Non-mechanical micropumps on the other hand generally have no moving parts. Magnetic pumps can be found in both categories in the literature.

Khoo and Liu [2] presented results on the design, fabrication and testing of a novel, micromachined magnetic membrane microfluidic pump. Their pump was composed of a magnetic microactuator, which is based on a thin polydimethylsiloxane (PDMS) membrane, and two polymer-based one-way diffuser valves. Membrane displacement was achieved by the interaction of an external magnet (Fig. 1) with ferromagnetic materials which are embedded within the membrane. It was indicated that the flow rate of the micropump can be controlled by controlling the magnetic field strength and the actuation frequency of the membrane.



Magnetic Pumps, Figure 1 (**a**) Cross-section of assembled micropump and (**b**) schematic cut-out of membrane actuator. Reprinted from [2] with permission from Dr. Liu

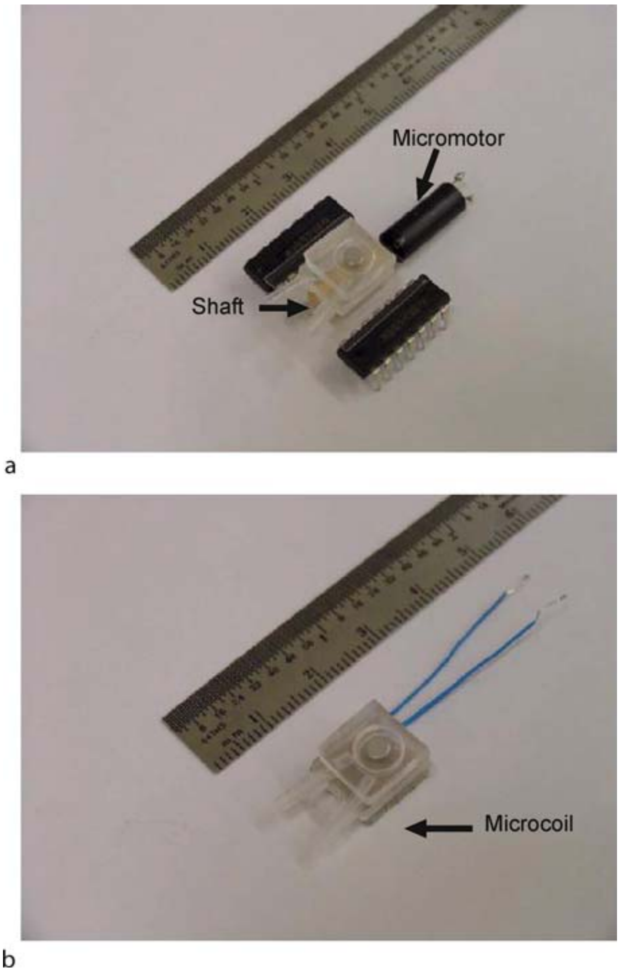


Magnetic Pumps, Figure 2 (**a**) Schematic and (**b**) photograph of micropump system of [4]. Reprinted from [4] with permission from Dr. Yamahata

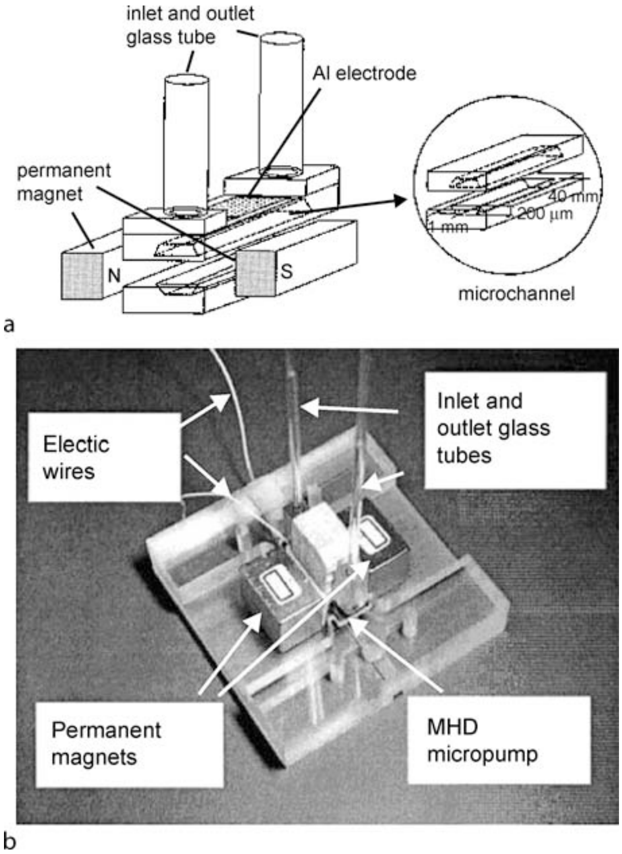
Yamahata et al. [3] fabricated and characterized a poly(methyl methacrylate) (PMMA) valveless micropump which was actuated magnetically using an external electromagnet. The pump consisted of two diffuser elements and a PDMS membrane with an integrated composite magnet made of magnetic powder. They tested the setup with water and air. They relate the flow rate with the actuation frequency, and showed that frequency near to the natural frequency of the membrane generates higher flow rates due to the larger amplitude membrane vibrations. In their following study [4] (Fig. 2), they used glass instead of PMMA, and used a newly designed membrane, an improved actuation coil and a solid magnet rather than a polymer-bound powder magnet. They achieved four times larger pumping pressures compared to their PMMA-based pump.

Pan et al. [5] studied a magnetically driven PDMS membrane micropump with two ball check-valves (Fig. 3). Two driving mechanisms to generate the external magnetic force for the membrane were used: one used a permanent magnet with a small direct current (DC) motor and the other an integrated coil. They obtained higher flow rates with the latter mechanism but lower power consumption with the former mechanism.

Non-mechanical micropumps using the principle of magnetohydrodynamics (MHD) for fluid motion have also been studied in the literature. If an electrical field, $\boldsymbol{E}$, and



Magnetic Pumps, Figure 3 Test and measurement setup for two micropumps of different driving mechanisms: (**a**) permanent magnet with a small DC motor; (**b**) integrated coil. Reprinted from [5] with permission from Dr. Ziaie



Magnetic Pumps, Figure 4 (**a**) Schematic and (**b**) photograph of micropump system of [6]. Reprinted from [6] with permission from Dr. Jang

a magnetic field, $\boldsymbol{B}$, are applied perpendicular each other they create a Lorenz force in the direction of $\boldsymbol{J} \times \boldsymbol{B}$, where $\boldsymbol{J}$ is the electrical current density. Since the mean free path of ions in a liquid is extremely small, momentum is transferred from the ions to the solvent molecules rapidly by collisions. Therefore, the sum of the Lorentz forces on all of the ions inside the liquid is just the net driving force causing the bulk liquid motion in MHD pumps. Jang and Lee [6] (Fig. 4), Huang et al. [7] and Zhong et al. [8] successfully applied the MHD principle for the development of micropumps using DC. The pressure head generated by MHD pumps can be controlled by adjusting the intensity of the magnetic field, the magnitude of the applied voltage across the electrodes and the length of the actuation section, which makes the usage of MHD pumps very flexible. However, all these micropumps suffer from bubble generation at certain voltage values at the electrodes that are used to generate the electrical field. Lemoff and Lee [9] used alternating current (AC) in their MHD micropump and eliminated bubble generation (Fig. 5). They used an electromagnet to generate the magnetic field. They showed that by using an electromagnet, multiple pumps can be driven independently by varying the amplitude and phase of the currents of electrodes and electromagnet.

Cross References

- ► Electrical Pumps
- ► Ultrasonic Pumps
- ► Thermocapillary Pumping

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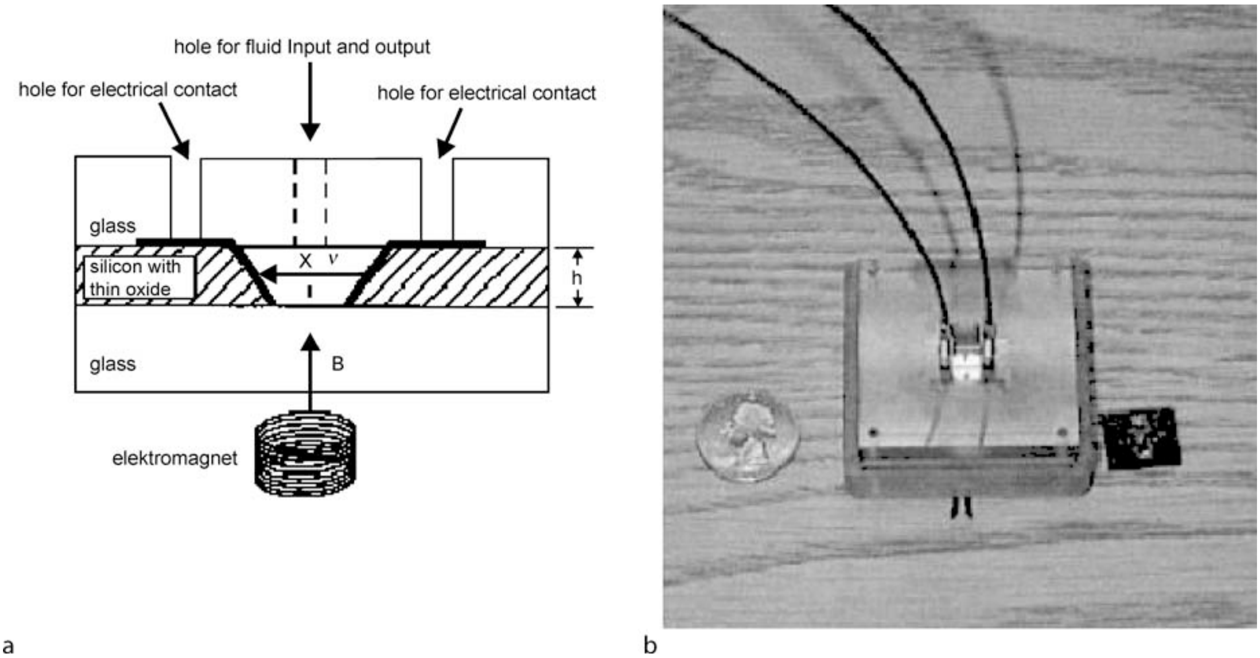

Magnetic Pumps, Figure 5 (**a**) Cross-section of AC MHD and (**b**) photograph of micropump system of [9]. Reprinted from [9] with permission from Dr. Lee

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Magnetic Split-Flow Thin Fractionation

► Magnetophoresis

Magnetic Susceptibility

Definition

The magnetic susceptibility represents the amount of magnetization of a material in response to an applied magnetic field.

Cross References

► Magnetic Field-Based Lab-on-Chip Devices

Magnetohydrodynamic Pumps

► Magnetic Pumps

Magnetophoresis

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Synonyms

Free-flow magnetophoresis; On-chip free-flow magnetophoresis; Magnetic split-flow thin fractionation; Capillary magnetophoresis; Electromagnetophoresis

Definition

Magnetophoresis, a nondestructive method for selectively collecting or separating magnetic particles, is the process of magnetic particle motion in a viscous medium under the influence of the magnetic field; the viscous medium may