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A review of microfluidic device applications

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Abstract – Microfluidics has various applications, including micromixing, particle separation, micropumping, drug delivery, particle sorting, particle manipulation, etc. This paper reviews two types of microfluidic devices, i.e. micromixers and separation devices, that work based on active and passive methods. The active devices employ external actuators to improve their efficiency and the passive ones operate based on their geometry. It can be concluded that passive and active microfluidic devices have particular applications in different systems according to their major characteristics. Investigators may use hybrid techniques and new materials to industrialize the devices.

Keywords – Microfluidics, Micomixers, Separation Devices, Industrial Applications

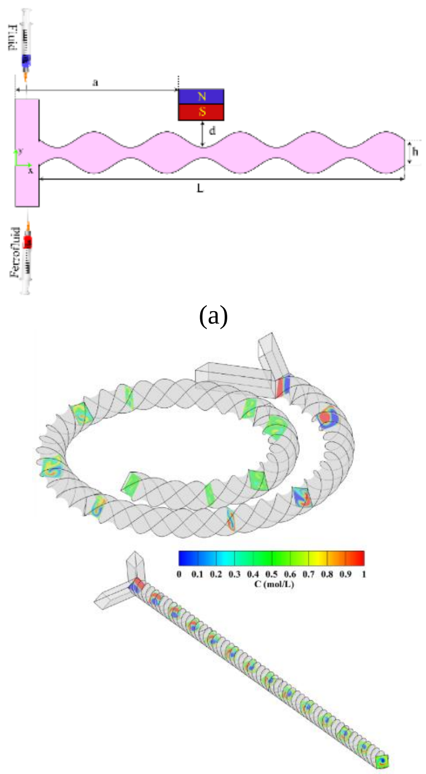
I. Introduction

Microfluidics has different applications, such as cell analysis, micromixing, drug delivery, particle sorting, particle manipulation, micropumping, etc. One of the major applications of these devices is micromixers [1]. Active micromixers utilize external forces and passive ones do not use any external actuator. Separation devices are also employed in micro-scale [2]. They are also categorized into two groups; active and passive. Numerical and experimental works have been carried out to analyze the operating conditions of these devices [3]. Hence, one should know their main working principles [4].

This review paper introduces these two applications and compares their main characteristics. Some future directions are also recommended.

II. Micromixers

As mentioned before, active and passive micromixers have been considered by various researchers. Table 1 compares the main specifications of these microchips. It is found that the mixing efficiency (ME) of active and passive devices depends on the external force, Reynolds number, device geometry, etc. Fig. 1 depicts the schematic of two active and passive micromixers.



(a)

(b)

Fig. 1. Schematic of (a) magnetic-field-based micromixer [6] and (b) micromixers with twisted walls [13].

Table 1. Passive and active micromixers.

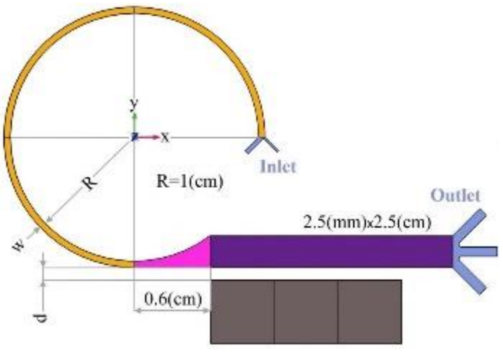
Fluid type	**Actuator**	**ME_{max}**	**Ref.**
Water-ferrofluid	Magnetic field	91%	[5]
Water-ferrofluid	Magnetic field	100%	[6]
Water-water	Acoustic field	100%	[7]
Water-water	Convergent-divergent channel	100%	[8]
Water-water	Electrophoretic force	95.56%	[9]
Water-ferrofluid	Magnetic field	83%	[10]
Non-Newtonian fluids	Electrophoretic force	97.67%	[11]
Water-water	Spiral siusoidal channel	99.11%	[12]
Water-water	Twisted channel	91.87%	[13]
Water-water	Serpentine siusoidal channel	99.89%	[14]
Water-water	Serpentine channel	94.44%	[15]
Water-water	Electrophoretic force	98.7%	[16]
Water-water	Electrophoretic force	100%	[17]
Water-water	Acoustic field	100%	[18]

III. SEPARATION DEVICES

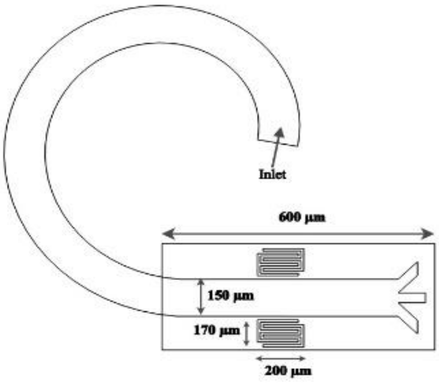
As mentioned previously, active and passive techniques have been considered by various investigators to consider separation devices. Table 2 compares the main characteristics of these devices. Besides, Fig. 2 depicts the schematic of two active and passive separation devices.

Table 2. Passive and active separation devices.

Particle type	Actuator	ME_{max}	Ref.
Circulating Tumor Cells	İnertial force	100%	[21]
Blood cells	Magnetic field	100%	[22]
Polystyrene	İnertial force	100%	[23]
Polystyrene	İnertial-based magnetic field	100%	[24]
Polystyrene (PS) and polymethyl methacrylate (PMMA)	Acoustic field	88%	[25]
Circulating Tumor Cells	DLD	--	[26]
Live and dead yeast cells	Electrophoretic force	100%	[27]
Polystyrene (PS) and polymethyl methacrylate (PMMA)	İnertial-based acoustic field	94%	[28]
Polystyrene	İnertial-based electrophoretic field	100%	[29]
Prostate cancer cells	Acoustic field	99%	[30]



(a)



(b)

Fig. 2. Schematic of (a) an inertial-based magnetic separation device [24] and (b) an acousto-inertial separation device [28].

IV. CONCLUSION

Microfluidics has different applications, such as cell analysis, micromixing, drug delivery, particle sorting, particle manipulation, micropumping, etc. This review paper focuses on two kinds of microfluidic devices, including micromixers and separation ones. Passive micromixers utilize water to assess micromixing when passive techniques are used. Ferrofluids are employed when the external actuator is magnetic force. In separation devices, polymer microparticles or biological cells are isolated using passive and active methods. Some investigators employ hybrid methods to perform the separation. Real conditions should be considered by researchers in future works. Besides, microfluidic devices should be industrialized by introducing cost-effective materials.

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