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Effect of Interelectrode Gap to the Manipulations of Particle Using AC Electroosmosis

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ABSTRACT

AC Electroosmosis (ACEO) is a phenomenon where AC signal is used to induce fluid flows and manipulates particle in a suspension medium. ACEO is a type of AC Electrokinetic (ACEK) and it has been utilized in many lab on a chip (LOC) applications featuring microfluidics technology. The effect of ACEO is electric field dependent. The generation of electric field relies on the signal supplies and electrodes geometry. Zipper electrodes is a type of electrodes that exhibit ACEO. It consist of electrodes pad and interelectrode gap fabricated on Indium Tin Oxide (ITO) coated glass. In this work, Zipper electrodes were fabricated using laser technology by RapidX250-L machine. Zipper electrodes with ACEO will manipulate suspension medium and trap particles to the center of electrode pad. Manipulation of particles is dependent on many parameters such as properties of electrode geometry (size and gap), properties of medium (conductivity, permitivity, temperature and viscosity), properties of signal (voltage and frequency) and many more. This work exhibits multiple zipper electrodes with variation of interelectrode gaps to study the effect of interelectrode gaps to the manipulations of particle when influence by ACEO.

Keywords: Interelectrode Gap; Zipper electrodes; AC Electroosmosis, Lab on a Chip

1. INTRODUCTION

AC Electroosmosis (ACEO) is a phenomenon where AC signal is used to induce fluid flows and manipulates particle in a suspension medium. ACEO is a type of AC Electrokinetic (ACEK), arises from the interaction of the nonuniform electric field with the free charge generated in the diffuse double layer above the electrodes in a microelectrode array [1]. ACEO will induce fluid flow, generating vortices at the edge of the electrode and influence particle to move orthogonally inwards toward the center of the electrode.

Microfluidic technologies has been utilizing ACEK to develop lab on a chip (LOC) devices. LOC devices have been used in many field such as the chemistry, biotechnology, process control, environmental and medical sciences, etc. [2]. Such systems have many advantages such as of low-cost fabrication, high

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throughput, easy operation, quick processing and low consumption (~nL) of analytes [3]. Due to these advantages, rapid growth of research has been done on the topic.

During the 1990s, when microelectromechanical systems (MEMS) technology became widely available to researchers and polydimethylsiloxane (PDMS) microchannel were introduced, microfluidics was quickly recognized as a new, exciting scientific field and its applications to chemical and biological processes rapidly expanded [4]. With MEMS technology, the chances to make the scientific discovery are very high. Due to favorable scaling with miniaturization, electrokinetic phenomena are finding many new applications in microfluidics [5-7]. One of the applications is the particle trapping. Particle trapping is quite an important issue that should be taken seriously as it will help in many area of study. However, the manipulation of particles is dependent on many parameters such as properties of electrode geometry (size and gap), properties of medium (conductivity, permitivity, temperature and viscosity), properties of signal (voltage and frequency) and many more.

This work intended to study the effect of interelectrode gaps to the manipulations of particle when influence by ACEO. Computer aided design (CAD) software was used to design Zipper electrodes. Zipper electrodes is interlocking teardrop shapes electrode[8]. Zipper electrodes is used in this work because under the influence of ACEO Zipper electrodes acted to focus all particles from across a large area towards a central spot of its' electrode pads. In this work, Zipper electrodes is designed with variation of interelectrodes gap sizes to investigate the significant of gap size on the effect of the electrode to trap the particles. The hypothesis is, when there is reduction of interelectrode gap, the number of the particle trap is reduce due to the higher field intensity producing greater fluid velocities, hence reducing the area on which particles can come to rest. Eight electrodes were fabricated. Four different interelectrode gap sizes for each 500ìm diameter and 1000ìm diameter electrode. Interelectrode gap sizes was set to be 100ìm, 150ìm, 200ìm and 225ìm.

2. MATERIALS AND METHOD

2.1. Electrode Fabrication

Previous works has shown that the electrode fabrication process for electrokinetic can be done using photolithography technique [9, 10]. However in this work a new technique which utilize laser technology using RapidX250-L machine as shown in Figure 1 has been used. The electrodes were fabricated on the Indium Tin Oxide (ITO) coated glass. ITO is used because it is transparent. This property is crucial as it will allow the visibility of trapped particles on the electrode pad. The fabrication is carried out in a cleanroom to avoid interference by any pollutants such as dust, airborne microbes, aerosol particles or chemical vapors during the fabrication process.

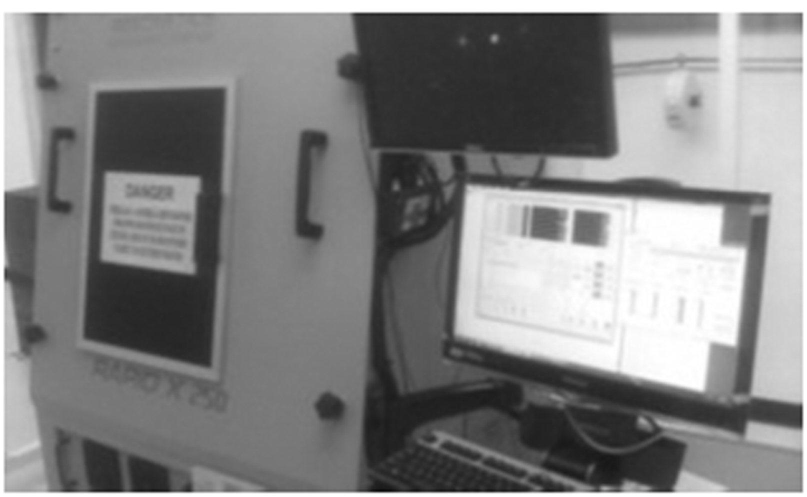


Figure 1: Resonetics RapidX250-L Series machine

The geometry of the electrode is designed using CAD software. The complete drawing is then translated into machine language using computer aided design and computer aided manufacturing (CAD-CAM) software. CAD-CAM software will determine the coordinate of the drawing. The coordinate will be used for navigation of the base of the RapidX250-L machine. The parameter of the laser such as the diameter, the lasers' energy, the laser's repetition rate need to be determine according to the specification of designed geometry. This is done using RapidX250-L software. RapidX250-L is capable to fabricate up to 1 micron feature size. The diameter is set by changing the rectangular variable aperture (RVA) values. Value of 1.0 RVA gives the laser diameter of 100ìm. The energy can be set by setting the pulses in the software. The pulses may be varied from 0 to 300. The maximum energy for the machine is 18kVA. The laser's repetition rate can be adjusted by varying the value of wavelength. The value can be varied from 0 to 200 Hz.

The RVA is set to 1.0, 1.5, 2.0 and 2.25 to produce lasers' diameter to 100ìm, 150ìm, 200ìm and 225ìm which are the area need to be etched to produce interelectrode gap as designed for the zipper electrodes. The repetition rate and pulse is set to maximum which is 200Hz and 300 respectively. This is possible as the value will not have any unwanted effects to the glass substrate. Figure 2 shows zipper electrode with 500ìm diameter and 100ìm interelectrode gap fabricated using RapidX250-L machine. RapidX250-L uses laser technology to etch the ITO layer from ITO coated glass to form interelectrode gap and develop zipper electrodes. The fabrication of the electrode is clear and smooth. Minimal time were taken to laser etch the electrode. Four different interelectrode gap sizes of 100ìm, 150ìm, 200ìm and 225ìm were fabricated for each 500ìm diameter and 1000ìm diameter electrode. The chamber height is set to be 390ìm as suggested in previous work as the optimum chamber heights [10].

2.2. Sample Preparations

AC Electroosmosis (ACEO) can trap particles independent of its sizes. In this work, chocolate particle which is ranged between 8µm to 10µm has been used because of its size and to mimic the water pollution. This will enable the investigation of ACEO for clarification of water from colloidal particles. The experimental sample consist of 200mg chocolate powder suspended into 10mL of deionised water.

Signals were supplied using Tektronix AFG3252C function generator for sinusoidal signals of 1KHz, 10Vp-p. Tektronix MSO 4104 oscilloscope was used to cross check the electrical signal. The

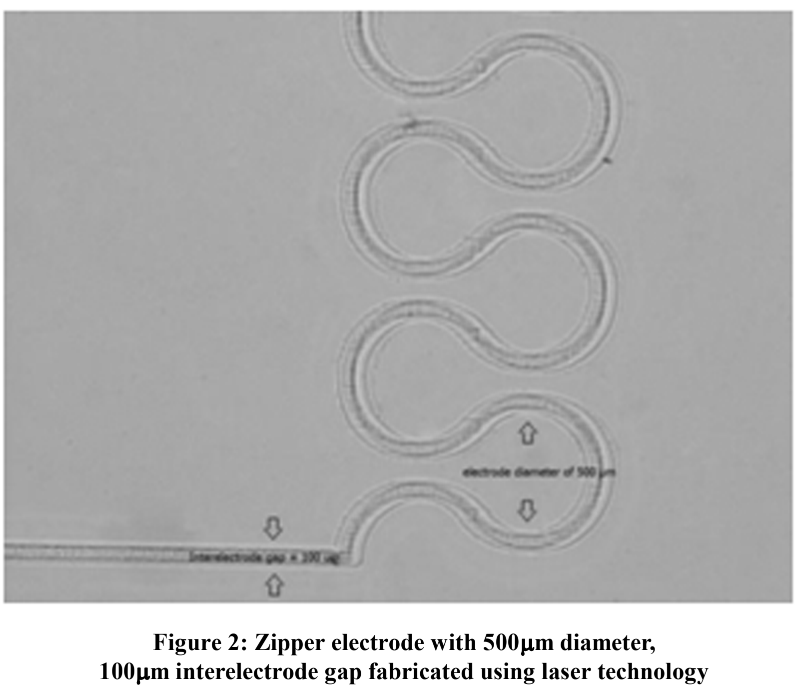


Figure 2: Zipper electrode with 500µm diameter, 100µm interelectrode gap fabricated using laser technology

sample of 30ìl is pipetted onto the electrode and covered with a cover glass. The movement of particles is then observed and recorded using NIS-Elements BR 4.20.00 software under Nikon Eclipse Ci microscope for 1000s.

3. RESULTS AND DISCUSSION

When the electrical signals is applied to the electrode, colloidal particles were observed to move over the electrodes edges and move orthogonally inward to the centre on the electrode. This is concurrence with the

Table 1
Particles Trapping by ACEO on Zipper Electrodes 500µm with Interelectrode Gap Variations

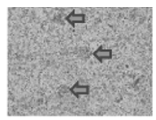
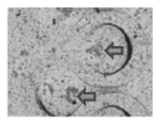
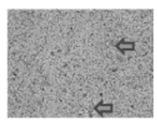
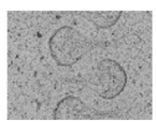
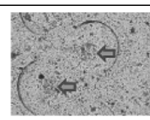
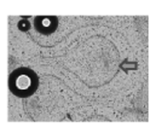
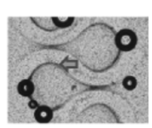
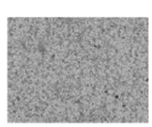
Electrode Diameter (µm)	Interelectrode Gap (µm)	Particles	Description
500	100		The particle trappedat the electrode pad.
500	150		The particle trappedat the electrode pad.
500	200		The particle trappedat the electrode pad. Few particles trappedinsidethe vortex.
500	225		Few particles trapped at the electrode pad. Most particles trappedinsidethe vortex.

Table 2
Particles Trapping by ACEO on Zipper Electrodes 1000µm with Interelectrode Gap Variations

Electrode Diameter (µm)	Interelectrode Gap (µm)	Particles	Description
1000	100		The particle trappedat the electrode pad.
1000	150		The particle form a ring and trapped at the electrode pad.
1000	200		The particle form a ring and trapped at the electrode pad. Few particles trappedinsidethe vortex.
1000	225		No particletrapped at the electrode pad. The particle trappedinsidethe vortex

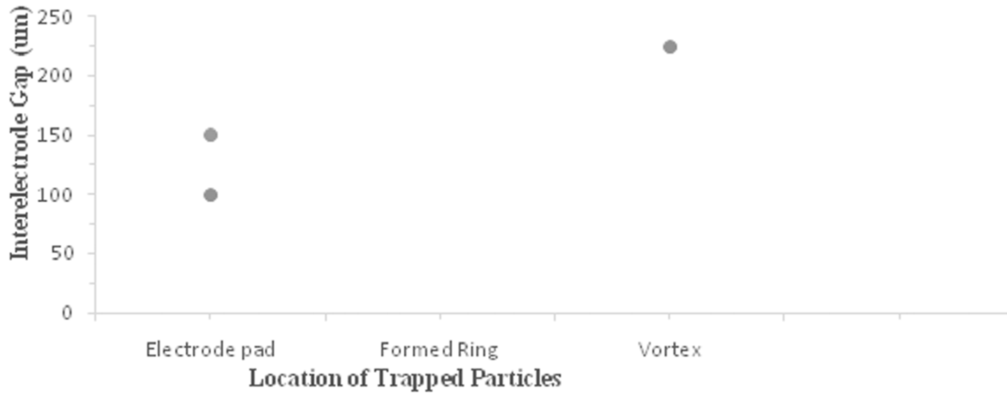


Figure 3: Particles Trapping by ACEO on Zipper Electrodes 500µm with Interelectrode Gap Variations

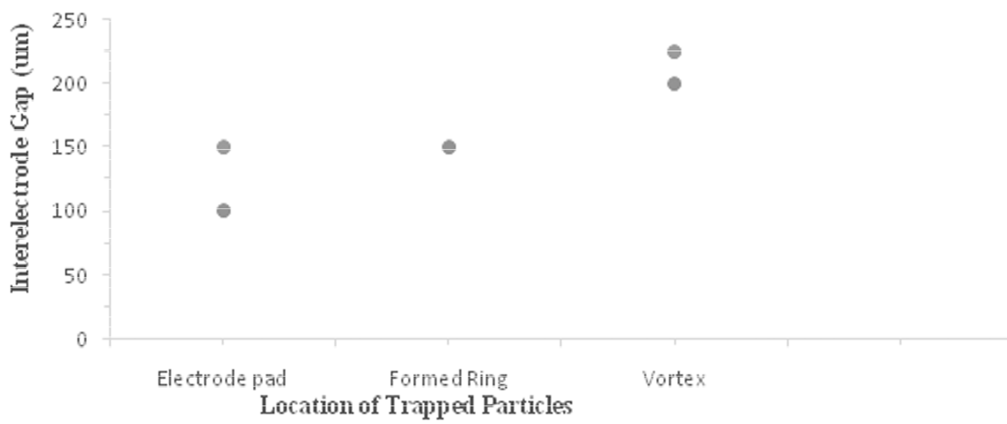


Figure 4: Particles Trapping by ACEO on Zipper Electrodes 1000µm with Interelectrode Gap Variations

previous work by Mohtar[10]. It is observed that there are fluids motion moving perpendicular to the electrodes through the interelectrode gap and form a vortex at electrode edge. Table 1 and Table 2 show the particles trapping by the electrodes under the influence of ACEO. The arrow shows where the particle accumulated.

Table 1 and Table 2 show the trap particles under the influence of ACEO Zipper electrodes supplied with AC electric field. The electrodes acted by focussing all particles from across a large area towards a central spot of its' electrode pads. It is shown that the particles trapped at the electrode pad for electrode with 100µm and 150µm interelectrode gap for both electrode with 500µm and 1000µm diameter electrode pad. For larger interelectrode gaps the behaviour of trapped particles changes from forming a ring shape on the electrode pad to trap in the vortices. This is anticipated because of the forces from the vortices is weaker due to the size of interelectrode gap and insufficient to send the particles to the centre of the electrode.

4. CONCLUSION

It has been observed and shown that Zipper electrodes with smaller interelectrode gaps manage to accumulate and collect particles at the center of electrode pads whilst Zipper electrode with larger interelectrode gaps only manage to form ring shape accumulation at the adjacent to electrode edge. This establish the fact that Zipper electrodes with smaller interelectrode gaps under the influence of ACEO has a better manipulation capability for particles in suspended medium.

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