Effect of Conductivity and Viscosity in the Velocity Characteristics of a fluid flow induced by nonuniform AC electric field in electrolytes on microelectrodes

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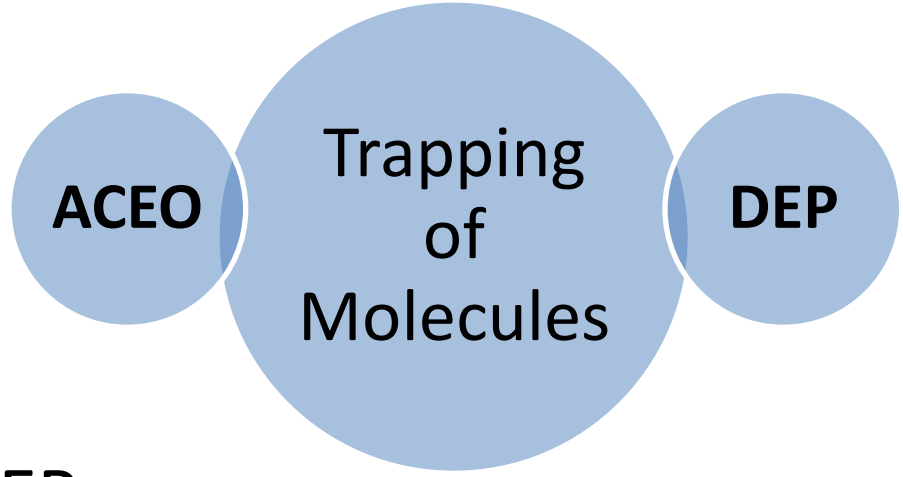
THE BIG PICTURE

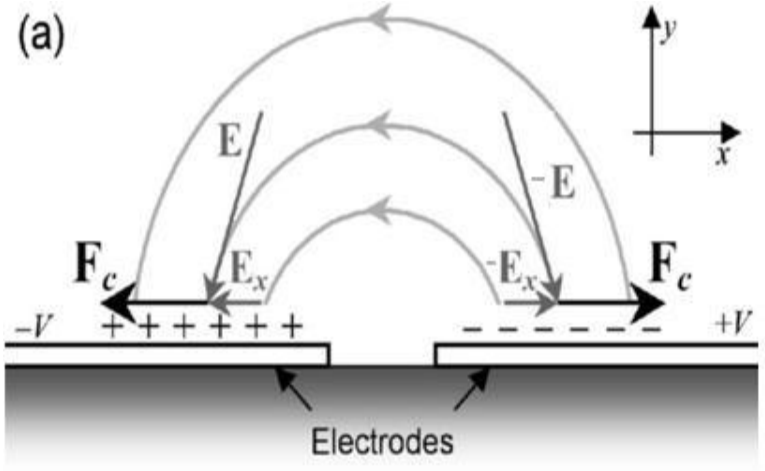
Aim: Study the ***electrical properties*** of biomolecules ***suspended in solution*** on application of electric field

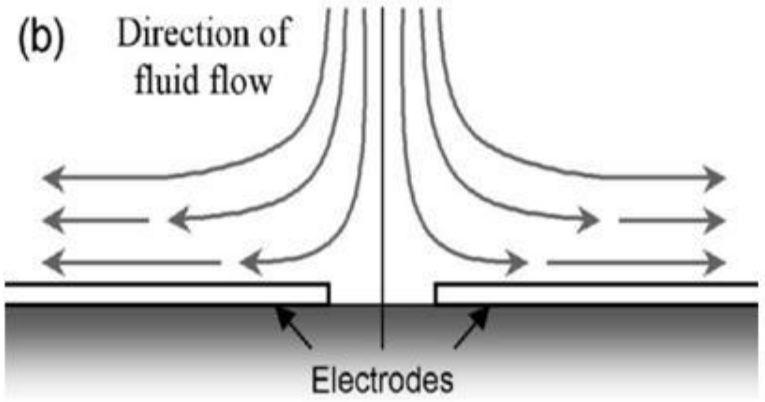


ACEO and DEP:

- opposite in nature
- frequency dependent.

ELECTRO-OSMOTIC FLOW





Caused by Coulomb force on net mobile charge

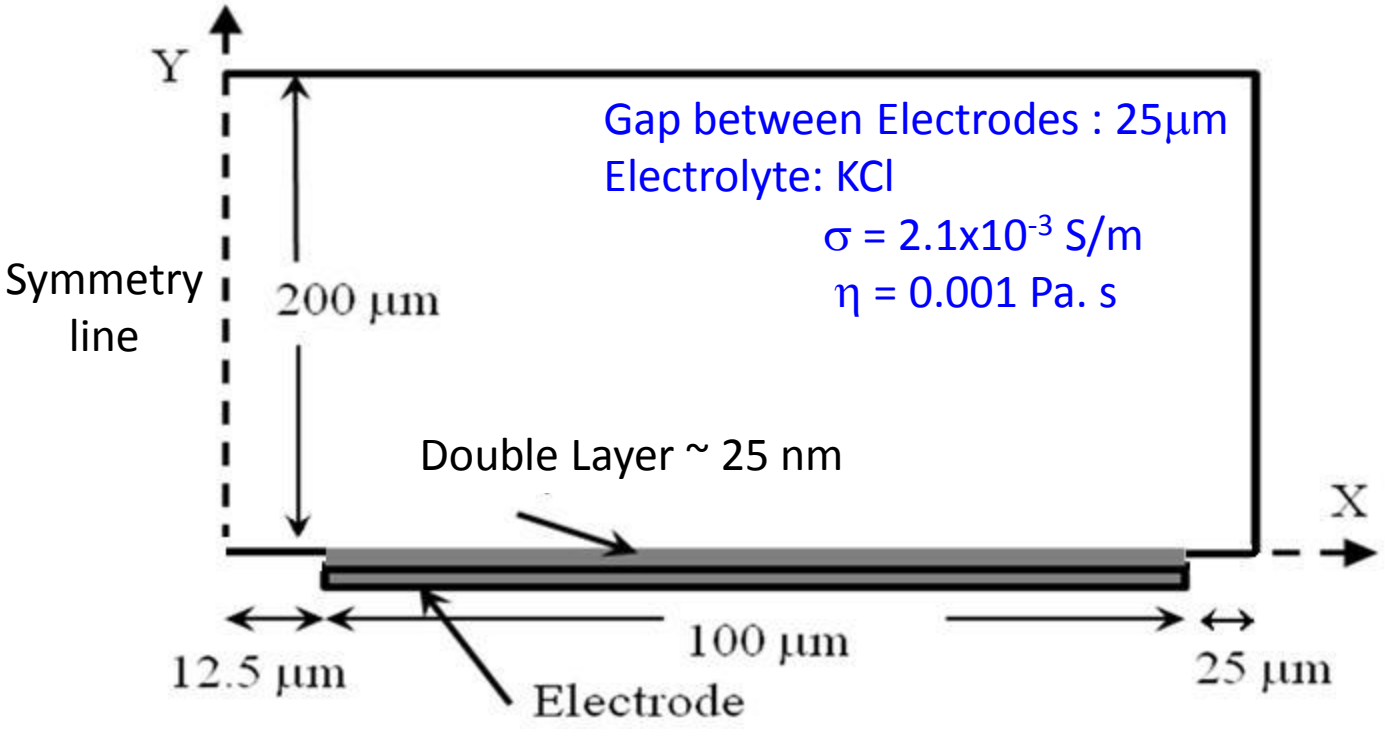
In the process, it creates an electric double layer

Fluid is pushed away from the gap between the electrodes towards the electrode surfaces

[1] Green et al, Physical Review E,2002

NUMERICAL MODEL

Coplanar parallel electrode (CPE) geometry was used and the phenomena of AC electro-osmosis was simulated using **COMSOL Multiphysics Software**.



SIMULATION DETAILS

- Frequency of the applied electric potential :
  1Hz to 80kHz

- Electric field was computed using Electric currents interface

- Fluid Flow was computed using the Creeping flow interface which makes use of the time dependent Navier Stokes equation

- The Debye layer was modeled as a capacitive boundary condition on the electrode surface

SIMULATION DETAILS

- The electro osmotic velocity was computed using the inbuilt equation(Helmholtz Smoluchowski formula)

- System response studied for :

  300 sinusoidal cycles

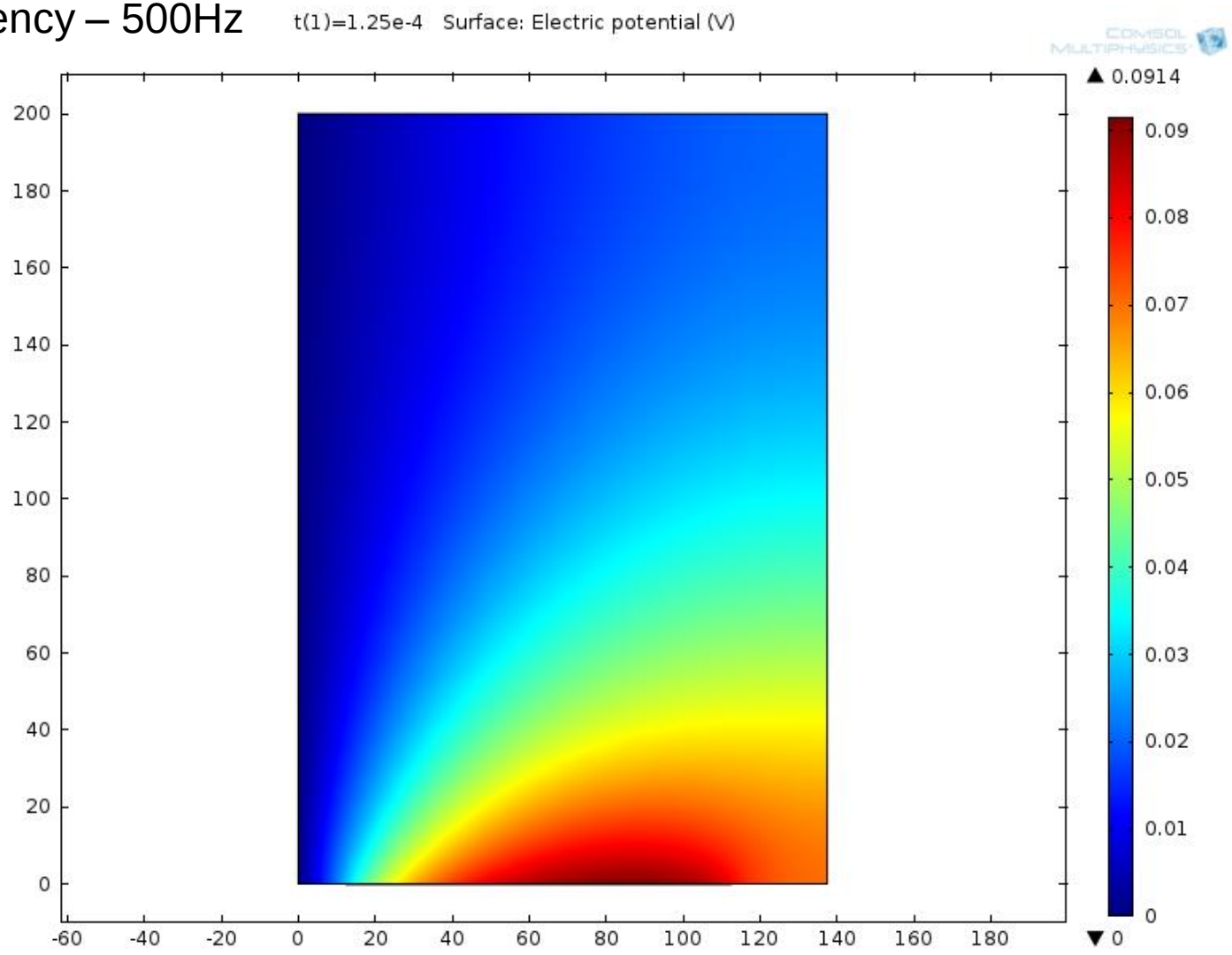
- Symmetry of electrodes:

  Only the right half electrode geometry simulated

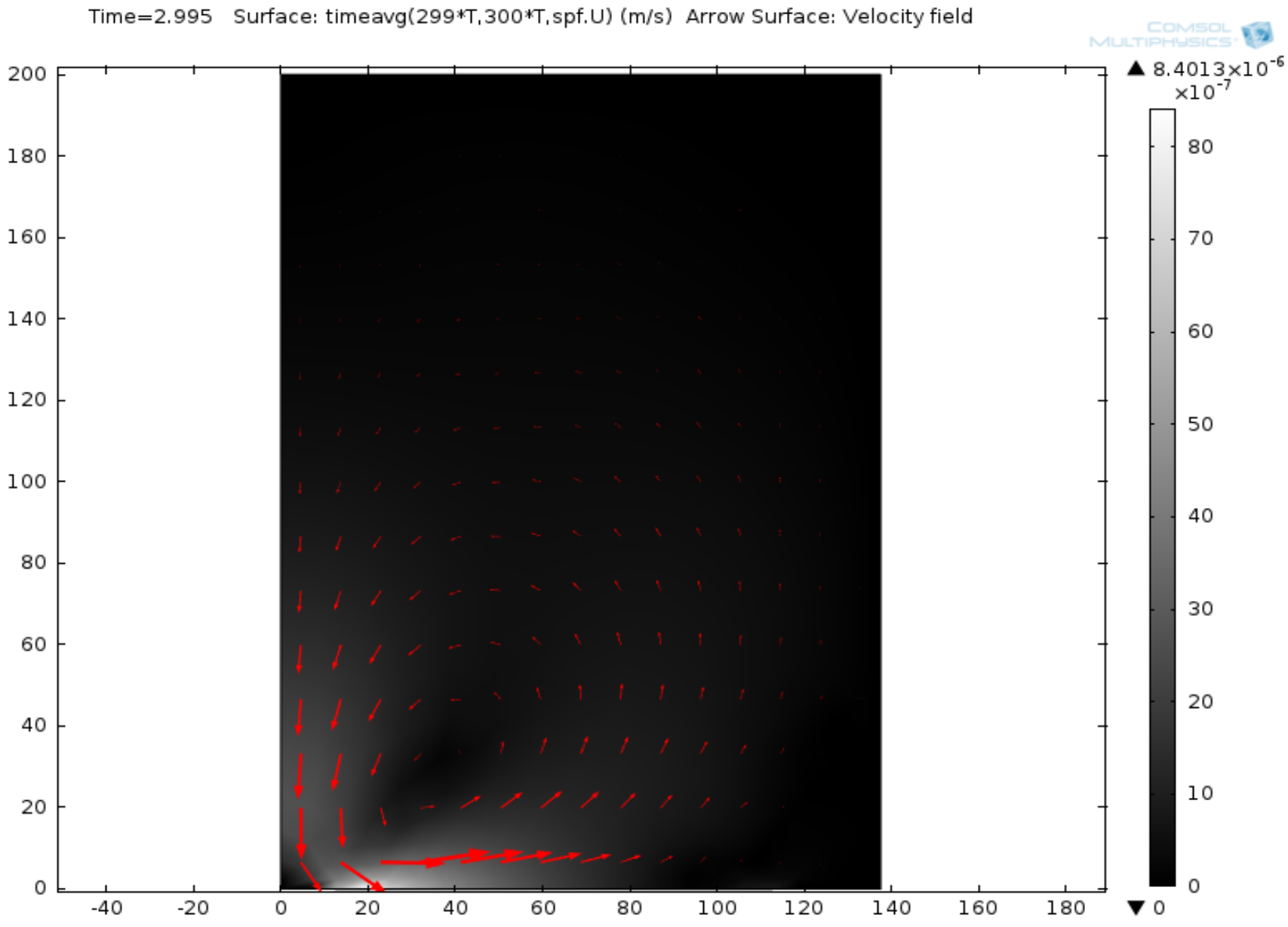
- The time averaged velocity was computed at various distances along the electrode surface

ELECTRIC POTENTIAL

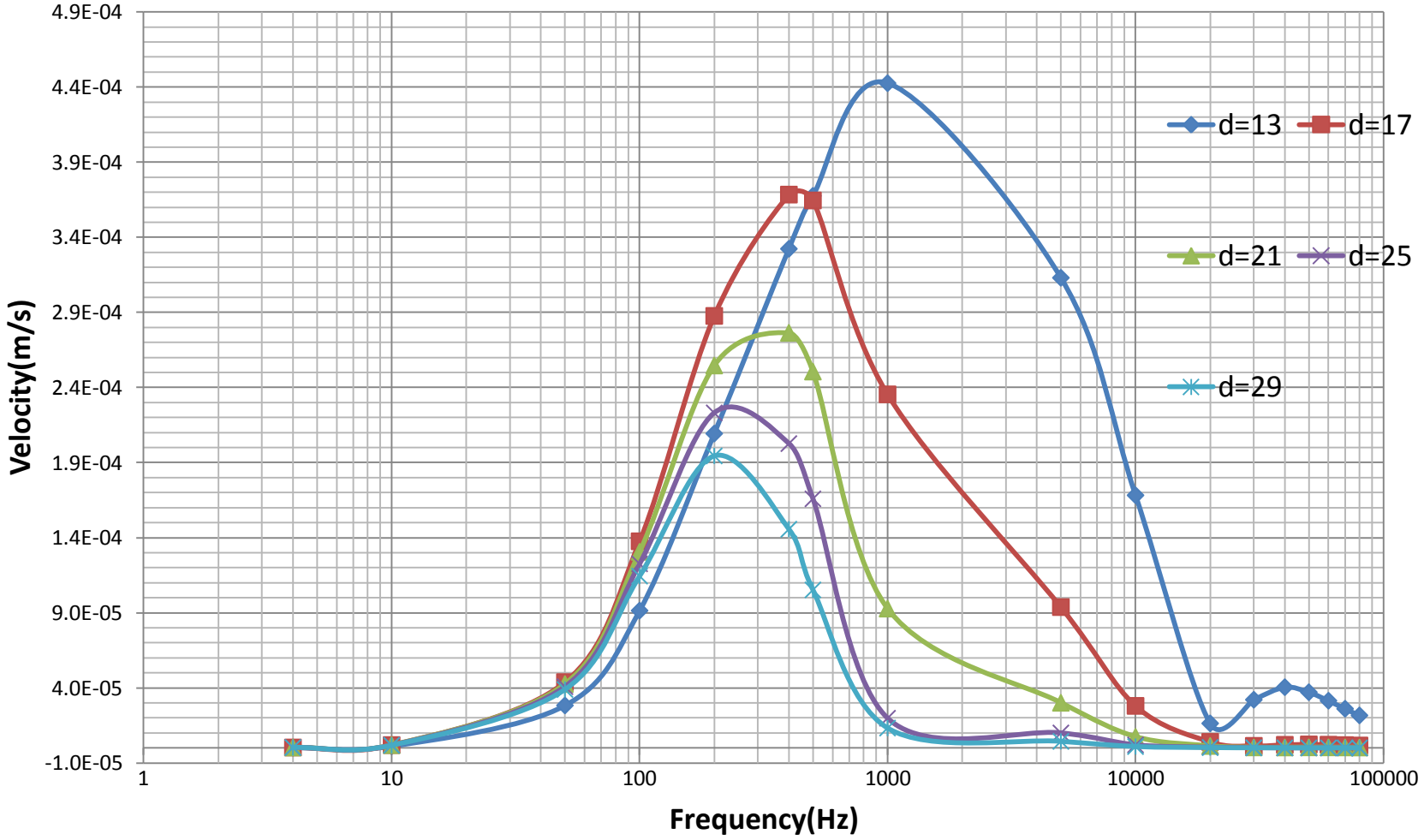
Frequency – 500Hz



FLUID FLOW PATTERN

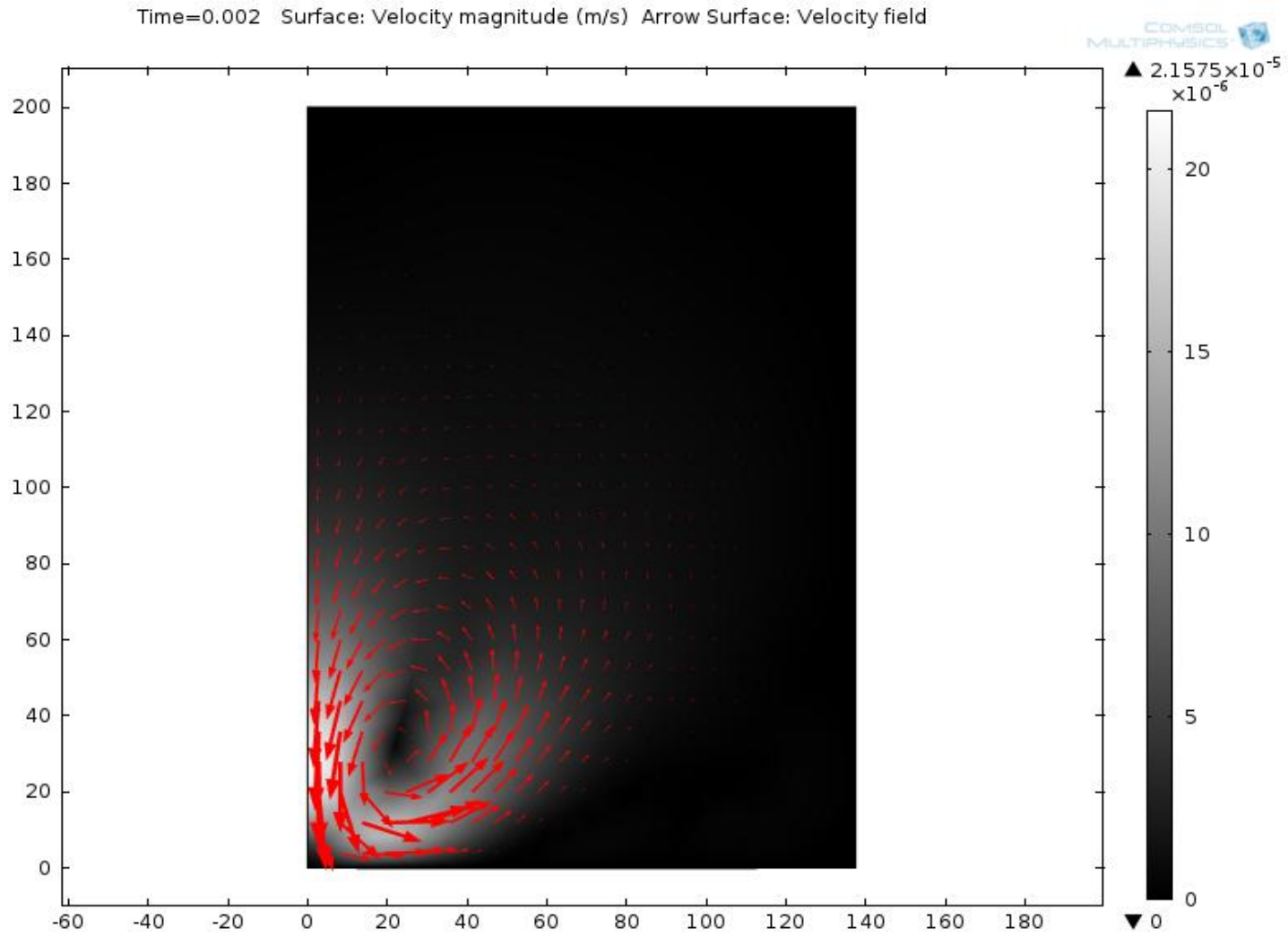


VELOCITY MAGNITUDE AT DIFFERENT DISTANCES ON ELECTRODE SURFACE



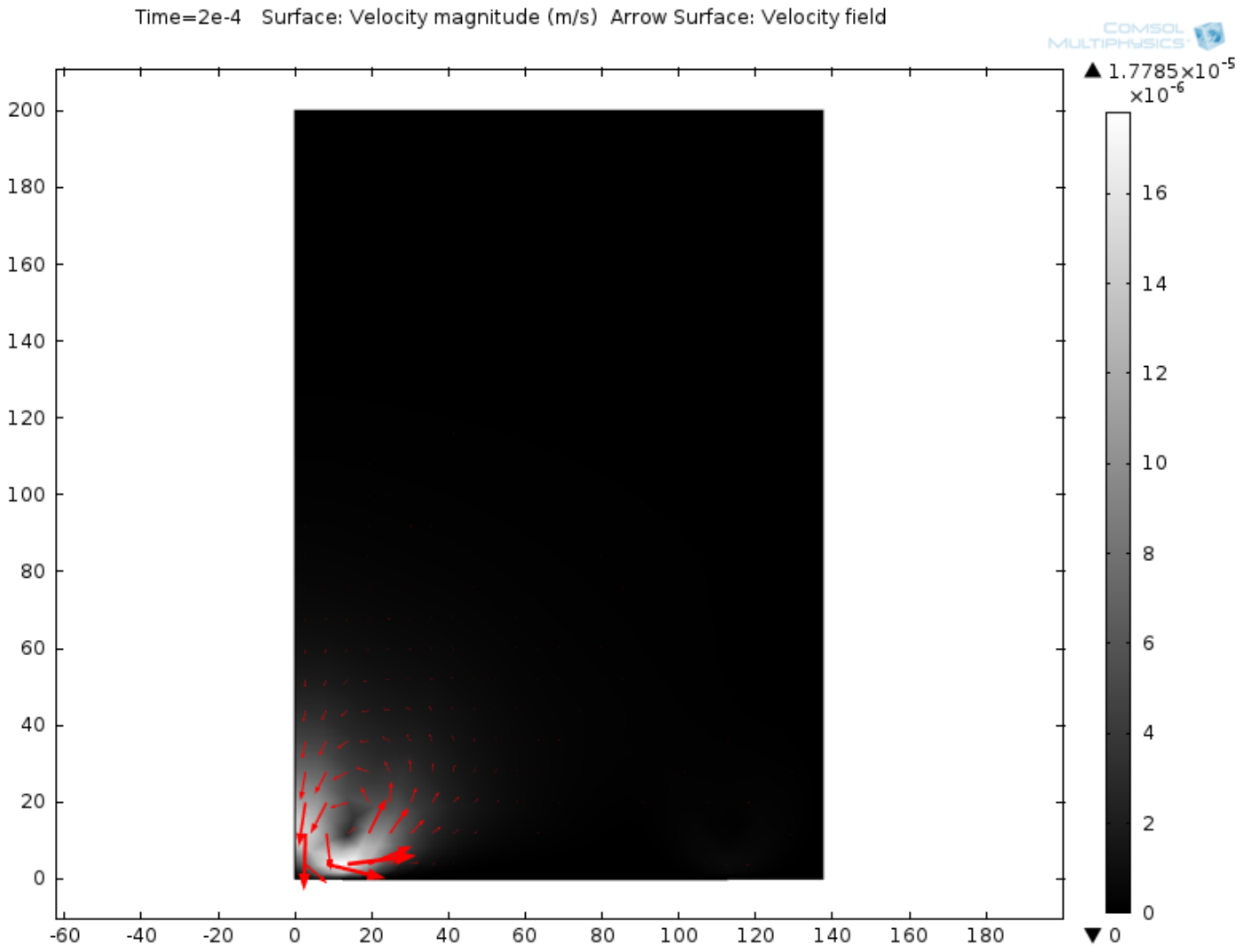
FLUID FLOW AT DIFFERENT FREQUENCIES

Frequency – 1000Hz



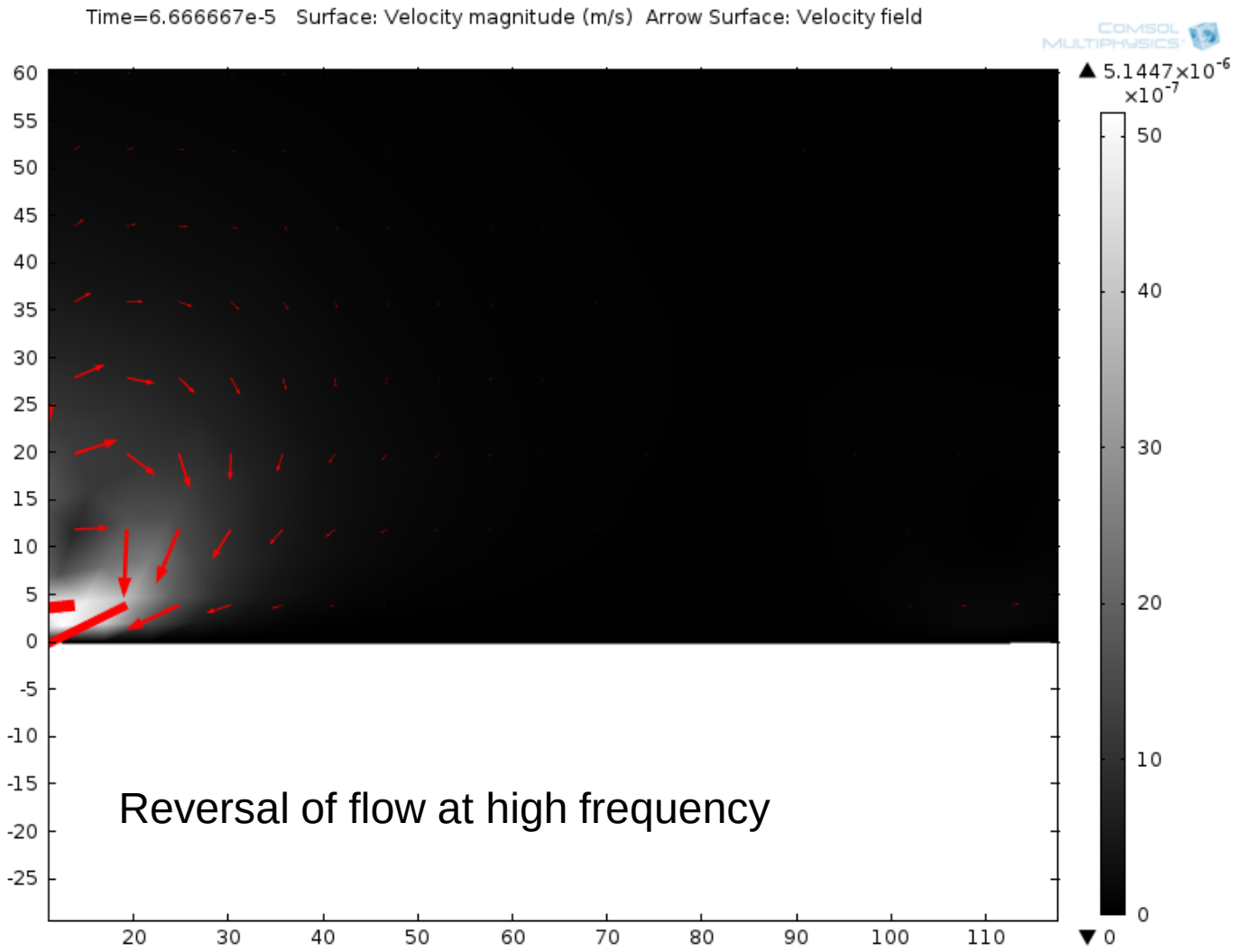
FLUID FLOW AT DIFFERENT FREQUENCIES

Frequency – 10000Hz



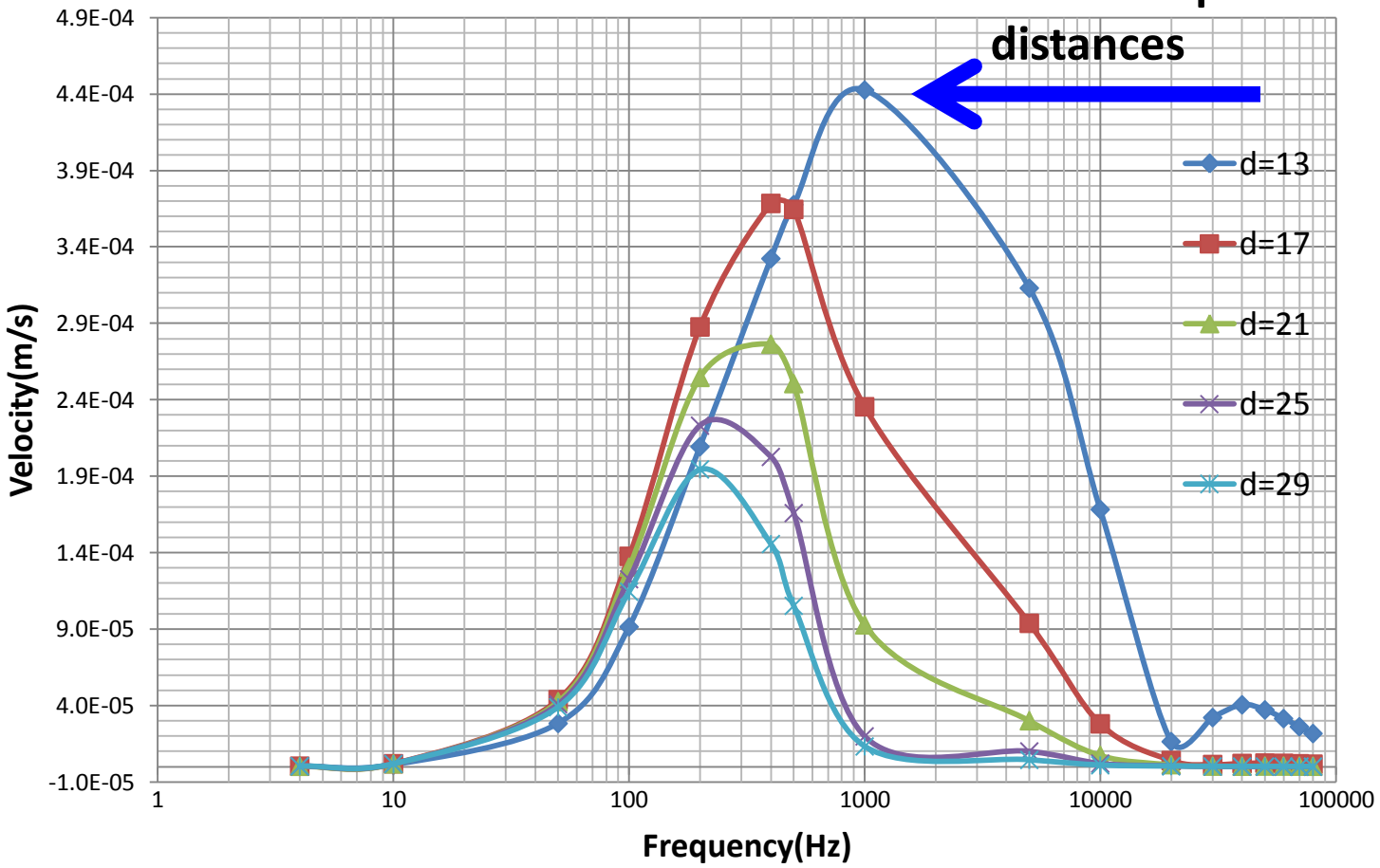
FLUID FLOW AT DIFFERENT FREQUENCIES

Frequency – 30000Hz



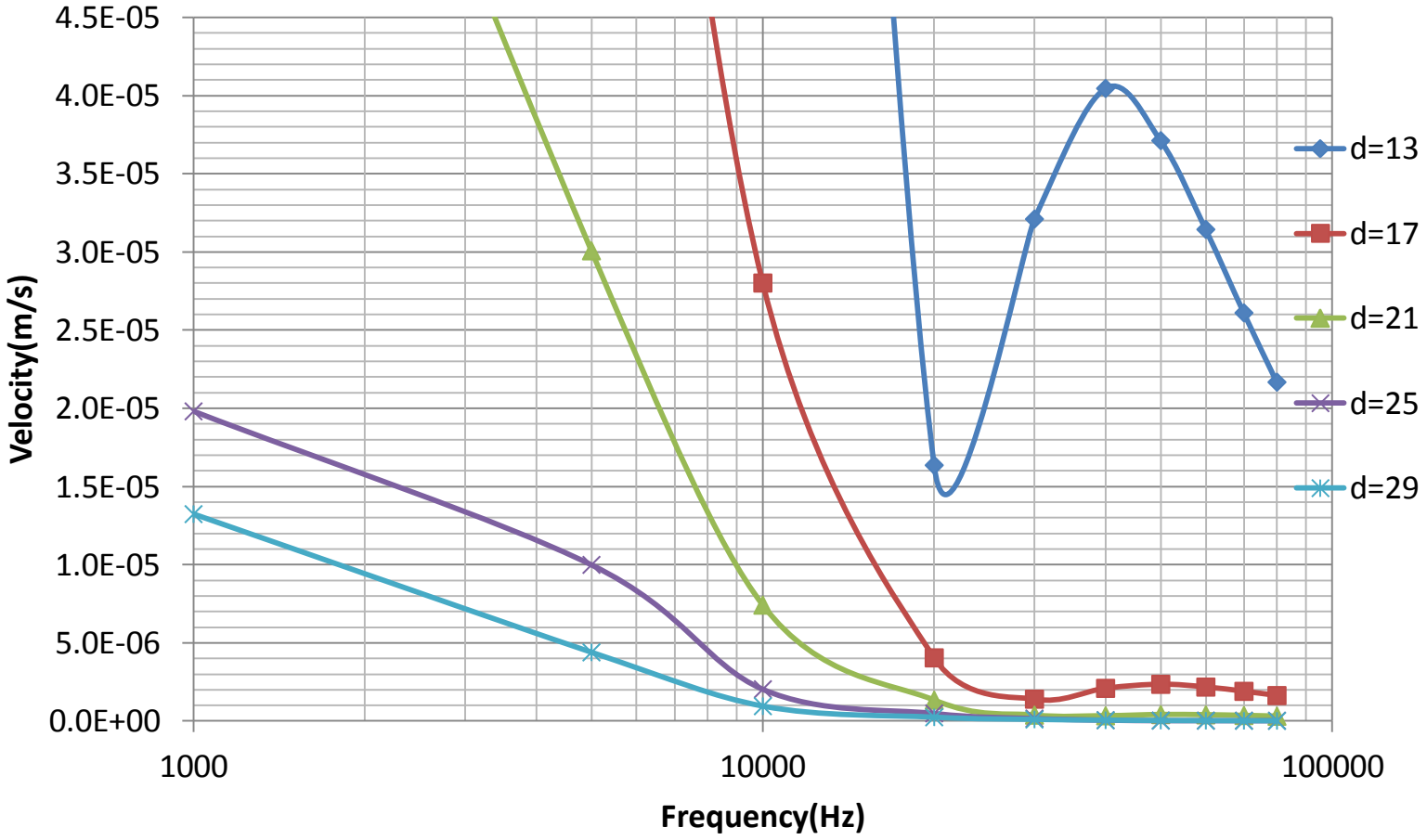
OBSERVATIONS FROM PLOT

The velocity maximum shift to lower frequencies for larger distances



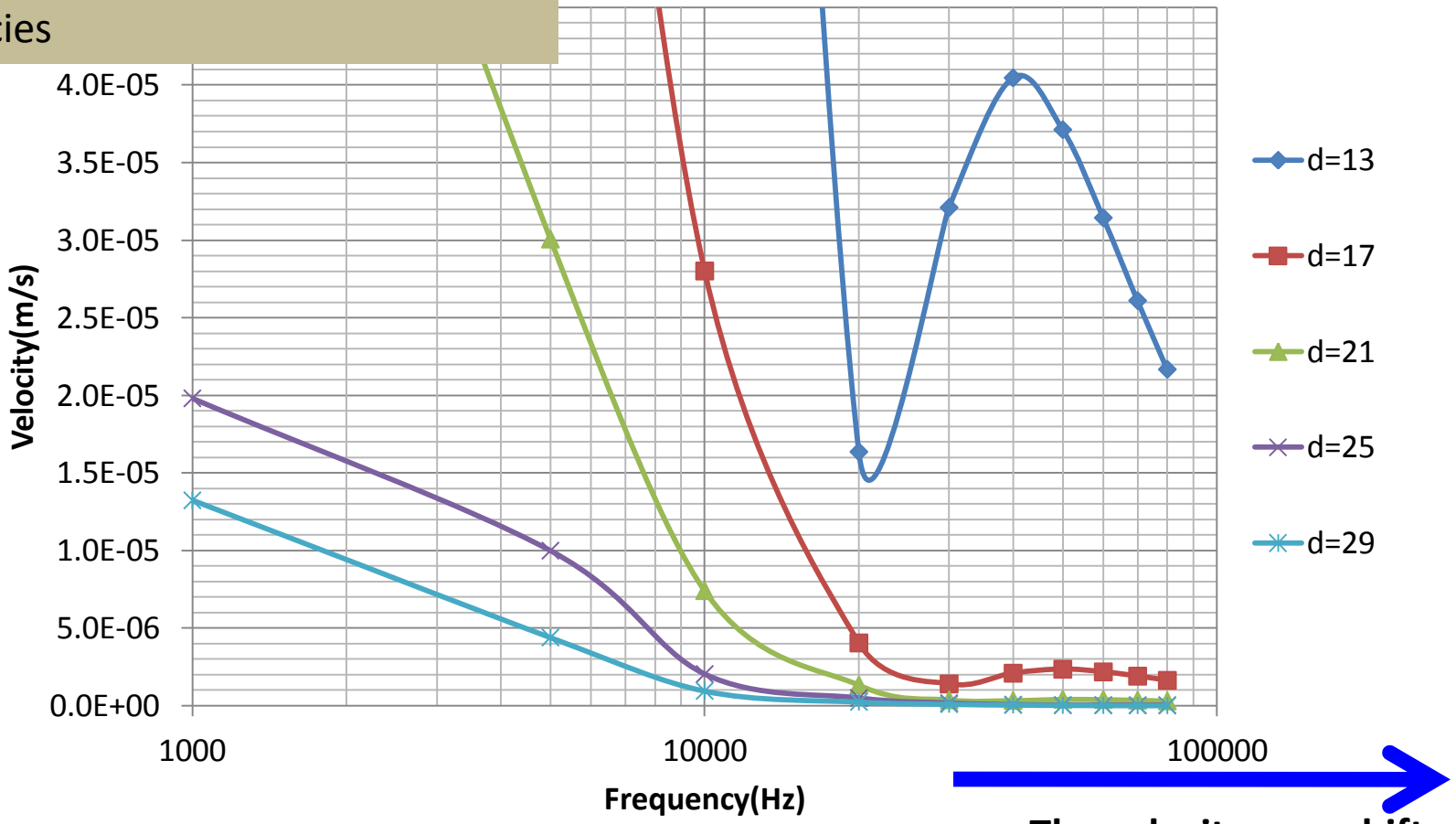
d: Distance from the edge of electrode

SECOND PEAK


4.5E-05
4.0E-05
3.5E-05
3.0E-05
2.5E-05
2.0E-05
1.5E-05
1.0E-05
5.0E-06
0.0E+00
Velocity(m/s)
1000
10000
100000
Frequency(Hz)
d=13
d=17
d=21
d=25
d=29

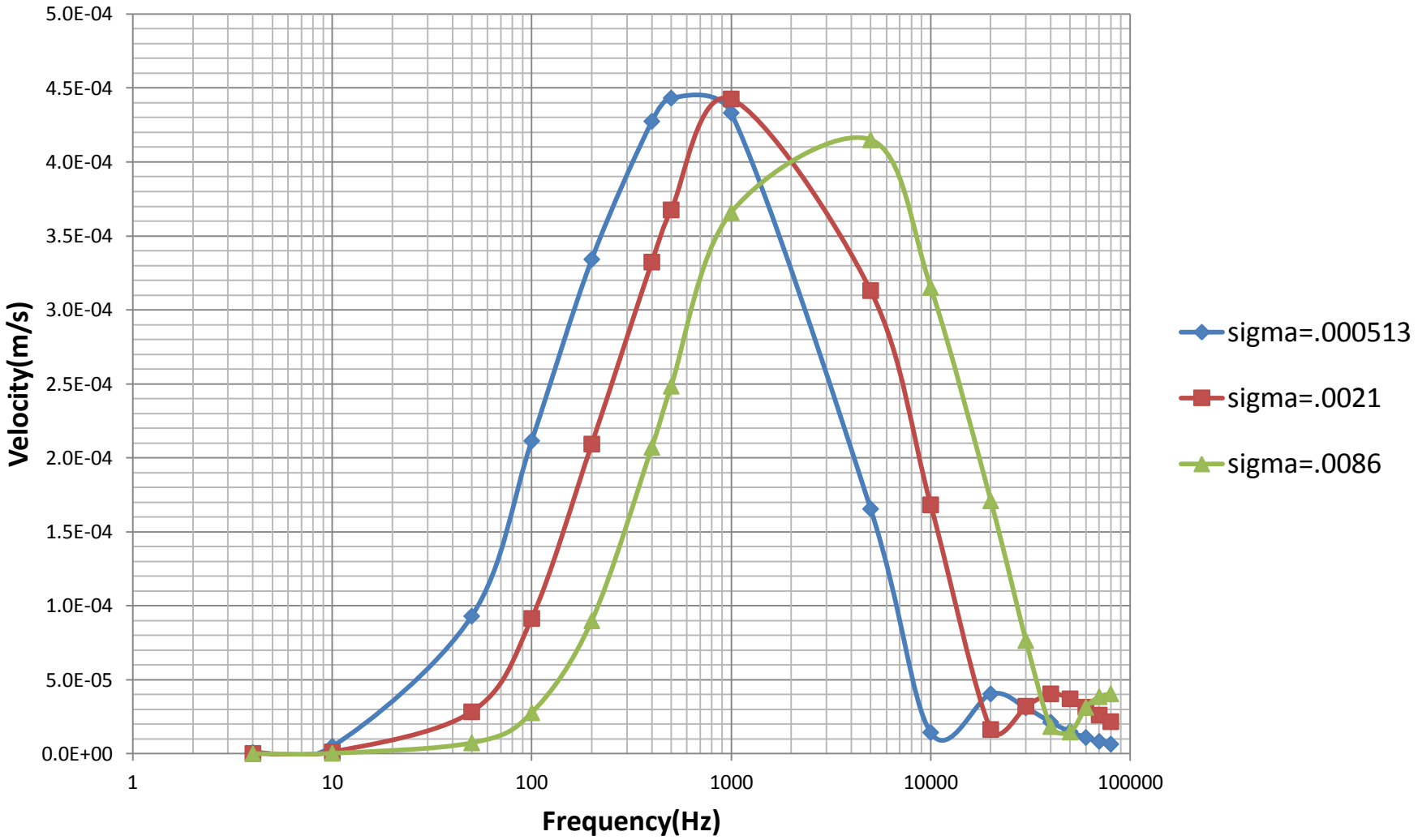
OBSERVATION FROM PLOT

Another peak smaller by one order of magnitude was observed at higher frequencies

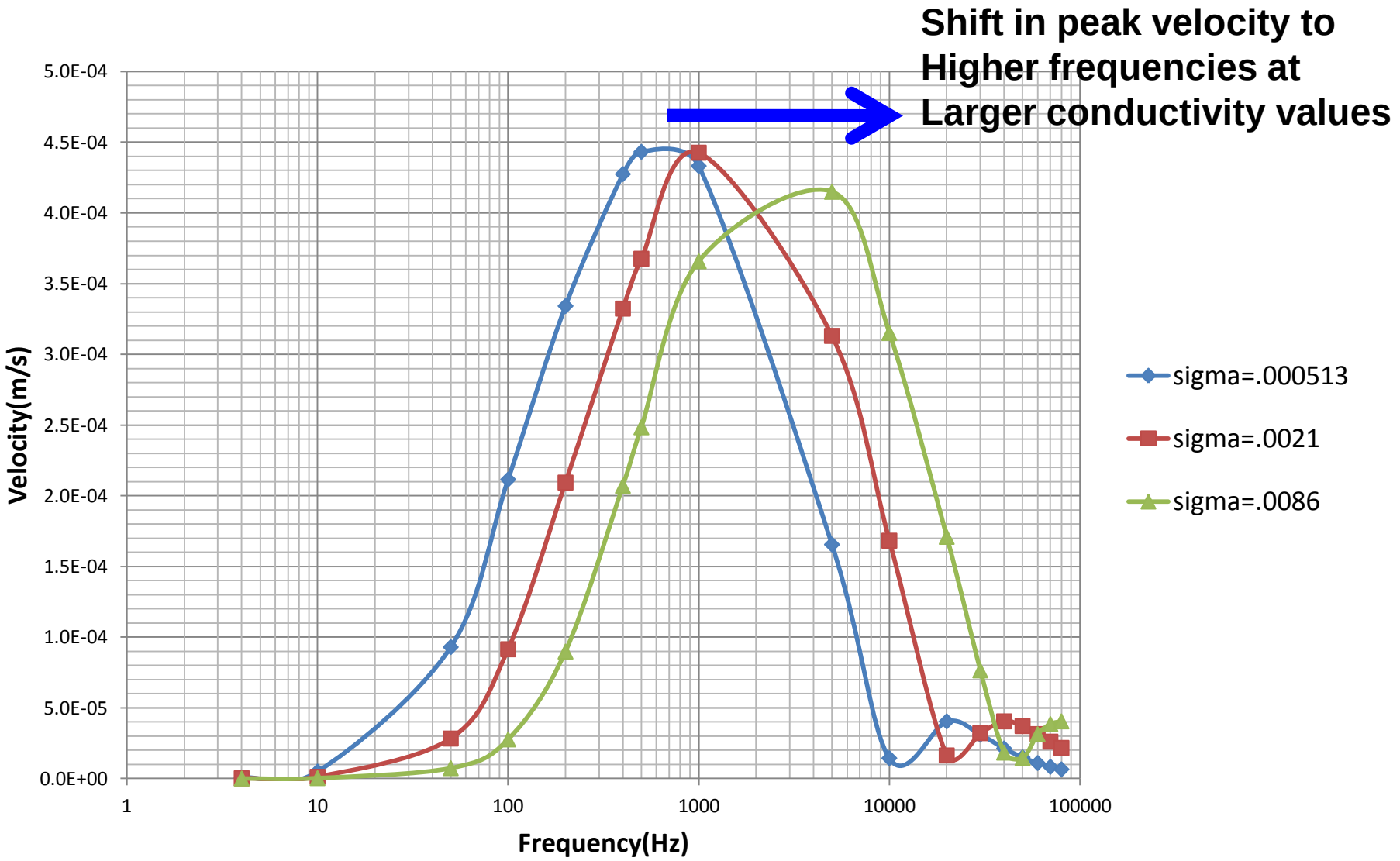


The velocity max shift to higher frequencies for larger distances

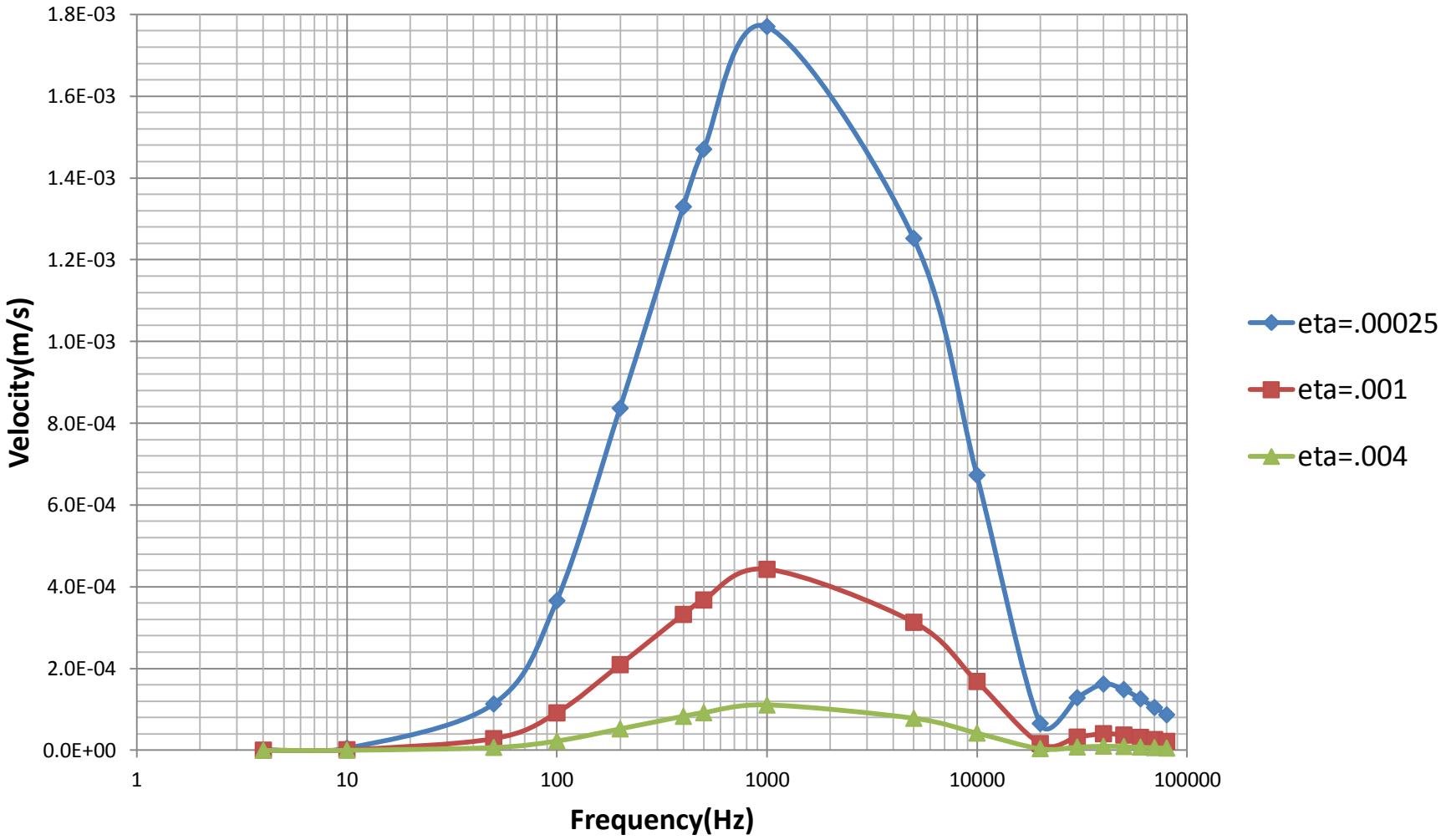
VARIATION IN CONDUCTIVITY



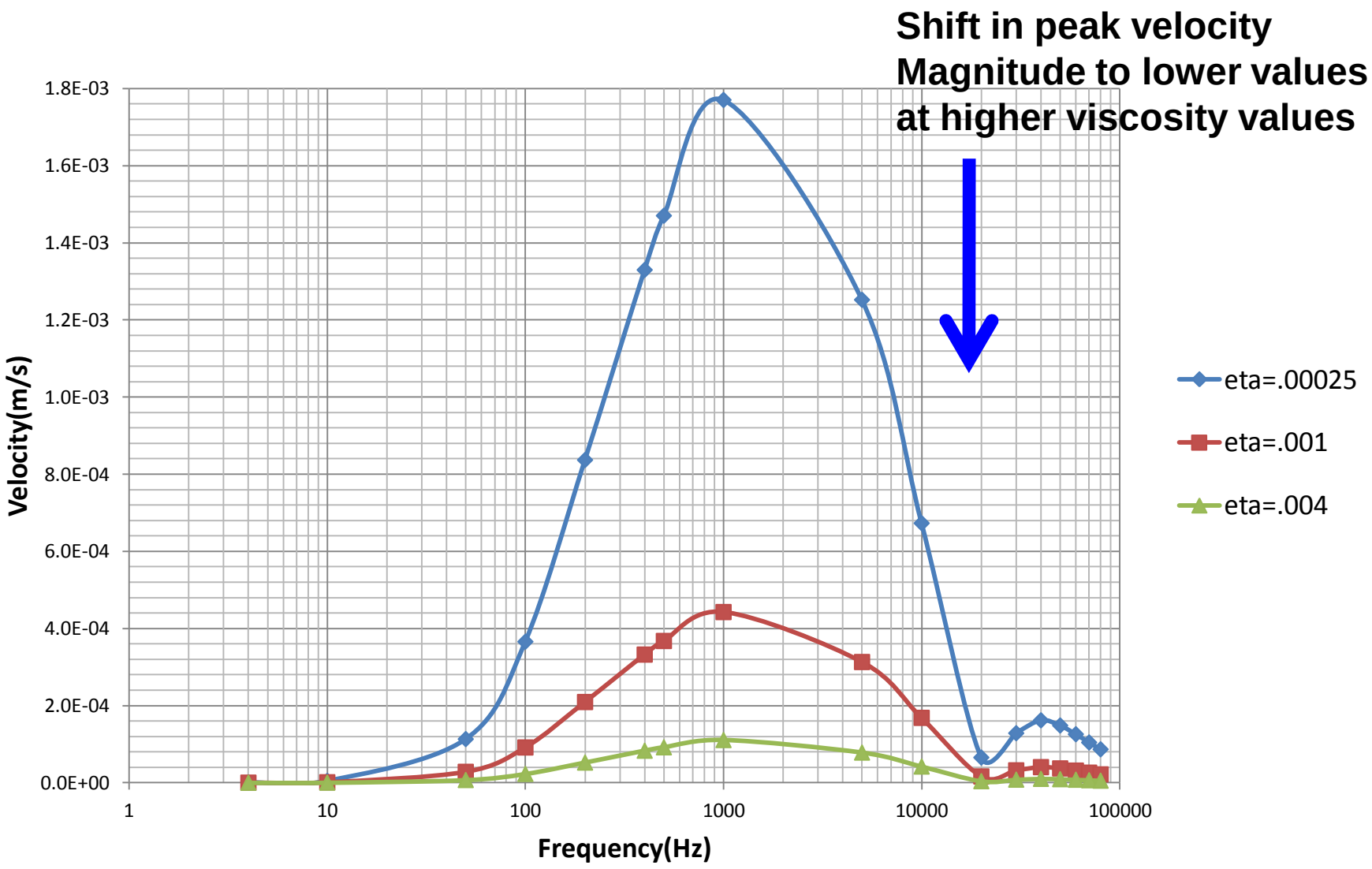
OBSERVATION FROM PLOT



VARIATION IN VISCOSITY



OBSERVATION FROM PLOT



SUMMARY

- Observation of a ***weak second maxima*** in Velocity versus Frequency plots indicative of complete reversal of fluid flow

- Examination of the ***distance dependence*** of the two peaks.

- Observation of effect of conductivity and viscosity on electro osmotic velocity as a function of frequency

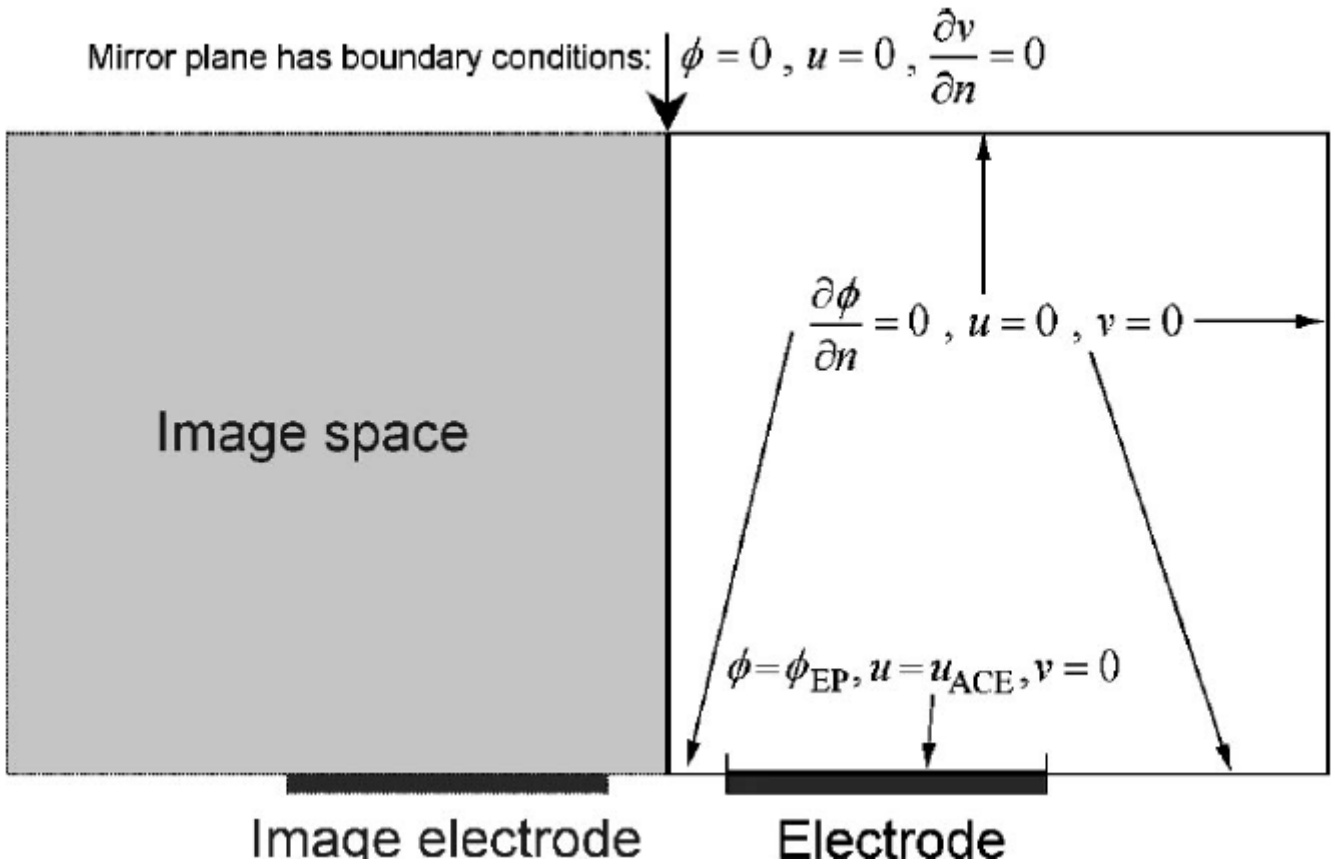
CONCLUSION

The conductivity, viscosity of the electroylte and frequency of applied electric field affect the electro osmotic velocity.

- **The direction of flow can be tuned by the frequency of applied electric field**
- **The magnitude of the peak velocity can be tuned by the viscosity**
- **The position of the peak velocity as a function of frequency can be tuned by the conductivity**

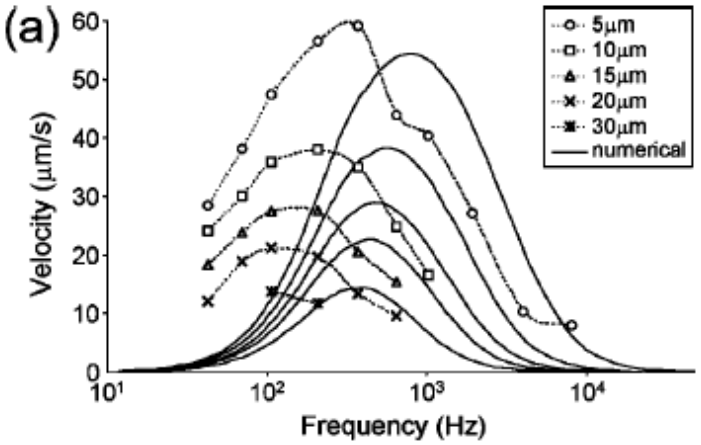
THANK YOU

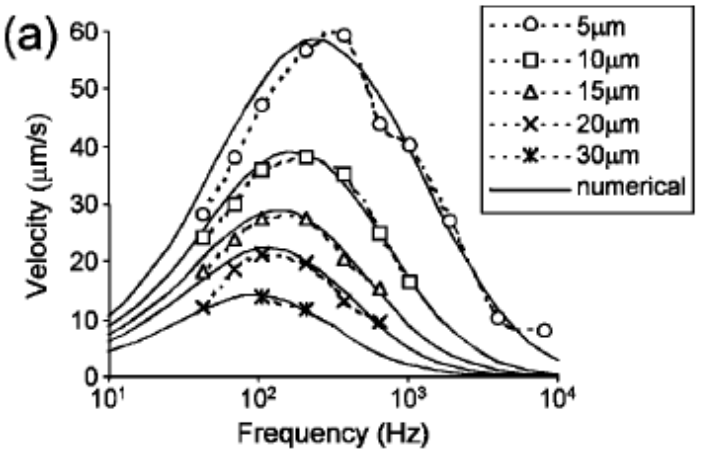
BOUNDARY CONDITIONS

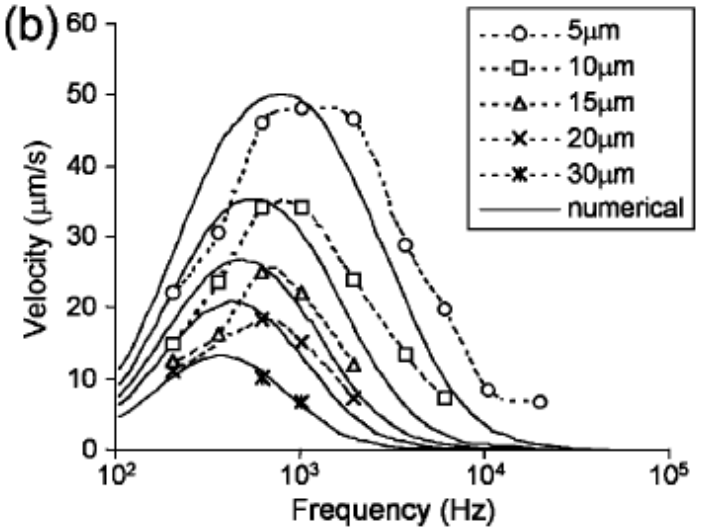


ϕ: Potential
u: Normal velocity
v: Tangential vel
u_{ACE} :Electro-osmotic vel

COMPARISION







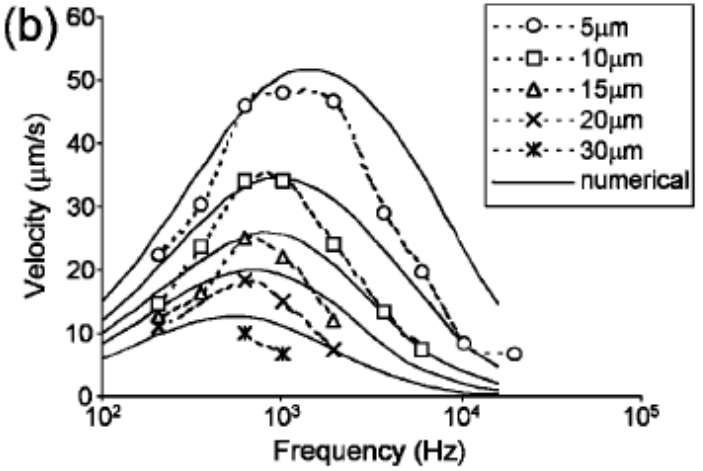


FIG. 10. Comparison of the calculated horizontal electro-

[1] Green et al, Physical Review E,2002