**Introduction:** Dielectrophoresis (DEP) has been increasingly regarded as an important technique to manipulate small particles such as biological cells in bioengineering applications. Modeling plays a significant role in advancing the DEP field as it helps to explain experimental observations and provides guidance in experiment design. Not being able to coherently explain various phenomena with the conventional DEP theory, we realized that an in-depth elucidation of how particles interact with each other is necessary but missing in the current knowledge of DEP. We propose a new way to simulate movement of multiple particles under DEP and implement it computationally in COMSOL 4.4 using Mathematical particle tracing module. The modeling results show very good agreement with experimental observations including the formation of pearl chains and antenna-like structures as well as capturing cells in flow.

**Computational Methods:** In particle tracing module, forces exerted on a single particle by environment and particle-particle interaction have to be well defined. A particle experiences following forces (not including interaction):

1. **DEP force:**
   \[ F = (\vec{P} \cdot \nabla) \vec{E} \]  
   \[ \text{(1)} \]
2. **Gravitational force:**
   \[ F_g = \text{vol} \cdot \rho_{\text{particle}} \cdot g \]  
   \[ \text{(2)} \]
3. **Buoyancy force:**
   \[ F_b = \text{vol} \cdot \rho_{\text{medium}} \cdot g \]  
   \[ \text{(3)} \]
4. **Hydrodynamic force:**
   \[ F_h = 6\pi \eta rv \]  
   \[ \text{(4)} \]
5. **Upward normal force:**
   \[ F_n = k(d + r - qy) - (qy < (d + r)) \]  
   \[ \text{(5)} \]

A particle is also subject to particle-particle interaction:

6. **Dipole interaction:**
   \[ E_{\text{particle}} = \frac{1}{4\pi\varepsilon_0} (3(\vec{P} \cdot \vec{R})\vec{R} - \vec{P}) \]  
   \[ \text{(6)} \]

7. **Normal force:**
   \[ F_y = k(q\alpha_x - q\alpha_\beta)(\exp((2r - d_\beta)/l) - 1) \cdot (2r >= d_\beta) \]  
   \[ \alpha = x, y, z \]  
   \[ \text{(7)} \]

**Results:** Simulation results are compared with experimental observations. Three cases are examined: pearl chain structure, antenna-like structure and capturing of cells in flow.

1. **Pearl chain structure**

2. **Antenna-like structure**

3. **Cell capturing in flow**

**Conclusions:** Alignment and movement of multiple particles under DEP are simulated using particle tracing module in COMSOL 4.4 with particle-particle interaction taken into consideration. All our simulation results exhibit very good agreement with experimental observations, confirming the validity of our new approach to advance the DEP theory.

**References:**