Stochastic Electrotransport Device for tissue clearing application.

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Background

- Traditional Method (Diffusion) to process biological tissue (Clearing) take too long to process. Electrophoresis is technique that is used to process biological tissue. It's fastest method, however it would damage the tissue. Stochastic Electro-transport is as fast as the Electrophoresis technique but guarantee low tissue damage.
- One of the applications of the electro-transport device is tissues clearing. We are using the detergent Sodium Dodecyl Sulfate to remove light-scattering liquids from the tissue. By placing the tissue between the rotational electric field, we can clear tissues quite rapidly, without harming the tissue.
- However, the price of the device is expensive and the popularity of the device is low. Therefore, it's difficult for researchers and students to acquire and conduct their own research. It's also very limited in size and hard to control intensity of the electric field.

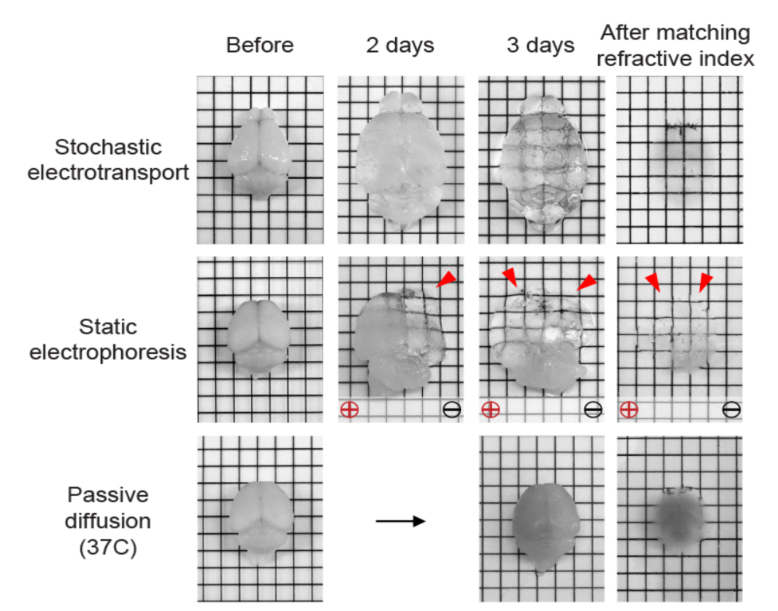

Figure 1. Image to compares the result of stochastic Electrotransport to electrophoresis (static electric field) and diffusion (no electric field) [1].

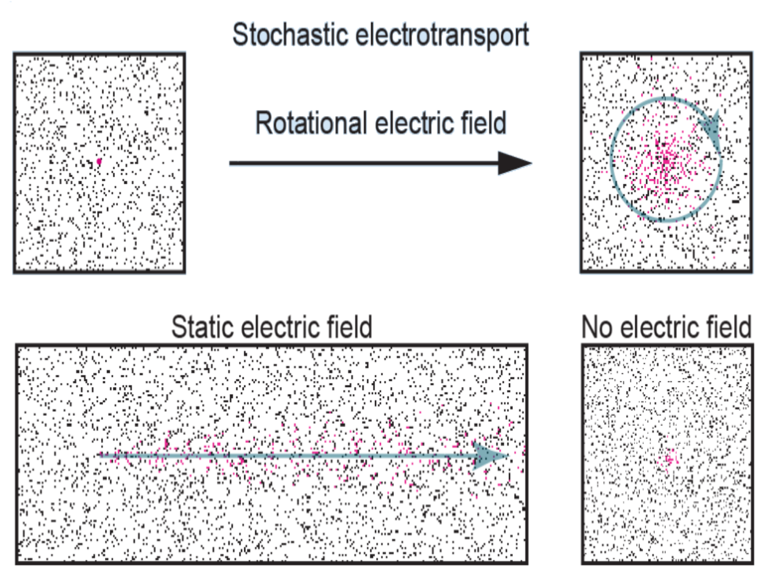

Figure 2. Image to compares stochastic Electrotransport to electrophoresis (static electric field) and diffusion (no electric field) [1].

Objective

- Main objective of the application is placing the tissue between the rotational electric field. We are planning to generate approximately E = 2000V/m – 2500V/m on each set of electrodes. The distance and voltage between each set are depend on the geometry of the device/chamber. The rotation electric field is generated by constantly switching the set of electrodes by using microcontroller.
- Construct a device using 3D printed material to contain and seal the electrode solution and clearing solution. Also control the flow of the solution in the device. Design and test the 3D material to construct to device as well as electrode solution to dissipate the heat from the electrodes. It's crucial to maintain the temperature of the device/electrodes during the clearing application. If the temperature went too high, it would destroy the tissue as well as the device.
- Determine to optimum concentration of clearing reagent (Boric acid, Lithium Hydroxide, Spectra/Por 1 , Sodium Dodecyl Sulfate…) for the best result.

Future Plan

- Writing an application on C# that allows us to interface between the control board and the computer to monitor the clearing process.
- Improve the efficiency of the clearing application.
- Further develop the device that allows us to perform the tissue labeling application and other applications as well.
- Design and control the flow of electrode and clearing reagent inside the chamber and improve heat dissipating on the electrodes during the clearing application.

Results

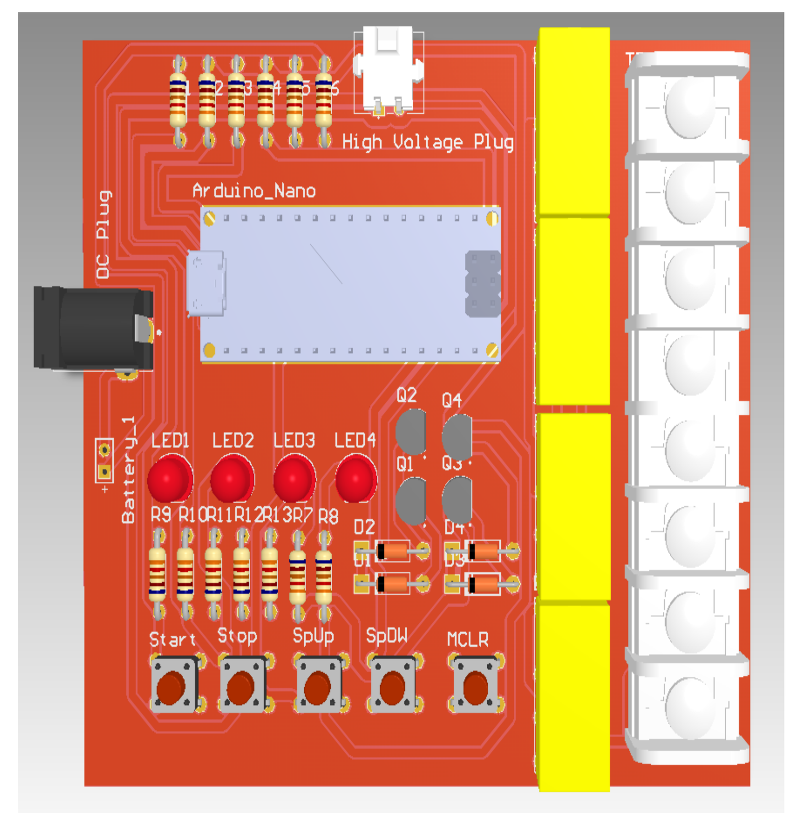

Figure 3. PCB of the control system

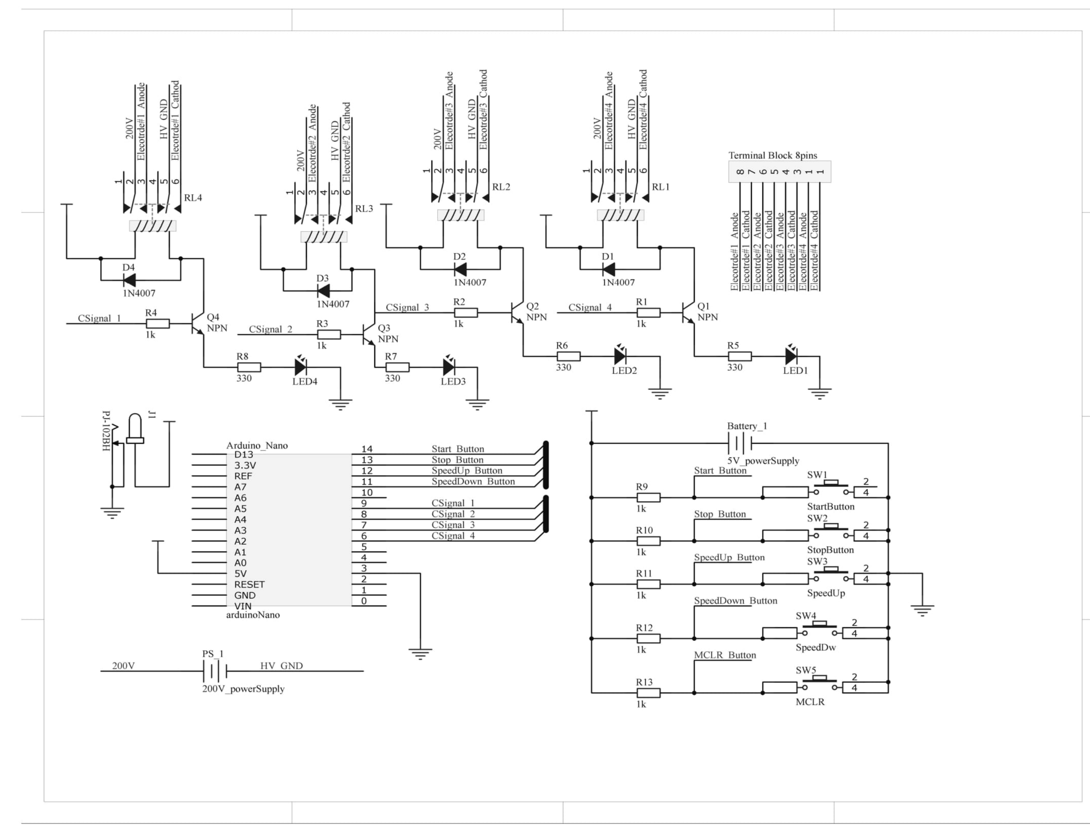

Figure 4. Schematic diagram of control system

Operation: The control board allows us to manually/automatically control the operating of the clearing application. The operation of the control board is controlled by a microcontroller. The microcontroller will control the switching interval between each the set of electrodes to maintain an evenly rotation electric field. Due to the flexibility of the microcontroller/Arduino Nano, it will allow us to further upgrade the system by integrating some other features into it such as temperature control, flow rate control, etc.

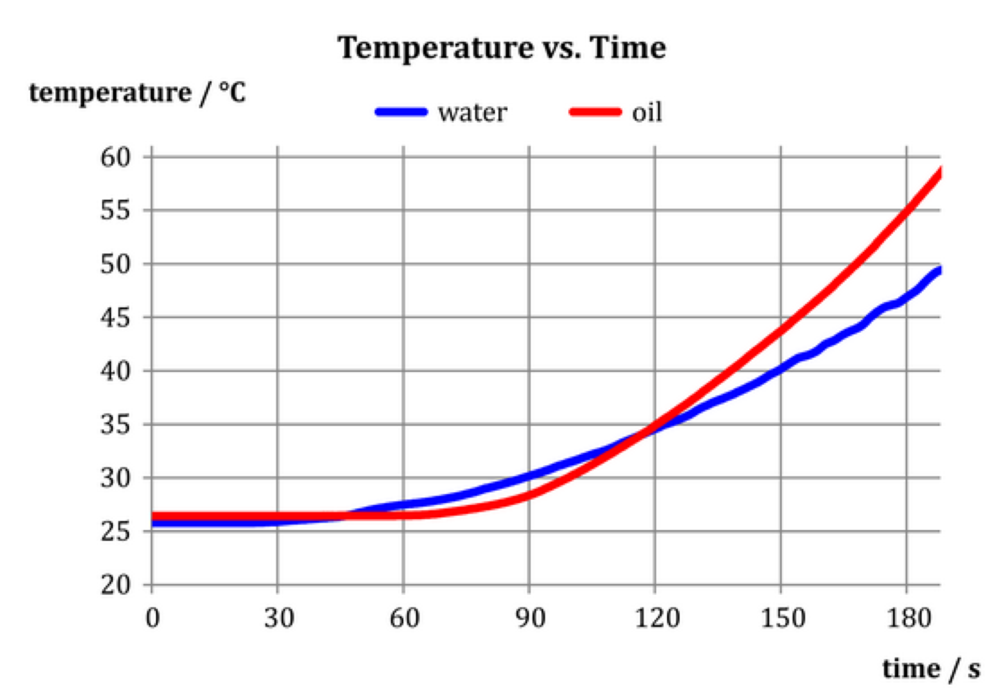

Figure 5. Heat dissipate/transfer efficiency between oil and pure water

Based on our test between pure water and high insulating oil, both are non-electricity conductive, pure water allow us to dissipate/transfer heat better than oil as the graph show above.

Type	Tensile Strength	Toughness	Heat Deflection Temperature
ABS	33 MPa (4700 psi)	106 J/m	204 °F
Nylon	48 MPa (7000 psi)	200 J/m	207 °F
PLA	50 MPa (7250 psi)	80 J/m	150 °F
PC	68 MPa (9800 psi)	53 J/m	280 °F
PEI	81 MPa (11735 psi)	41 J/m	415 °F

Table 1. Testing result of 3d material used to construct the device [3]

Voltage (V)	Current (A)	Watt (W)	Joule (J)	Aluminum Specific Heat (J/g °C)	Temperature (°C)
100	0.2	20	18000	0.897	200.67
150	0.2	30	27000	0.897	301.00
200	0.2	40	36000	0.897	401.34

Table 2. Calculation of heat generated on each set of aluminum electrodes during the clearing application.
Note: Calculation Condition: Operation time 30 (min), Mass of the electrode: 100(g). Assume power lost to surroundings 50% of heat gain. Equation: $Q = m \times Cp \times \Delta T$, $\Delta T = Q \div m \div Cp$.

As the result, the electrodes might get really hot after a period of time. Without proper cooling solution, the electrodes and the chamber might get overheat., which would destroy the device as well as the tissues.

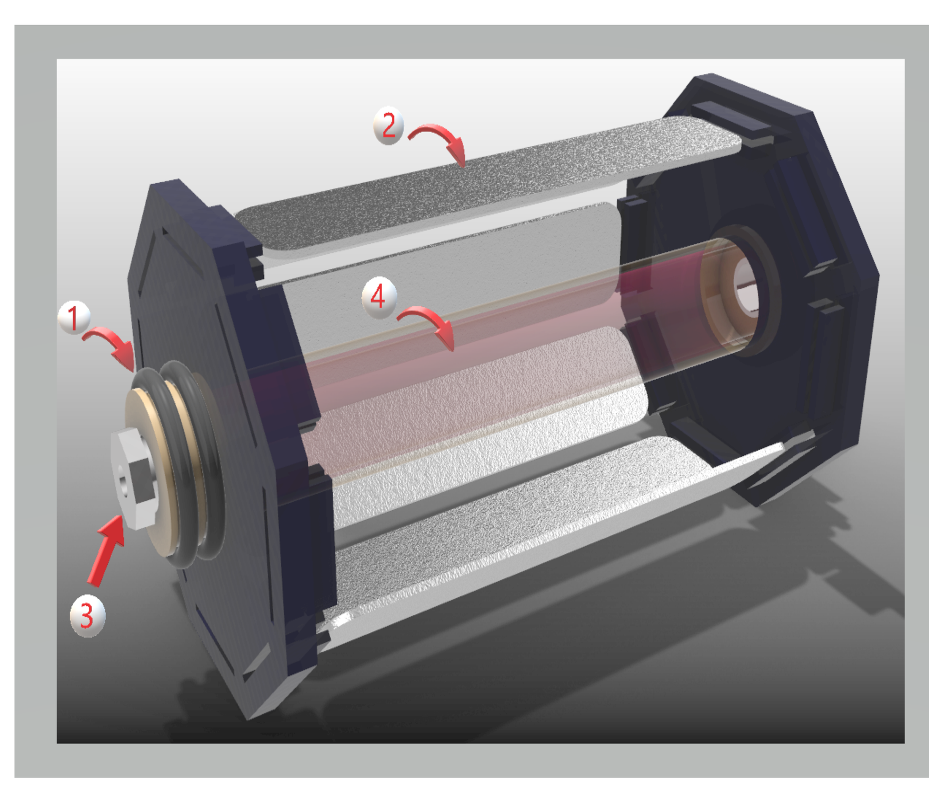

Figure 6. 3D model - Inside view of the device

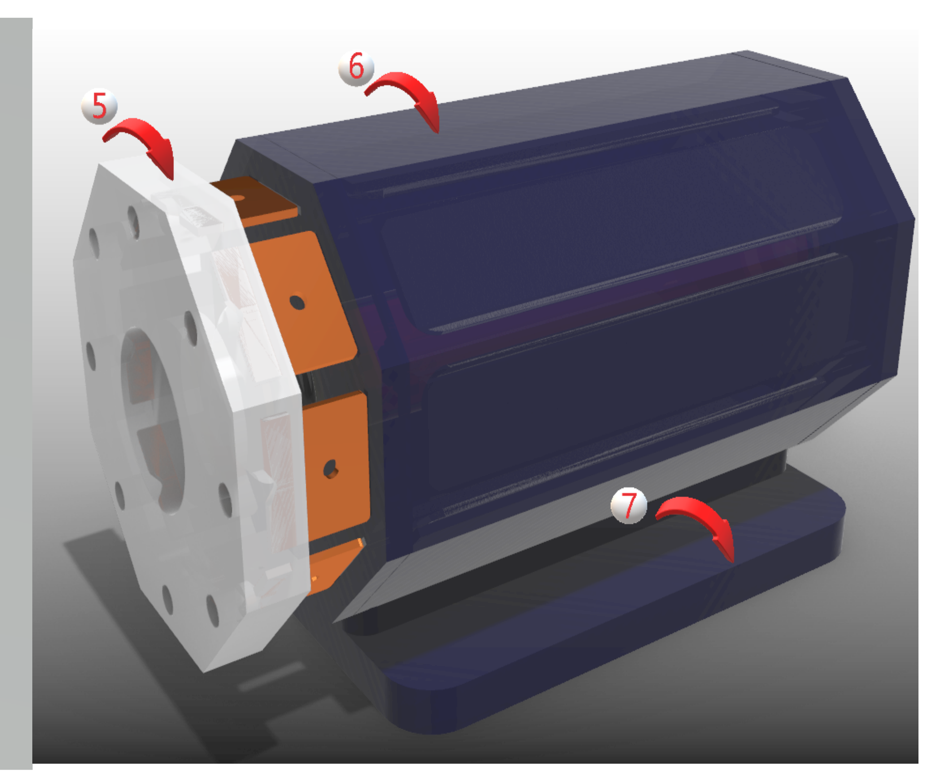

Figure 7. 3D model - Outside view of the device

1st. O-Ring – Sealing and Locking the dial tubing inside the chamber.
2nd. Set of Electrodes – Generating rotation electric field.
3rd. Pneumatic fitting Valve. – Seal and control the flow of clearing solution
4th. Dial Tubing Membrane – .
5th. Electric plug – Supply power for the set of electrodes.
6th. Chamber Cover.
7th. Base Stand. - Support

Acknowledgement

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Reference

[1] Stochastic Electrotransport selectively enhances the transport of highly electromobile molecules, PNAS, 2015 Nov 17: 112(46): E6274-83. doi: 10.1073/pnas.1510133112. Epub 2015 Nov 2. PubMed PMID: 26578787; PubMed Central PMCID: PMC4655572.
*[2] Scientific Reports **volume6**, Article number: 18631 (2016) [2]*
[3] Material Property Testing of 3D-Printed Specimen in PLA on an Entry-Level 3D Printer, ASME IMECE 2014, At Montreal, CA.