Electronic supplementary information:

Hybrid analytical-numerical approach for investigation of differential effects in normal and cancer cells under electroporation

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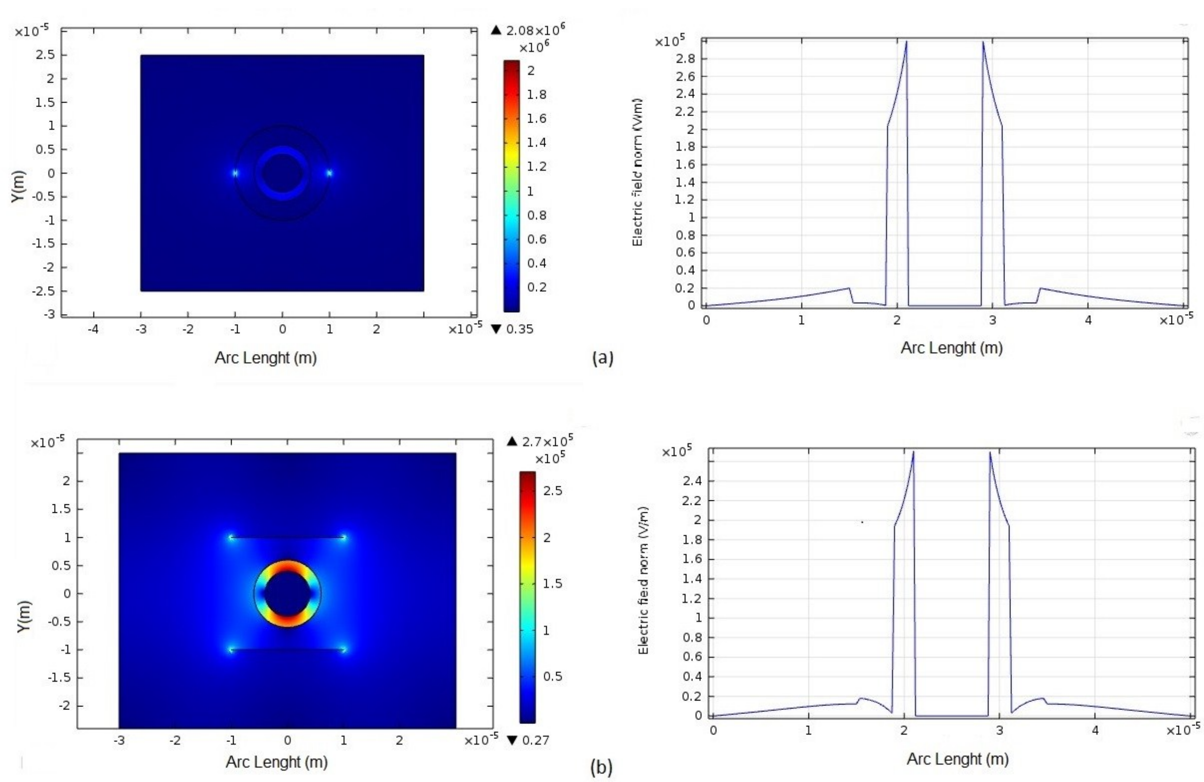
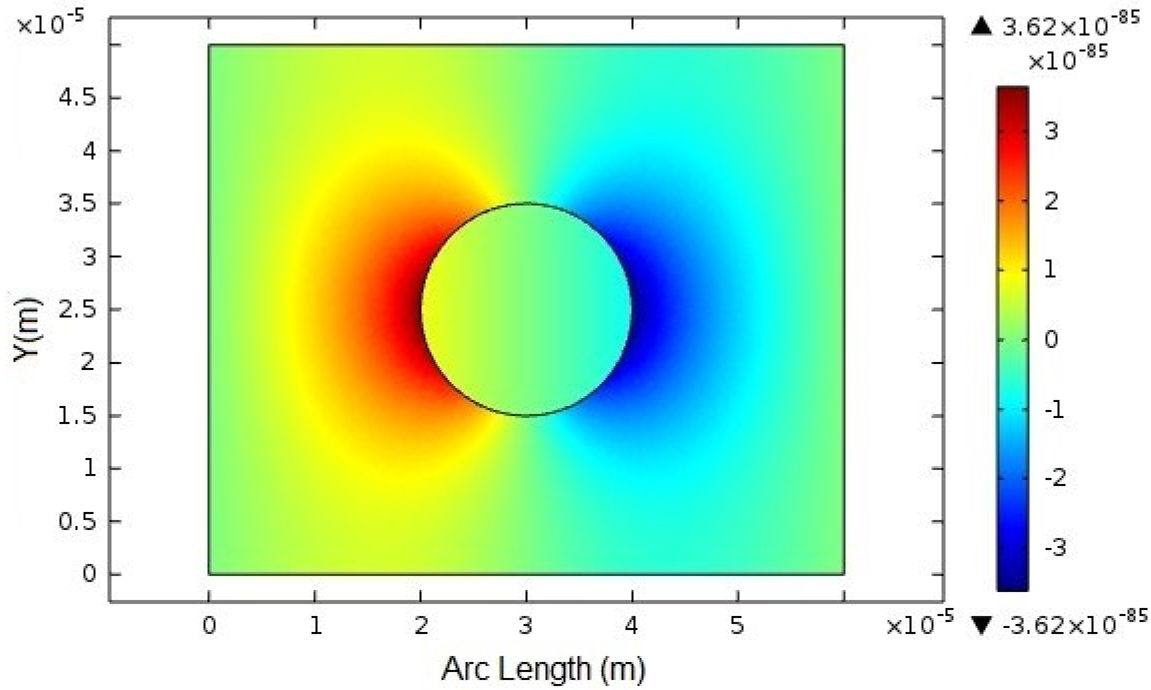
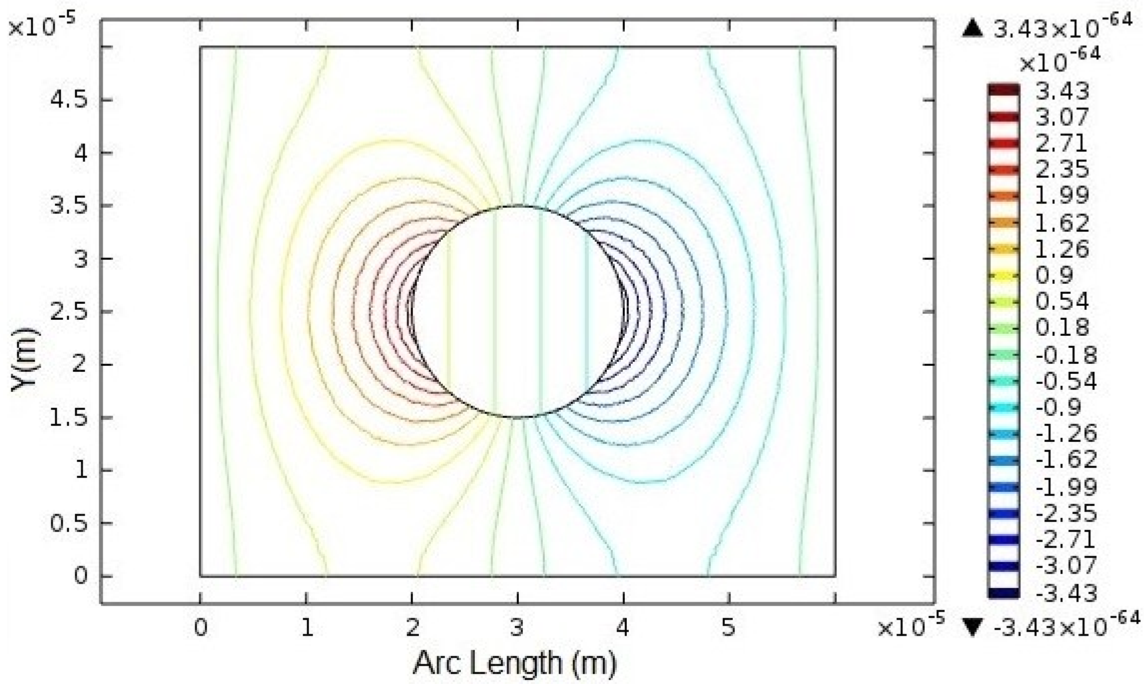


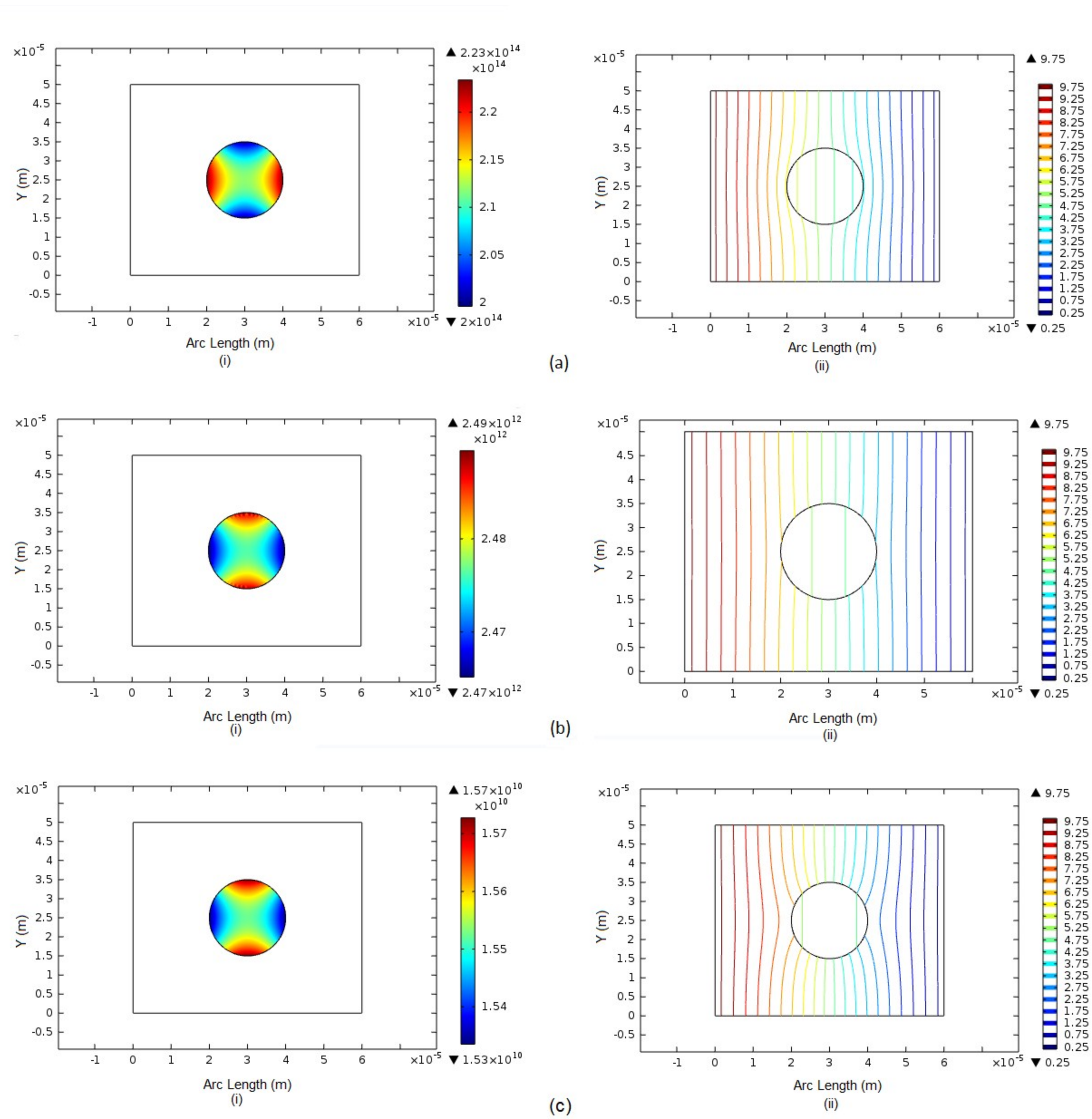
Supplementary Figure 1: Electric field distribution (V/m) of planner and circular electrodes at 1V incorporating MCF-10A. (a) circular electrodes' surface plot and 1-D plot of uniform normalized electric field. (b) planner electrodes' surface plot and 1-D plot of uniform normalized electric field.



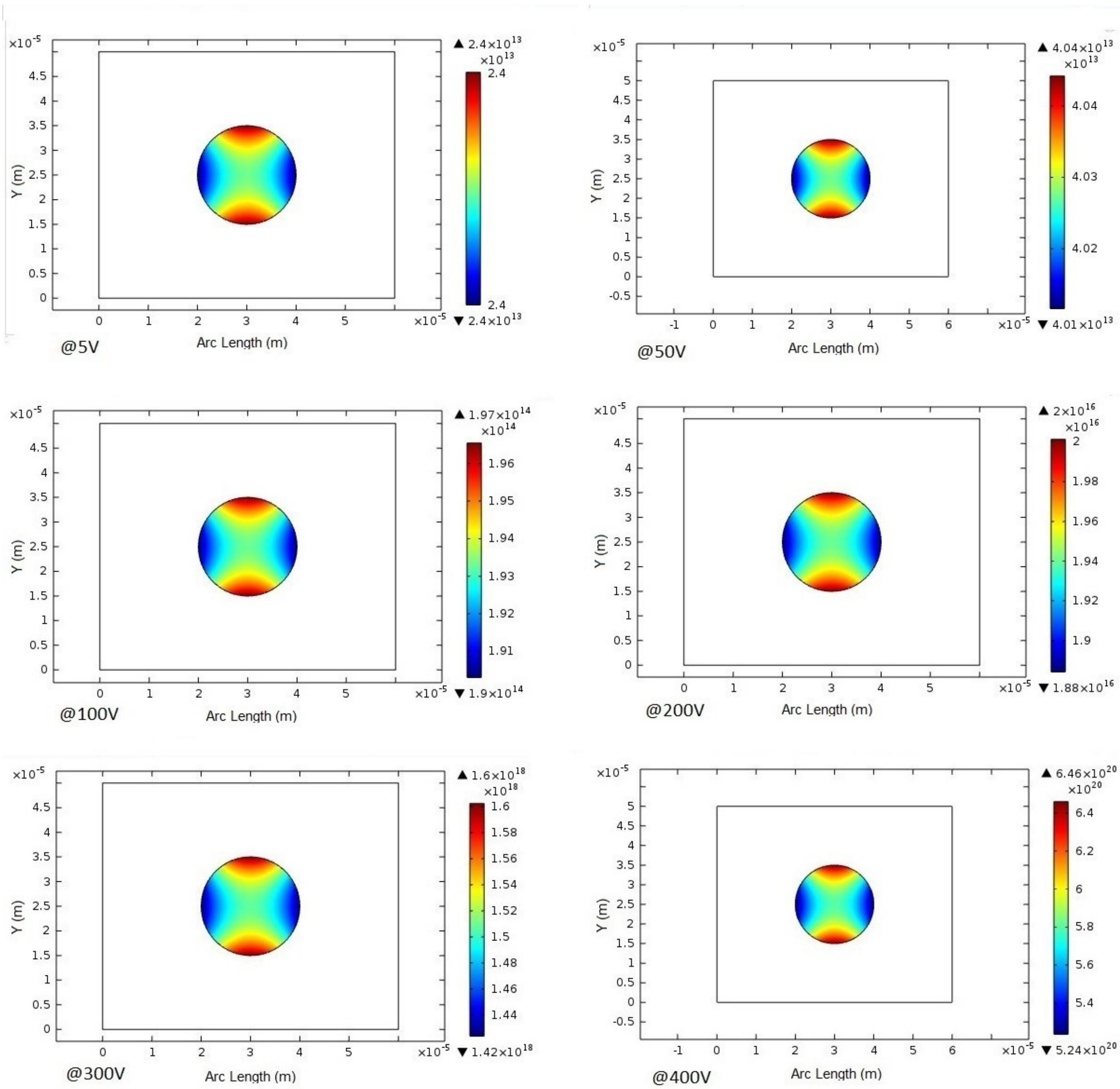
Supplementary Figure 2: Visualization of electric potential (V) stress on cell surface with 4s rectangular applied pulse using piecewise function with 30V amplitude. The membrane conductivity is in the range of 10^{-6} S/m.



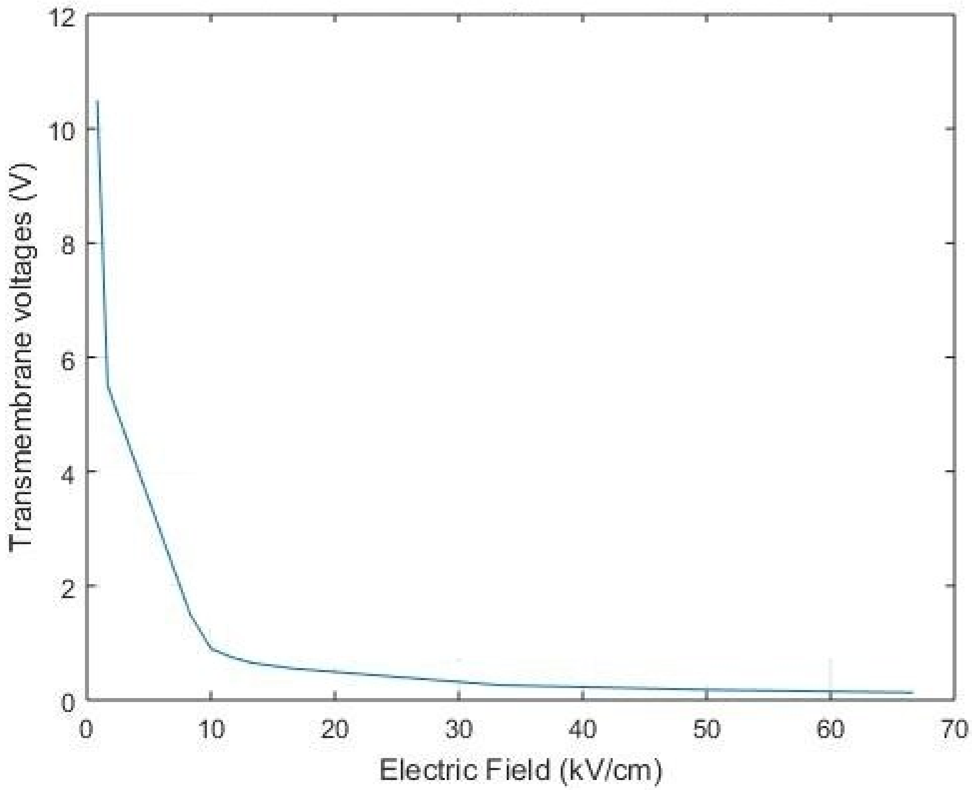
Supplementary Figure 3: contour plot of electric potential (V) stress with 4s rectangular applied pulse using piecewise function with 30V amplitude. The membrane conductivity is in the range of 10^{-6} S/m.



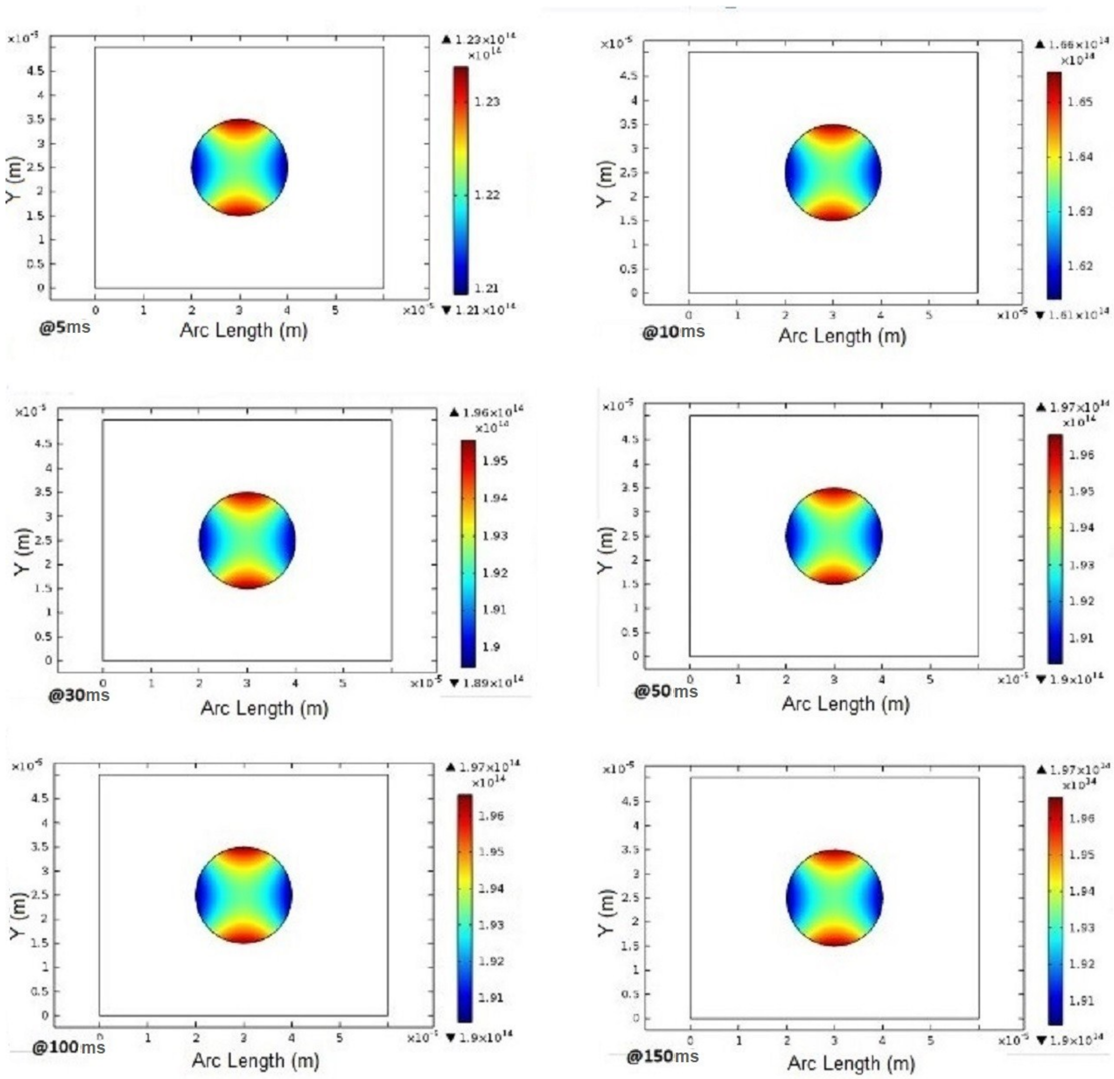
Supplementary Figure 4: Representing the trend of pore densities and electric potential as the membrane conductivity is decreased for MCF-10A at 10V. a) (i)Pore density's surface plot and (ii)electric potential contour at 10^{-3} S/m conductivity. b) At membrane conductivity of 10^{-4} S/m. c) At membrane conductivity of 10^{-6} S/m (realistic membrane conductivity).



Supplementary Figure 5: Represents effect of electric potential applied on electroporation or pore densities of MCF-7.



Supplementary Figure 6: Transmembrane voltage reduction plot of MCF-7 as we increase electric potential because of the increase in pore densities.



Supplementary Figure 7: Time of applied pulse Vs Pore densities analysis on MCF-7 Breast cancer cell.

Appendix A:

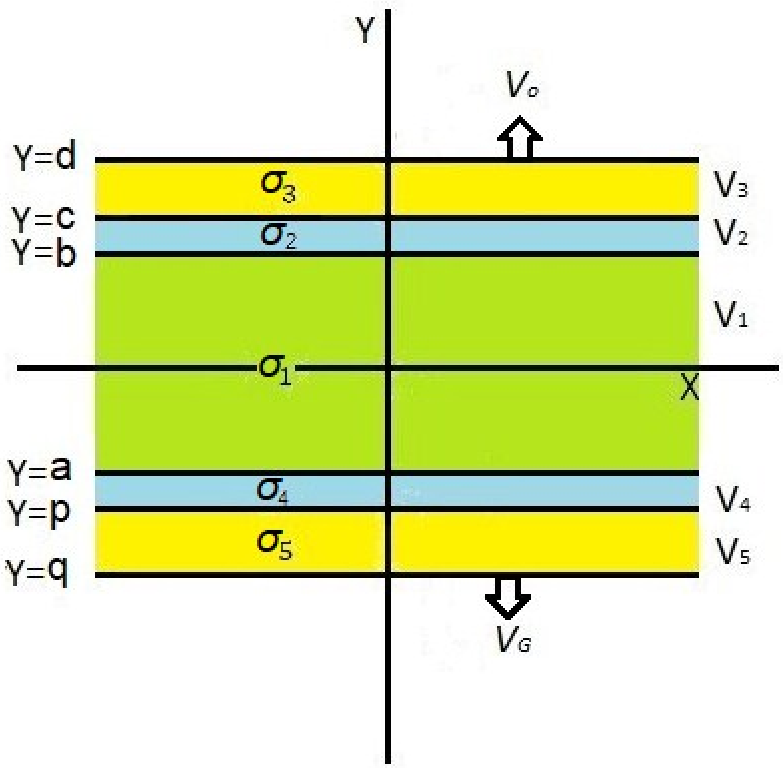
With the help of gauss's law eq.1 we obtain Poisson equation eq.2.and with the help of Poisson equation we obtain Laplace equation eq.3.

$$\nabla . \boldsymbol{D} = \rho_{\upsilon} \qquad (1)$$

$$\nabla^2 V = \frac{\partial^2 V}{\partial x^2} + \frac{\partial^2 V}{\partial y^2} + \frac{\partial^2 V}{\partial z^2} = -\frac{\rho}{\epsilon} \qquad (2)$$

$$\nabla^2 V = \frac{\partial^2 V}{\partial x^2} + \frac{\partial^2 V}{\partial y^2} + \frac{\partial^2 V}{\partial z^2} = 0 \qquad (3)$$

We have to find potential at five different regions as you can see from the figure



By integrating equation twice as; for all five regions we get (its only the function of y)

$$\iint (\nabla^2 V_1) dydy = \iint (0)\ dydy$$

$$\int \nabla V_1 dy = \int A dy$$

$$V_1 = AY + B$$

For our own convenience we replace a notation Y *by* x*. And we get;*

$$V_1 = Ax + B \qquad (4)$$

We did the same for remaining four regions and we get

$$V_2 = Cx + D \qquad (5)$$
$$V_3 = Fx + G \qquad (6)$$
$$V_4 = Hx + J \qquad (7)$$
$$V_5 = Mx + N \qquad (8)$$

In this calculation we represent the conductivity of different regions with σ*.*

As the figure above shows the biological cell replica when we join region 2 & 4 and 3 & 5 circularly then they form cell membrane and cell exterior (cell medium) respectively that is why in these regions the conductivity is same which shows:

$$\sigma_3 = \sigma_5$$

$$\sigma_2 = \sigma_4$$

As we have ten unknowns so the ten boundary conditions are

$$V_5(Q) = V_G \qquad (i)$$

$$V_3 = V_O \qquad (ii)$$

$$V_1(b) = V_2(b) \qquad (iii)$$ *So,* $$D_1 = D_2 \Rightarrow \sigma_1 E_1 = \sigma_2 E_2$$

$$E_1 = -\nabla V_1 \Rightarrow -\nabla(Ax + B) = -A$$

$\therefore E_2 = -C$

$$\therefore D_1 = D_2 \Rightarrow \sigma_1 A = \sigma_2 C \qquad (iv)$$

Did same for remaining

$$V_1(a) = V_4(a) \qquad (v)$$

$$D_1 = D_4 \Rightarrow \sigma_1 A = \sigma_2 H \qquad (vi)$$

$$V_2(c) = V_3(c) \qquad (vii)$$

$$D_2 = D_3 \quad \Rightarrow \quad \sigma_2 C = \sigma_3 F \qquad \textit{(viii)}$$

$$V_4(P) = V_5(P) \qquad \textit{(ix)}$$

$$D_4 = D_5 \quad \Rightarrow \quad \sigma_2 H = \sigma_3 M \qquad \textit{(x)}$$

By (iv) & (vi)

$\sigma_2 C = \sigma_2 H$

$$C = H \qquad \textit{(a)}$$

By (viii) & (x) by using (a)

$$F = M \qquad \textit{(b)}$$

From (iv)

$C = \frac{\sigma_1}{\sigma_2} A = H$

$F = \frac{\sigma_1}{\sigma_3} A = M$

By equation (i)(ii)(4) to (8)

$$V_G = M.Q + N$$

$$V_o = F.d + G$$

$$A.b + B = C.b + D$$

$$A.a + B = H.a + J$$

$$C.c + D = F.c + G$$

$$H.P + J = M.P + N$$

by putting the values of F, M, C, H *in above equations*

$$N = V_G - \frac{\sigma_1}{\sigma_3} A .Q \qquad \textit{(9)}$$

$$G = V_o - \frac{\sigma_1}{\sigma_3} A .d \qquad \textit{(10)}$$

$$A .b + B = \frac{\sigma_1}{\sigma_2} A .b + D \qquad \textit{(11)}$$

$$A.a + B = \frac{\sigma_1}{\sigma_2}A.a + J \tag{12}$$

$$\frac{\sigma_1}{\sigma_2}A.c + D = \frac{\sigma_1}{\sigma_3}A.c + G \tag{13}$$

$$\frac{\sigma_1}{\sigma_2}A.P + J = \frac{\sigma_1}{\sigma_3}A.P + N \tag{14}$$

Putting (9) in (14)

$$\frac{\sigma_1}{\sigma_2}A.P + J = \frac{\sigma_1}{\sigma_3}A.P + V_G - \frac{\sigma_1}{\sigma_3}A.Q$$

$$J = A.\left(\frac{\sigma_1}{\sigma_3}.P - \frac{\sigma_1}{\sigma_3}.Q - \frac{\sigma_1}{\sigma_2}.P\right) + V_G \tag{14a}$$

Putting (10) in (13)

$$D = A.\left(\frac{\sigma_1}{\sigma_3}.c - \frac{\sigma_1}{\sigma_3}.d - \frac{\sigma_1}{\sigma_2}.c\right) + V_o \tag{13a}$$

Putting (13a) in (11)

$$A.b + B = \frac{\sigma_1}{\sigma_2}A.b + A.\left(\frac{\sigma_1}{\sigma_3}.c - \frac{\sigma_1}{\sigma_3}.d - \frac{\sigma_1}{\sigma_2}.c\right) + V_o$$

$$B = A.\left(\frac{\sigma_1}{\sigma_3}.c - \frac{\sigma_1}{\sigma_3}.d - \frac{\sigma_1}{\sigma_2}.c - b + \frac{\sigma_1}{\sigma_2}.b\right) + V_o \tag{11a}$$

Putting (11a) & (14a) in (12)

$$A.a + A.\left(\frac{\sigma_1}{\sigma_3}.c - \frac{\sigma_1}{\sigma_3}.d - \frac{\sigma_1}{\sigma_2}.c - b + \frac{\sigma_1}{\sigma_2}.b\right) + V_o = \frac{\sigma_1}{\sigma_2}A.a. + A.\left(\frac{\sigma_1}{\sigma_3}.P - \frac{\sigma_1}{\sigma_3}.Q - \frac{\sigma_1}{\sigma_2}.P\right) + V_G$$

$$A = \frac{V_o - V_G}{\left(\frac{\sigma_1}{\sigma_2}.a + \frac{\sigma_1}{\sigma_3}.P - \frac{\sigma_1}{\sigma_3}.Q - \frac{\sigma_1}{\sigma_2}.P - \frac{\sigma_1}{\sigma_3}.c + \frac{\sigma_1}{\sigma_3}.d + \frac{\sigma_1}{\sigma_2}.c - \frac{\sigma_1}{\sigma_2}.b + b - a\right)} \tag{15}$$

Now all the unknown variables are:

∴

$$A = \frac{V_o - V_G}{\left(\frac{\sigma_1}{\sigma_2}.a + \frac{\sigma_1}{\sigma_3}.P - \frac{\sigma_1}{\sigma_3}.Q - \frac{\sigma_1}{\sigma_2}.P - \frac{\sigma_1}{\sigma_3}.c + \frac{\sigma_1}{\sigma_3}.d + \frac{\sigma_1}{\sigma_2}.c - \frac{\sigma_1}{\sigma_2}.b + b - a\right)}$$

$$B = A.\left(\frac{\sigma_1}{\sigma_3}.c - \frac{\sigma_1}{\sigma_3}.d - \frac{\sigma_1}{\sigma_2}.c - b + \frac{\sigma_1}{\sigma_2}.b\right) + V_o$$

$$C = \frac{\sigma_1}{\sigma_2}A$$

$$D = A.\left(\frac{\sigma_1}{\sigma_3}.c - \frac{\sigma_1}{\sigma_3}.d - \frac{\sigma_1}{\sigma_2}.c\right) + V_o$$

$$F = \frac{\sigma_1}{\sigma_3}A$$

$$G = V_o - \frac{\sigma_1}{\sigma_3}A\ .d$$

$$H = \frac{\sigma_1}{\sigma_2}A$$

$$J = A.\left(\frac{\sigma_1}{\sigma_3}.P - \frac{\sigma_1}{\sigma_3}.Q - \frac{\sigma_1}{\sigma_2}.P\right) + V_G$$

$$M = \frac{\sigma_1}{\sigma_3}A$$

$$N = V_G - \frac{\sigma_1}{\sigma_3}A\ .Q$$