Design of Integrated Microrobotic Fish

Presentation 3 - Physical Model (Complete) & COMSOL Simulation

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Antecedent

Total Impedance Z

In[1]:=

$$R=\frac{Pi*x*\left(\sqrt{k}+\frac{1}{\sqrt{k}}\right)}{2\sigma*\delta x};$$

$$C_{DL}=\frac{\epsilon*\delta x*\sqrt{k}}{\lambda_D};$$

$$C_{DS}=\frac{\epsilon*\delta x}{\sqrt{k}*\lambda_D};$$

$$Zx=R+\frac{1}{I*\omega*C_{DL}}+\frac{1}{I*\omega*C_{DS}}$$

Out[4]=

$$\frac{\left(\frac{1}{\sqrt{k}}+\sqrt{k}\right)\ \pi\ x}{2\delta x\ \sigma}-\frac{i\lambda_D}{\sqrt{k}\ \delta x\epsilon\ \omega}-\frac{i\ \sqrt{k}\ \lambda_D}{\delta x\ \epsilon\ \omega}$$

In[10]:=

Simplify[Zx]

Out[10]=

$$\frac{(1+k)\ (\pi\ x\ \epsilon\ \omega-2\ i\ \sigma\lambda_D)}{2\ \sqrt{k}\ \delta x\ \epsilon\ \sigma\omega}$$

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Remind the formula given in the article

$$Z = \frac{\pi\left(\sqrt{k}+\frac{1}{\sqrt{k}}\right)}{2l\sigma}\frac{\ln A - i\theta}{(\ln A)^2+\theta^2}$$

where

$$A = \frac{\sqrt{\left[(2\lambda_D\sigma)^2+(\omega\varepsilon\pi)^2+x_{min}x_{max}\right]^2+\left[2\lambda_D\sigma\omega\varepsilon\pi\left(x_{max}-x_{min}\right)\right]^2}}{(2\lambda_D\sigma)^2+(\omega\varepsilon\pi x_{min})^2}$$

and

$$\theta = \arctan\frac{2\lambda_D\sigma\omega\varepsilon\pi\left(x_{max}-x_{min}\right)}{(2\lambda_D\sigma)^2+(\omega\varepsilon\pi)^2 x_{min}x_{max}}$$

The author made a mistake of the parameter A. The correct formula is

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In[∘]:=

$$(*A=\frac{\sqrt{\left((2\lambda_D*\sigma)^2+(\omega*\epsilon*Pi)^2+x_{min}*x_{max}\right)^2+(2\lambda_D*\sigma*\omega*\epsilon*Pi(x_{max}-x_{min}))^2}}{(2\lambda_D*\sigma)^2+(\omega*\epsilon*Pi*x_{min})^2};*)$$

$$A=\frac{(2\,\lambda_D*\sigma)^2+(\omega*\epsilon*Pi*x_{max})^2}{(2\,\lambda_D*\sigma)^2+(\omega*\epsilon*Pi*x_{min})^2};$$

$$\theta=\mathrm{ArcTan}\left[\frac{2\,\lambda_D*\sigma*\omega*\epsilon*Pi\,(x_{max}-x_{min})}{(2\,\lambda_D*\sigma)^2+(\omega*\epsilon*Pi)^2\,x_{min}*x_{max}}\right];$$

反正切

$$Zo=\frac{Pi\left(\sqrt{k}+\frac{1}{\sqrt{k}}\right)}{2\,l*\sigma}*\frac{\sqrt{Log[A]}-I*\theta}{Log[A]+\theta^2}$$

Out[∘]=

$$\frac{\left(\frac{1}{\sqrt{k}}+\sqrt{k}\right)\pi\left(-i\,\mathrm{ArcTan}\left[\frac{2\pi\epsilon\sigma\omega\,(x_{max}-x_{min})\,\lambda_D}{\pi^2\epsilon^2\omega^2x_{max}x_{min}+4\sigma^2\lambda_D^2}\right]+\sqrt{\mathrm{Log}\left[\frac{\pi^2\epsilon^2\omega^2x_{max}^2+4\sigma^2\lambda_D^2}{\pi^2\epsilon^2\omega^2x_{min}^2+4\sigma^2\lambda_D^2}\right]}\right)}{2\,l\,\sigma\left(\mathrm{ArcTan}\left[\frac{2\pi\epsilon\sigma\omega\,(x_{max}-x_{min})\,\lambda_D}{\pi^2\epsilon^2\omega^2x_{max}x_{min}+4\sigma^2\lambda_D^2}\right]^2+\mathrm{Log}\left[\frac{\pi^2\epsilon^2\omega^2x_{max}^2+4\sigma^2\lambda_D^2}{\pi^2\epsilon^2\omega^2x_{min}^2+4\sigma^2\lambda_D^2}\right]\right)}$$

In[∘]:=

$$Z=\frac{1}{\int_{x_{min}}^{x_{max}}\frac{2\sqrt{k}\,\epsilon\,\sigma\,\omega}{(1+k)\,(\pi\,x\,\epsilon\,\omega-2\,i\,\sigma\,\lambda_D)}\,dx}$$

Out[∘]=

$$\left((1+k)\,\pi\right)\Big/\left(\sqrt{k}\,\sigma\left(2\,i\,\mathrm{ArcTan}\left[\frac{\pi\epsilon\omega x_{max}}{2\sigma\lambda_D}\right]-2\,i\,\mathrm{ArcTan}\left[\frac{\pi\epsilon\omega x_{min}}{2\sigma\lambda_D}\right]+\mathrm{Log}\left[\pi^2\epsilon^2\omega^2x_{max}^2+4\sigma^2\lambda_D^2\right]-\mathrm{Log}\left[\pi^2\epsilon^2\omega^2x_{min}^2+4\sigma^2\lambda_D^2\right]\right)\right)\ \text{if}\ \text{condition}$$

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```
In[]:= λD = 4.56 * 10^-9;
       σ = 0.018;
       k = 6.12;
       vL0 = 2.82 * 10^-9;
       xmin = 1.6 * 10^-6;
       xmax = 12 * 10^-6;
       Φ0 = 0.1;
       ω = 2 Pi * 1000;
              圆周率
       l = 0.235;
       ϵ = 80;
       Z
       —
       l
       θ
       A
       Zo
Out[]= 530.432 - 1.48237 × 10^-8 i
Out[]= 5.63092 × 10^-11
Out[]= 56.25
Out[]= 532.405 - 1.49341 × 10^-8 i
```

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Here we restore the resistance to three-dimensional by dividing by the total length of the electrodes in the cell $l = 23.5$ cm.
From the results above, we found that the corrected value of $\mathrm{Re}\{Z\}$ is in the range of 0.1 kΩ - 1 kΩ but differs from the value in FIG. 7. of the article.