*International Journal of Engineering & Technology*, 7 (2.24) (2018) 570-577

International Journal of Engineering & Technology

*Website: www.sciencepubco.com/index.php/IJET*

***Research paper***

# Stimulating electrode Design for Implantable Sub Retina Research Application: A Novel Approach

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**Abstract**

This paper aims to study and converse the theoretical model of neural stimulation implant electrodes with the electrochemical aspects of design. The study investigates the practically realizable hypothetical model of minimal invasive retinal implant (miRI) stimulating electrodes for restoring lost sight of patients blinded by degenerative retinal diseases. The basic elemental methods of charge injection by the stimulation electrode to tissue are pointed out. A prologue on the developments of vision implants and electrode characteristics were presented. We communicated the most important factors considered in this design stage of modeling, such as electrode position, size, impedance, charge injection capability, temperature change of the targeted retinal tissue and it's surrounding for vision implant system. In this design, a mathematical model is created to investigate for the all above said factors which influence implants positioned at internal surface of the retinal tissue. This investigation gives an initial step in design verification before the fabrication.

***Keywords:*** *Microelectrode, electrode electrolyte, Artificial retina, Prosthesis, Bionic eye, Bio implant.*

## 1. Introduction

The aim of this paper is to present mathematical modeling of physiology, theoretical model of various electrochemical related challenges for the development of bionic retinal device in general. For the past 100 years, the Mathematical models have been used in visual science. Normally mathematical models are used to describe how nature works, what are the limiting factors[1-6]. To make advancement in understanding a physical phenomenon under the lack of good experimental data condition a mathematical model plays a vital role. These model goals to converge both experimental and theoretical phenomenon on mathematically formulated descriptions of nature.Designing assist devices is emerging multidisciplinary fields which face lots of technological challenges[1]. For example different disciple research people how they view the charge transfer mechanism is shown in Figure 1. The quality of visually challenged people life is improved by biomedical vision implant assist devices. An artificial retina is a manmade device that is intended to replace the neurobiological photoreceptor system that duplicates retinal neural systems in real-time under same condition[1]. Still safe and efficient stimulation by a high density electrode array face problems. Since the threshold current necessary for stimulating target neuron depends on physical, biological, electrical characteristics of retina and stimulating devices[6]. The specific circuit solutions to implants depend on the functional requirements. The stimulating biomedical implants progress through interdisciplinary efforts which lead to better understanding of the design issue and challenges. The list of physical characteristics that need to be defined for vision implant is, stimulation electrode dimension, target neuron dimension, placement of electrode which includes distance between electrode and type of tissue, optimal inter-electrode spacing, maximum amount of current injection, thermal behavior of retinal tissue by a particular structure cell for a given scenario epiretinal or subretinal[6]. In addition to this, the polarity, pulse width, time period, conductivity, permittivity are required to be made clear for electrical characteristics. The spatial resolution of the implants is always improved by upgrading the stimulation electrode design..

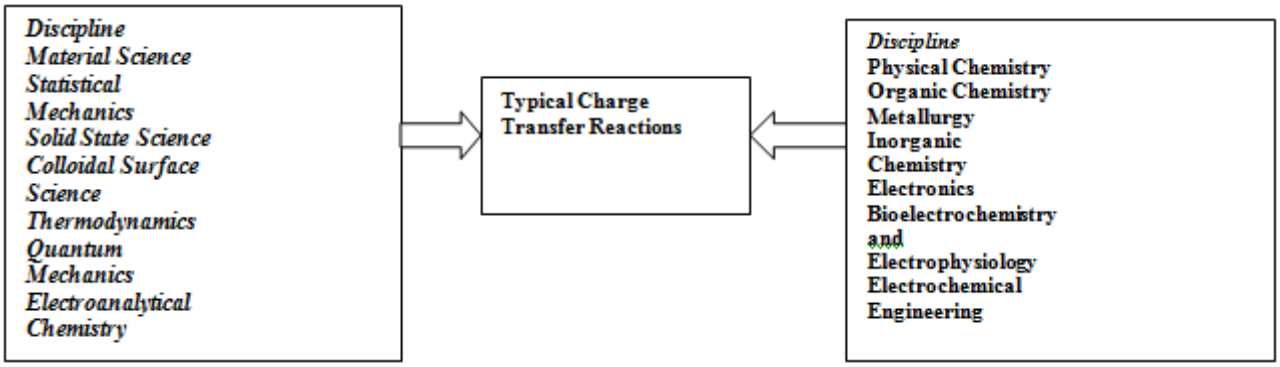


**Fig. 1:** Multidisciplinary view of charge transfer mechanism.

Due to the complicated cellular cascade in the retina, most of the existing models are not fully stating the electrophysiological processes within the retina during stimulation[1-5]

## 2. Anatomical organization in Eye

The structure of the human eye is illustrated in Figure 2. Light rays are first focused by the cornea and the lens, and then pass the vitreous humour before finally reaching the retina at the back of the eyeball [1-5]. The retina is a delicate membrane, less than 0.5 mm thick [7]. Yet it has a highly complex structure consisting of ten distinct cell layers. These include three layers of cell bodies: (i) the outer nuclear layer having rods, cones and its cell bodies (ii) the inner nuclear layer have horizontal cells (HC), bipolar cells (BC) and amacrine cells (iii) the ganglion cell (GC) layer[1]. The synapses between these cell types are made in the outer and inner plexiform layers. The photoreceptors transduce light into electrical signals via a cascade of biochemical reactions. The electrical signals pass through the cells in the inner nuclear layer
which generates graded potentials. Were these graded potentials are converted into spikes by the ganglion cells[1-9]. The ganglion cells connect the optic nerve and convey spikes signals to visual cortex where image is formed.

## 3. Neurotransmitter-Releasing

Neurotransmitters plays vital role in conveying information. In visual cortex, retina and geniculate efferents, neurotransmitter released is Glutamate[11-20]. The glutamate is released by photoreceptors synaptic vesicles to the dendrites of bipolar cells. The glutamate will depolarize and hyperpolarize the ON-OFF bipolar cells. Recently some of the researchers show interest on glutamate-releasing prosthesis. One such prosthesis is located at missing photoreceptor spot in RP patient which communicates with the lasting bipolar cells to transfer the visual signal to ganglion cells. As earlier stated the Neurotransmitter release by photoreceptors, makes ion current to flow and depolarize dendrites and soma[11-20]. Which cause signal amplification, also enables BC to generate spike. A low input to synapse will result in less amplification which produce graded potential, not a spike signal. The simulation result shows that 20 μm are the best suited distance in between the electrode and BC axon.

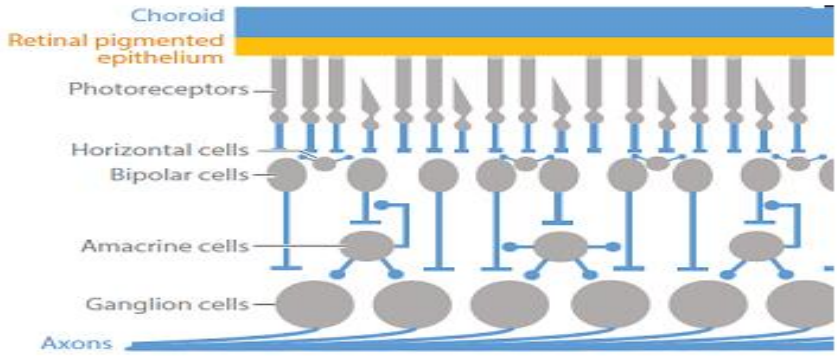


**Fig. 2:** Retina structure

## 4. Morphometric studies of Retinal

A major section of the inner retina stays alive despite widespread photoreceptor degeneration, which was identified with help of Morphometric experimental study [6-9]. The fovea region occupies 1 mm diameter space and covers 3° of vision in central retinal, were 1° of visual angle equals 275– 300 $\mu$m of retinal surface area. Normally the targeted region for electrical stimulation by bionic eye in the retina is Bipolar cells and ganglion cells regions. The subretinal implant electrode will stimulate the bipolar cells. The experimental investigation states that average center diameter of diffuse retinal bipolar cells is 92 μm and midget retinal bipolar cells is 42 μm. One of the latest study on BCs proved that it has the capability to produce sodium spikes which provide quick signal transport from receptor to Ganglion Cells. As compared to graded potentials, a spike causes stronger synaptic activity at the BC terminal. As a finishing point of Morphometric studies survey we summarized the thickness, conductivity which go over the main points for all artificial retinal circuitry, 22(μm) & 0.0226 (S/m) for ganglion layer, 23(μm) & 0.0372 (S/m) for inner plexiform layer, 27(μm) & 0.0128 (S/m) for inner nuclear layer, 16(μm) & 0.0187(S/m) for outer plexiform layer, 40(μm) & 0.0483(S/m) for subretinal space, 20(μm) & $4.167*10^{-4}$ (S/m) for retinal pigment epithelial cell, 407(μm) & 0.037 (S/m) for choroid and sclera.

## 5. Electrochemical Aspects of Neural Stimulation

The nature of neural stimulation by an electrode results in the electrochemical process. An electrode electrolyte double layer is formed when an electrode has a contact with tissue[11-16]. Normally the electrical neural stimulation depolarizes the excitable cells membrane by developing a voltage gradient across the semi-permeable cell membrane and electrodes. In order to meet the practical demands we need to understand the interactions between stimulating electrodes and the complex micro-environment for the successful design of efficient subretinal prosthesis devices, figure 3 shows the demand. A good neural stimulation electrode should satisfy the requirement like electrode–tissue interface materials, excellent electrochemical performance, good stability and biocompatibility[11-17].Various parameters are shown in table 1 decide the performance, but not all the characteristics are satisfied by single stimulating devices. Some compromise is made between the parameters. One such
case is the impedance in implant varies with changes in tissue resistivity in surrounding region of the electrode and electrochemical shift at the electrode surface with time[11-18].

**Table 1:** Factors that considered for retinal electrode design

| | |
|---|---|
| Electrode materials<br>Electrode double layer<br>Electrode potential | Type of tissue<br>Conducting medium<br>Inhomogeneity |
| Surface area<br>Diffusion or adsorption<br>Charge transfer | Geomentric area<br>Tissue response<br>Implant position |

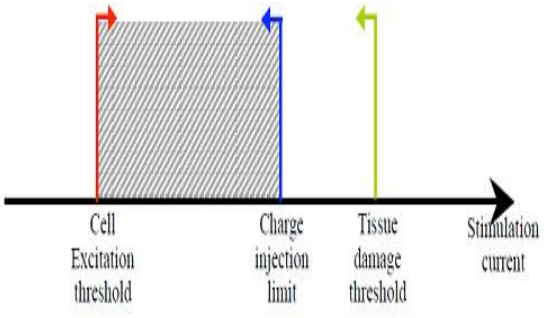


**Fig. 3:** Steps in neural simulation

## 6. Retina Implants types

Several retinal research groups have already designed and fabricate different types of artificial retina[1-20]. These devices stimulating electrode are attached to the retina space to restore vision in visually blind patients. The vision implants are categorized as extraocular and intraocular prostheses, shown in figure 4. The Extraocular devices are externally powered and located at the surface of the eye, but the intraocular device is located in sub retinal space[10-20]. The vision implant gives constructive results during testing process, but some barriers still existing that have to be short out, before retinal prostheses used for human. One of the key components in vision implant is stimulating electrode[10-20]. Stimulating electrodes communicate with the tissue faces different electrochemical associated challenge biocompatibility, electrode-electrolyte interaction, contact impedance, charge injection ability, electrode corrosion and dynamic range. Some of the key issued discussed below.

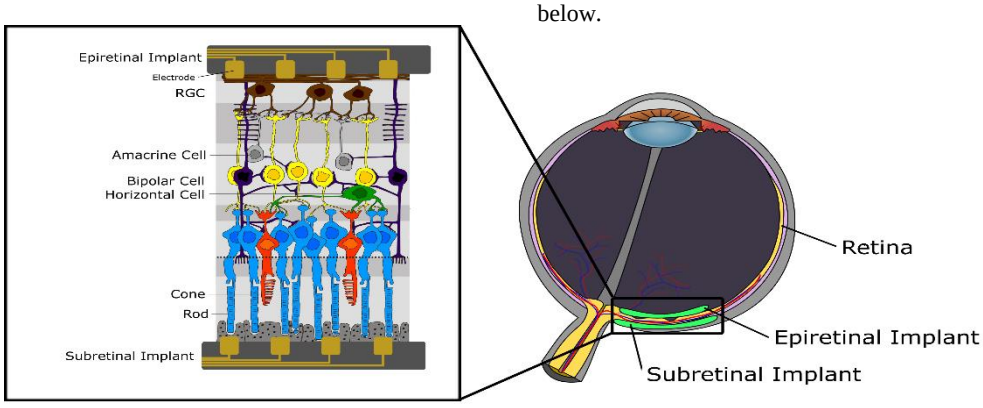


**Fig. 4:** Retinal implant type and its stimulation position.

### 6.a. Stimulus characteristics affecting retinal stimulation:

**T**he external stimulus is not a continuous function but it is a time change function. The strength of the stimulation relay on the relation between the pulse width and the amplitude, which propose the total charge injected to the neural stimulation. Charge injection to the target neuron also depends on the type of electrode and stimulus configuration[16].

### Cathodic &Biphasic current:

The variant input stimulus alters stimulation of a neuron. Two types of stimuli are used for simulation study are cathodic and biphasic current. The cathodic current will always propagate in each direction from the depolarized excitation node. A small hyperpolarisation may occur in the lateral area due large enough reverse anodic current[10-15].These anodic current generate an action potential opposite direction of cathodic bias. The biphaseic stimulus is similar to cathodic stimuli, while typical biphasic pulse maintains charge balance using symmetric phases to overcome cathodic bias[10-17].

### Monopolar and Dipolar or Bipolar configuration:

The electric potential of the entire stimulating electrode are defined with respect to the return electrode, where the electric field of each electrode is superposition with each and every nearby electrodes[10-17]. Which influence an electric field spread at distant tissue regions which affect the spatial resolution of the implant. This problem is overcome by the bipolar electrode were the return electrode are placed in surrounding area of the stimulating electrodes[10-20]. Thus stimulation is much more

improved by reducing the superposition of electric field effect between the neighboring electrodes.

### 6.b. Stimulation electrodes its size:

One of the most influencing factors for retinal stimulation is the electrode geometry[10-20]. To cover 1° visual angle in retinal, electrode diameter should be 0.3 mm. For higher resolution still smaller size electrodes needed. But in practice the electrode size not to fall below safety limits of current densities. Electrode size is compromised to have long period secured biocompatible excitation, and to avoid erosion of the electrodes' metal surface[14-17]. The smaller electrodes should provide essential electrical charge for the exciting retinal neuron.

### 6.c . Electrode placement location or positioning of electrodes:

The threshold current need to be optimized with respect to electrode-retina distances for the different electrode sizes[15-18]. Similarly, impedance deviations need to be found as a function of electrode-retina distance. Hence it is evident that the Stimulation threshold depends on electrode-retina distances. There are two main electrical factors that affect the efficiency of the vision implant. The first factor is the excitation stimulus magnitude unevenness results by the unstable positioning of the electrodes at the inner surface[11-20]. This will change electrochemical properties of the electrodes and retina. Second factor is charge density required to bring out vision for long-term, should ensure stimulation without damaging the retina or the electrodes[13]. Thus the electrode-retina distance affects the resolution of the vision implant due to varying current altering stimulation region. Most of the experimental and analytical data confer that raise in distance between electrode and retina rises the threshold current and charge density. Generally, the dynamic range of distance lies between 0 μm and 150 μm and the retinal resistivity is calculated for this range[11-20].

### 6.d. Electrode Impedance:

Usually, the impedance is related to the contact surface area between the Electrode and tissue. As the surface area increases the impedance decreases. Normally the neural stimulation and its output behavior are high frequency in nature[11-18]. Therefore for vision implant electrode design, impedance behavior at high frequencies is very much required and to be formulated. For impedance study, a constant current input of 100uA is normally used. The morphometric studies on retinal shows that the resistivity of the retinal pigment epithelium has 500 Ω·m, and other layers resistivity change from 35 Ω·m at the photoreceptor layer to 2 Ω·m in the RGC layer[11-20].

### 6.e. Tissue heating

A prolonged long term vision implant depends and variation of temperature in the target cell. Normally the electrical stimulation in tissue increases the temperature. The stimulation of tissue is described by Jule heat and metabolic equation[6,11]. Joule heat forms in the presence of electric field. The amplitude frequency and pulse width parameters of electrical signal determine the temperature changes in the tissue[6,11]. A smooth variation and low temperature has a low cause of harm and injure. While abrupt variation and high temperature will rupture, damage the tissue. The many of the experimental results shows that 3°C increase in temperature in a normal tissue cause abnormalities and fault. Amount of pixel density is limited by the heating effect on tissue due to hyperthermia. The steady distribution of temperature depends on the continuous train of pulses which heat diffuse heat into the surrounding[6,11].

### 6.f. Factors which affect the conversion efficiency

Additional factors which affect the conversion efficiency were discussed below. The area of absorption of incoming light is limited by electrodes, trenches and metal leads. Apart from these factors the electron hole pair generation and recombination is less in low thickness wafer and high in large thickness wafer. The thermal effect due the light absorption by a tissue limits the incoming light to avoid the tissue damage. To afford adequate protection to tissue by an implantable device the materials used for electrode, tissue-contacting, insulation materials are required to be biocompatible and biostable[1-20]. Tissue damage assurance is given by is biocompatibility and stimulating electrode corrosion, degradation assurance is given by biostability [1-20]. Thus the selection of electrode material for stimulation should satisfy these unique challenges as a function of high frequency for long term stability.

### 6.g. Presumptions and recommendations for Stimulation:

Few research groups make an effort to analyse the electrical response of electrode to optimize the design. The parameter considered for the retinal stimulation are electrode size, electrode shape, threshold current, charge density, electrode impedance, distance between electrode to the retina, retinal tissue temperature increase, inter electrode interference of the signals[1-20]. The table 2 shows the parameter range of values recommended for stimulation. In this study, the electrode-tissue interface is modeled with varying electrode diameters[1-20]. These retinal tissue layers are modeled with dimensions close to the human retinal tissue structured. Nearly most researchers evidently recommend these specifications are essential to replace vision[1-20]. The factors recommended limit the cross-talk, electrochemistry reaction, heating tissue, pixel density and distance from the target cells[1-20].

## 7. Conceptual Groundwork of Stimulating Electrode Modeling

The primary aim is to build up quantitative narratives of neuronal functional operations and their synchronization between the neuron. The narrative will provide information about integrated neural processing system. At this juncture it is obvious, for a bionic vision understanding the electrical properties of retinal cells is very important. Generally, the Modelling and simulation suggest a scheme of estimation of design parameters suitable for experimental conditions which is not possible during straightforward experimentation at the first attempt. Our initial investigational study shows only a small number of simulation studies were carried out on

**Table 2:** Retinal prosthesis designs and thresholds

| Threshold / Vision implant Type | Epiritina | Subretina |
|---|---|---|
| Curre Electrode current | 25–700 $\mu$A | 70–100 $\mu$A |
| Electrode Diameter | 250–500 x$10^{-6}$ m | 50 x$10^{-6}$m |
| charge density | 0.35 mC cm−2 | 1.0 mC cm−2 |
| Distance between Tissue and electrode | 20 -40μm | 20-50 μm |
| Number of electrode | 50–600 | 50-1000 |
| Distance between electrode | 10-30 μm | 10-50 μm |
| Temperature value for cellular damage | 52° C | 45°C |

vision implant electrode design in spite of the existence of models on retina biophysics and retinal circuitry. Fgure 5 shows the steps involved in our vision implant electrode design. For a decade and more, there have been extensive efforts made by researchers in the field of modelling studies. Hence for learning the physical phenomenon and to innovate a new device the Simulation tools becomes a vital accessory to researchers.

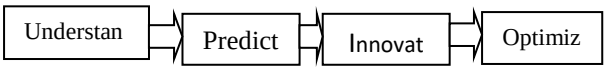


**Fig. 5:** Steps involved in research

### 7.A. Stimulus model

The deviation in stimulation signal parameters changes the threshold of neuron stimulation. The connection involving the magnitude and the frequency (width) of a pulse should define a threshold value that needed to excite the tissue. This relation is known as strength-duration relationship. Thus the sensitivity of the tissue is measured by stimulation pulse Strength duration relationship which is expressed by the Laplace equation

$$I = b(1 + c/d) \quad (1)$$

Were
I =stimulus amplitude (current)
b=rheobase current
d =stimulus duration
c= time constant
I * d defines the threshold charge (mC) necessary for stimulation given by Weiss' Law. So let multiply d on both sides of equation 25 to get Weiss' Law equation

$$I * d = b * (d + c) \quad (2)$$

In real time experimentation pulse type shown below in fig 6 is used.

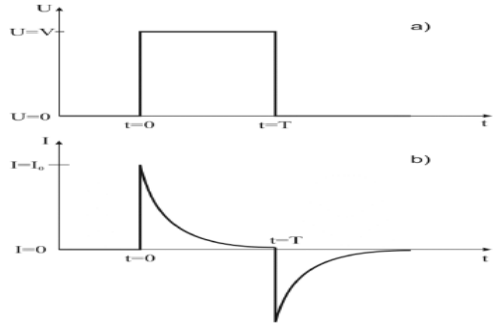


**Fig. 6:** Stimulus pulse

Then it is required to estimate the charge injected during the period *t=0* and *t=T*. Assume that I(t) switch on at $I=I_0$ and decay as exponential function given by

$$I(t)=I_0 \exp(-kt) \quad (3)$$

Were K= decay constant
The injected charge *Q(T)* as a function of pulse duration *T* is obtained by integration,

$$Q=\int Tdt \quad (4)$$
$$Q(T)=(I_0/k)\{1-\exp(-kt)\} \quad (5)$$

We make another approximation and say that the initial current *I*0 is proportional to the applied voltage *V*,

$$I_0=cV \quad (6)$$
$$\text{Then } Q(T)=(cV/k)\{1-\exp(-kt)\} \quad (7)$$

Now we demand that there is a threshold value *Qthres* of the injected charge *Q(T)*, for which the stimulation signal is strong enough to elicit a visual sensation. The key idea of the injected charge model is that this threshold charge is a constant, i.e. it is independent of *V* and *T*. If we put *Q(T)* at its threshold value *Qthres* we obtain the threshold voltage *Vthres*,

$$Q_{thres}=(cV_{thres}/k)\{1-\exp(-kt)\}. \quad (8)$$

We are interested in getting the threshold value *Vthres* of *V*, for given pulse duration *T*.

$$V_{thres}=(k\,Q_{thres}/c)\{1-\exp(-kt)\} \quad (9)$$

### 7.B. Thermal safety model:

Shannon express the thermal limits for tissue damaging and non-damaging by an electrical stimulation.
The amount of charge density to a tissue is given by

$$\log(D) = k - \log(Q) \quad (10)$$
$$Q=b(c+d) \quad (11)$$

Were
D= charge density
Q =charge per phase
K= constant varies between 1 to 2

### 7. C. The electrode capacitance model

An ionic charge flow takes place between biological tissue and stimulating electrode. The charge flow process is modeled through faradic and non-faradic mechanisms. The faradic and non faradic mechanism is characterized reversible and irreversible processes respectively. The reversible currents are modeled with a capacitor *Cdl* and Irreversible currents modeled as charge transfer resistor $R_{CT}$ . Below shown figure 7 is the equivalent circuit of the above said process.

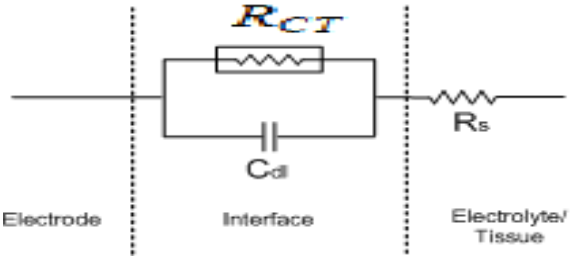


**Fig. 7:** Equivalent circuit model of electrode/tissue interface capacitance model in neural stimulation

For a small signal input the $R_{CT}$ obtained from the Butler-Volmer equation, it is given by

$$R_{CT} = RT/NfJ_0 \quad (12)$$

where
*J0*= exchange current density,
*N*= number of electrons involved in the electrode reaction,
*R*= gas constant,
*T*= temperature (K)
*F*= Faraday constant
The electrolyte double layer Cdl derived from interface capacitance *CI* given by Gouy-Chapman-Stern model. These capacitance are series combination of the Helmholtz capacitance *CH*, and the diffuse layer capacitance *CG*.

$$\frac{1}{C} = \frac{1}{CH} + \frac{1}{CG} \quad (13)$$

$$\frac{1}{CH} = \varepsilon 0 \varepsilon r / l \quad (14)$$

$$l = d/A \quad (15)$$

$$\frac{1}{CH} = \varepsilon 0 \varepsilon r A/d \quad (16)$$

Where

$l$= thickness of the double layer.

$$\frac{1}{CG} = [(\pi Z^2 e^2 n^0 \varepsilon 0 \varepsilon r)^{1/2}/kT]\cosh\frac{ze\phi}{2kT} \quad (17)$$

The tissue spreading resistance $R_s$ *is given by*

$$R_s = (\rho/\pi l)\ln(l/w) \quad (18)$$

where

$\rho$= resistivity of the tissue (in Ω.cm),

$l$ = length of the electrode

w= width of the electrode.

### 7.D. The electrode impedance model

The pseudocapacitive constant phase angle impedance, $Z_{faradaic}$, is described mathematically by Richardot and McAdams. The capacitance of electrodes at a given frequency is determined from the imaginary component of the impedance. Below shown figure 8 is the equivalent circuit of above said process.

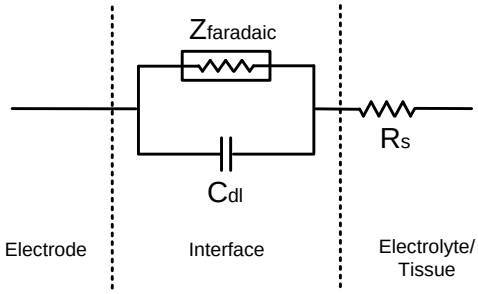


**Fig. 8:** Equivalent circuit model of electrode/tissue interface impedance model in neural stimulation

$$C_{dl} = 1/(2\pi f Z) \quad (19)$$

$$Z_{faradaic} = 1/(j\omega C_{dl}) \quad (20)$$

$Z_{faradaic}$=non faradic pseudo capacitance

$C_{dl}$ =electrode-electrolyte double layer capacitance

### 7.E. Heat transfer model:

Estimation of temperature variation in tissue depends on power dissipation. The following heat exchanges were needed to be considered 1.Exogenous metabolic heat, 2.Heat exchange with air 3.Evaporation of tears4.Vascular bed of the orbital cavity, 5. Endogenous metabolic heat, 6.Oculomuscle activity 7.Retinal heat by absorption of light

Electrical stimulation of the tissue causes increase in the temperature, which is categorized into two main parts, namely Joule heat and metabolic reactions.

Heat transfer is based on Pennes bioheat equation by :

$$\nabla.(-k\nabla T) = \rho_b C_b \omega_b (T_b - T) + Qmet + Qext \quad (25)$$

Where

K= thermal conductivity (W/mK)

$\rho_b$= density (kg/m3)

$C_b$= specific heat capacity which is the amount of energy to produce change of a unit temperature (J/kg.K)

$\omega_b$= volume of blood per second flowing through a unit volume of tissue (1/s)

Qmet = heat source of metabolism perfusion rate

Qext=external heat source (W/m3)

### 7.F. Model of electric fields in a volume conductive medium:

The environment of the vision implant electrode is surrounded by a conductive extracellular fluid. Hence it is necessary to understand the electric and current distribution in a homogeneous medium. A simple quasi static model can be used to describe the electrode in volume conducting medium obtained by solving Maxwell equation. Physiological fluid Current defined by Conservation of charge

$$\Delta \cdot J = 0 \quad (21)$$

The electric field is given by Gauss law:-

$$\Delta \cdot E = \rho/\varepsilon \quad (22)$$

Assuming quasi-static conditions, the curl of $E$ must be zero according to Faraday's law of induction:

$$\Delta \times E = -dB/dt = 0 \quad (23)$$

Retina model of current density is given by ohm's law

$$J = \sigma E \quad (24)$$

Substrate insulation

$$E = -\Delta V \quad (25)$$

The electric field intensity is given by

$$E = -\Delta\phi \quad (26)$$

Electric scalar potential V in the medium due to electrode stimulation is given by

$$\Delta \cdot [\sigma \Delta V] = 0 \quad (27)$$

Bounding box Electric insulation

$$-n \cdot J = 0 \quad (28)$$

Substituting Eq. (2) into Eq. (6) gives the Poisson equation

$$-\Delta^2\phi = \rho/\varepsilon \quad (29)$$

E=electric field (V/m) defined as gradient of the scalar potential *f*

J= current density crossing a given surface, in A/m$^2$

$\sigma$ = the conductivity in S/m;

ρ = the charge density, in C/m3;

ε = is the permittivity of the medium

$V = V_{stimulation}$

=Stimulation electrode Electric potential

V = 0 for Ground electrode

Δ = refers divergence vector

If the current density (*Js*) is estimated for a spherical surface having radius r net current (*I0*) is given by

$$J = I_0/4\pi r^2 \quad (30)$$

Then electric field is given by:

$$E = I_0/4\sigma\pi r^2 \quad (31)$$

The electric current in a conductive media, is modeled by solving the continuity equation with a current source Qj given

$$\Delta \cdot J=Q_j \quad (32)$$

where,
J= current density.
For the time dependent study, it solves for equation

$$J= \sigma E+dD/dt+J_e \quad (33)$$

Where, σ is the conductivity of the medium, being electric displacement, Je is the external current density.

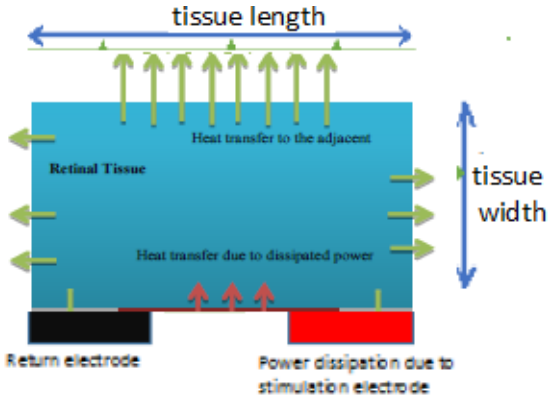


**Fig. 5:** Retinal tissue and electrode position and heat transfer model

### 7.G.Model of electric fields in a volume conductive with resistive medium:-

The environment in retina shows some resistivity. Hence it is necessary look at the conventional quasistatic limit under these conditions, to examine the electric scalar potential, V by solving the Laplace's equation:

$$\Delta \cdot [(\sigma+i\omega\varepsilon_0\varepsilon_r) \Delta V] = 0 \quad (34)$$

Substrate insulation

$$E = - \Delta V \quad (35)$$

The current density on the electrode, **J** is related to V given by Ohm's law:

$$\mathbf{J} = - [(\sigma+i\omega\varepsilon_0\varepsilon_r) E] \quad (36)$$

where, $\sigma$= conductivity of medium
$\varepsilon_r$ = relative permittivity of medium
$\varepsilon_r$ = relative permittivity of medium
$\omega = 2p$ f = angular frequency of driving stimulus
$\varepsilon_0$= permittivity of vacuum
i= imaginary unit
E=electric field (V/m) defined as gradient of the scalar potential *f*

## 8. Discussion

We now recognize a key constraint on retinal stimulation electrode design. This approach allows us to an efficient way of device design in places where we could have more constrains before. Specific tools for multi-domain simulation or design framework are not available which can meet the required design constraints. The improved mathematical model for electrode will make use of parameters related to retinal physiology and retinal environment. The performance of the mathematical model developed or shown above should match the real operating conditions. This can be archived by numerical simulation. The model framework proposed here, with a suitable modification of the models which already exist one.

## 9. Conclusion

These models are need to be validated by both numerical and analytical simulation computer tools like MATLAB and COMSOL for a full-fledged quantitative assessment for real time scope of Retinal stimulating electrode designs. The general issues in design and development of implant discussed here will motivate the researchers. Different category of visual prostheses perspective, how they work and how they are used are expressed in the paper. Computational modeling has been used to estimate the threshold current necessary for stimulating target neuron,the temperature increase in the eye and head due to heat generation by the retinal prosthesis system. Hence Simulation tools are becoming an essential accessory for scientists and engineers for the development of new devices and study of the physical phenomenon. More and more disciplines rely on accurate simulation tools to get insight but also to accurately design novel devices. This paper describes how we can use to create hierarchical models and to simulate vision implant devices and systems.

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